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# Experimental investigation of hand and finger usage in braille reading

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# AN EXPERIMENTAL INVESTIGATION OF HAND AND FINGER USAGE IN BRAILLE READING

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ABSTRACT

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A synthesis of research pertaining to literacy for students with visual impairments discovered one piece of scientifically-based evidence (as defined by the No Child Left Behind Act) on braille mechanics published in the last 50 years that contradicted what is considered best practice. Therefore, this investigation constructively replicated the research of Hermelin and O'Connor (1971) to determine if their findings of a left-index finger advantage for speed and a left-middle finger advantage for accuracy were valid, especially when compared to two-handed braille reading techniques utilizing the index and middle fingers.

A convenience sample of 15, congenitally blind, contracted braille users who attended four different residential schools for the blind read a series of braille symbols, words, and passages using their preferred hand and finger usage patterns and nine randomly ordered hand and finger usage patterns involving the index and middle fingers. In order to evaluate various aspects of braille mechanics, hand and finger movements were videotaped from below a transparent reading surface. These videos were then analyzed to calculate

fluency rates (measured as correct words per minute) and dominant reading finger(s) (measured as the finger(s) most frequently used to read the current line of text and to engage in scrubbing or retracing). Data were also collected via reports from parents, teachers of students with visual impairments, and students regarding personal attributes and instructional characteristics that had the potential to impact braille literacy.

A series of Analyses of Variance and Multiple Linear Regressions provided support for two-handed reading techniques. Even when eliminating hand and finger usage patterns added to this investigation, the left hand advantage found by Hermelin and O'Connor was not confirmed. Interaction effects revealed a left-index finger advantage for proficient readers and a right-index finger advantage for struggling readers. Finally, participants without additional disabilities who had always attended a school for the blind, whose primary language was English, and who preferred tactual learning attained the highest word and passage fluency scores. Given the significance of the dominant reading finger(s), per these results, more research is needed to better understand the specific role each finger plays during various reading tasks.

## DEDICATION

This dissertation is dedicated to all my students, especially those who participated in this research as you now are part of my professional family. Thank you for helping me to see the world through your eyes. You have given me the vision to view things as they can be, not as they are. Furthermore, you have inspired me to be the best that I can be, and for that, I am eternally grateful.

ACKNOWLEDGEMENTS

*We know what we are, but know not what we may be.*

*William Shakespeare*

Earning a doctorate is like embarking on a journey without a map. Although there is a definitive destination, each student must blaze a unique trail in his/her quest to become a producer of new knowledge. As a result of the inherent challenges involved in charting one's course of action during the trip, the traveler ends up going through a transformative process.

When I entered my doctoral program, I thought I knew who I was and where I was going. However, there were many encounters along the way that shook my very foundation of being and made me question my most basic assumptions. Ultimately, this enlightening and painful process of self-discovery inspired me to think in new ways. Without the support of so many great "teachers", I never would have had the confidence to set foot on this path, let alone to stay the course when everything seemed like an uphill battle.

First and foremost, I want to thank my family for teaching me how to be resilient. Without your unconditional love and encouragement, I would not be who I am or where I am today. The cheers of my mom (Brenda Hill), grandma (Barbara Green), and sister (Dawn Cassidy) motivated me to jump over all the hurdles along the way to the finish line. I also want to thank my uncles, Mack Hill

and Nick Hill, for designing and building the custom-made reading stand as this was the vehicle through which data for this study were collected.

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There were many bumps along the road, one being the fact that I am a non-driver. Data collection would not have been possible without the following drivers: Jane and Ralph Bartley, Jeremy Ockerman, and Eleanor Pester. Thanks for making sure that my custom-made reading stand arrived in one piece. I also want to thank Ralph Bartley, Tom Poppe, Frank Hayden, and Jeremy Ockerman

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Last, but not least, I want to express my gratitude to my committee for their tireless commitment to excellence. This dissertation is the direct result of the love of braille that was instilled in me by my first braille instructor, Dr. Madeline Milian. Thank you for expanding my viewpoints to include a diverse spectrum of possibilities. However, I would not have survived this arduous process without the mentoring of Dr. John Luckner. Thank you for teaching me to work smarter instead of harder—a lesson I am still trying to master. The most unexpected gift I received during this journey came about from the opportunity to take classes from Dr. Lewis Jackson. Thank you for giving me the confidence to voice my innermost passion—the inclusion of people with disabilities into all facets of society. Finally, words cannot express my gratitude for the never-ending support provided by my research advisor, Dr. Kay Ferrell. Thank you for

seeing and cultivating my potential. Without your gentle and persistent nudging, I never would have known the heights to which I could soar. I hope that I will sparkle as your legacy since you spent countless hours mining this diamond in the rough.

Although the doctoral journey has come to an end, it has opened my eyes to many new and exciting adventures. I hope that one day I will be able to repay all the love and kindness that I have experienced through this process. As I move on to the next phase of my personal and professional development, I want each and every one of you to know that you have forever touched my life.

*I've heard it said*
*That people come into our lives for a reason*
*Bringing something we must learn*
*And we are led*
*To those who help us most to grow…*
*…I know I'm who I am today*
*Because I knew you*

*So much of me*
*Is made of what I learned from you*
*You'll be with me*
*Like a handprint on my heart*
*And now whatever way our stories end*
*I know you have re-written mine…*

*Because I knew you*
*I have been changed for good*

*Stephen Schwartz*

TABLE OF CONTENTS

CHAPTER

## LIST OF TABLES

TABLE

LIST OF FIGURES

FIGURE

# CHAPTER 1

## INTRODUCTION

Equality is the ultimate goal in the field of blindness and visual impairment. Since the inception of formal education for students with visual disabilities, developing and promoting literacy has been a major platform for providing equal opportunity, and braille has been a hallmark literacy strategy. However, braille has a long and contentious history in the education and rehabilitation of individuals who are blind and visually impaired. Fierce debates have ensued regarding the efficacy of various tactile codes, literacy modalities (tactual, visual, and auditory), contracted versus uncontracted braille, tactual perception factors, and efficient finger/hand usage. Unfortunately, the paucity of research in these areas only serves to fuel the debate over what constitutes best practice.

Given the long history of braille, one would think that there is also a long line of research supporting current practices. While braille is a popular topic in both the professional and consumer literature, oftentimes having entire books and journal issues devoted to this tactual code, the majority of information is anecdotal in nature. Publications tend to either revisit history or describe teaching methods and materials used by a specific teacher with a particular

student or a small group of students. When research on braille is conducted, it is not uncommon for important procedural, participant, and statistical information to be omitted, thereby affecting the ability to analyze the quality and applicability of the findings. Furthermore, research is neither revisited to see if previous findings are still relevant in current times or replicated to see if there is indeed enough evidence to support the findings of a particular study. Thus, this inquiry attempts to add to the research base and diffuses some of the controversies surrounding best practice by conducting a constructive replication of previous research that contradicts current practices. The remainder of this first chapter delineates the context of this study, including background information, a statement of the problem and purpose of the study, research questions, delimitations of the study, significance of this research, and definitions of key terminology and concepts.

## Background

Literacy is hailed as the key to social and economic opportunity (Rex, Koenig, Wormsley, & Baker, 1994; Ryles, 1996; Schroeder, 1989). This is obvious when one contemplates all the ways in which literacy is weaved into the daily fabric of life. People read such things as signs, recipes, e-mails, texts, directions, and labels that facilitate their ability to lead independent, self-determined, and productive lives. Basically, people read and write to understand and express knowledge and ideas. In order to survive and thrive in the information age, people must be adept at accessing, examining, and exchanging

information. After all, information is power, and in turn, literacy is empowerment. Unfortunately, not everyone has attained proficiency in literacy, and thus, not everyone has achieved equal opportunity.

Braille is more than just a reading medium; it has become a symbol of empowerment and independence. This explains the passion with which this topic is debated. The issue extends beyond the ability to read and write; it truly revolves around the link between life outcomes and literacy. Initial research has shown that legally blind, braille readers attained higher education levels, employment rates, financial status, and self-esteem than legally blind, print readers (Ryles, 1996). The suggested explanation for this is that early exposure to braille as a primary reading medium increases one's ability to develop knowledge and skills that are used in higher education and employment. Thus, braille is believed to be an important factor that contributes to vocational success (Ryles; Schroeder, 1989). This finding is pertinent because 69% to 76% of blind and visually impaired adults of working-age are unemployed or underemployed (American Foundation for the Blind, 2012; Kirchner & Schmeidler, 1997; Wagner, Newman, Cameto, Levine, & Garza, 2006).

Since educators trained in visual disabilities believe that blindness does not affect what a child learns but how (s)he learns (Ferrell, 1997), achievement discrepancies are disconcerting. Results from statewide assessments show disturbing reading achievement levels for students with visual impairments. For example, less than 42% of $10^{th}$ graders with visual impairments attained reading

proficiency in 2006 as compared to 72% of 10th graders without disabilities (National Center on Severe and Sensory Disabilities, 2006). Likewise, a longitudinal study involving beginning braille readers in kindergarten through fourth grade showed that only about half of the students made expected gains in the areas of spelling, vocabulary, and reading level (Emerson, Holbrook, & D'Andrea, 2009). Another trend involves the steady decline in the number of children who read braille and the increase in the number of students classified as non-readers. Currently, 9.1 percent of students who are blind and visually impaired use braille as their primary literacy modality while another 4.7% use braille as their secondary literacy modality. Unfortunately, 34.1 percent are non-readers in any medium—braille, print, or audio—presumably because of the presence of other significant disabilities (American Printing House for the Blind, 2010). An additional prevalent and persistent concern regarding braille literacy is reading speed. Research consistently shows that braille users read at a slower rate than print readers (Caton, Pester, & Goldblatt, 1979; Emerson, Holbrook, & D'Andrea, 2009; Fertsch, 1946, 1947; Knowlton & Wetzel, 1996; Lowenfeld, Abel, & Hatlen, 1969; Nolan & Kederis, 1969; Trent & Truan, 1997; Wetzel & Knowlton, 2000; Wormsley, 1996; Wright, Wormsley, & Kamei-Hannan, 2009). It is evident that students with visual impairments are not achieving enough in literacy and consequently in life. While some people may dismiss issues affecting such a small proportion of the entire population, braille readers deserve quality instruction in skills that will facilitate social and economic equality.

These abysmal outcomes are disturbing to a profession that has prided itself on a long history of believing in the abilities and potential of people who are blind and visually impaired when no one else did. However, this pride has unintentionally created a resistance to adapting to the ever-changing needs of this population. Instead, practitioners cling to traditional pedagogy because it worked once upon a time. In fact, professionals "are often left with best practices that are more philosophical than proven, more descriptive than empirical, and more antiquated than modern" (Ferrell, 2007). As a result of the *No Child Left Behind Act* (NCLB), which mandates best practices derived from scientifically-based research, this rationale can no longer be tolerated.

In addition, teachers are now being held accountable for student proficiency (No Child Left Behind Act, 2002). Since teachers of students with visual impairments (TSVIs) typically assume the primary responsibility for teaching braille literacy, it is logical to assume that they will also be held accountable for the proficiency of braille reading students. Thus, it is important that test scores on statewide assessments improve for students who are blind and visually impaired. The intent of NCLB is that all learners demonstrate academic proficiency, and there is no reason why braille readers cannot achieve this same standard.

Although educators desperately want their students to be proficient, these new requirements have placed the teaching profession in a tailspin. Given constraints in time, resources, information, and collaboration, these requirements

seem impossible. Like it or not, these accountability measures are not going to disappear, and thus, the profession has no choice but to figure out how to achieve student proficiency using best practices supported by scientifically based research. In order to accomplish this daunting task, educational experts first need to understand what is meant by scientifically-based research, and then they need to identify current practices that are supported by such high caliber research.

Scientifically-based research "involves the application of rigorous, systematic, and objective procedures to obtain reliable and valid knowledge relevant to educational activities and programs" (No Child Left Behind Act, 2002). Components of scientifically-based research include systematic and empirical methods, experimental or quasi-experimental designs, reliable and valid data, sufficient detail and clarity to allow for replication, and acceptance by a peer-reviewed journal or an independent panel of experts (No Child Left Behind Act). Both experimental and quasi-experimental research requires the manipulation of at least one independent variable, but experimental designs also require random assignment of subjects to treatment and control groups.

Prior to the passage of NCLB, the National Reading Panel (NRP) was commissioned by Congress to compile and evaluate existing, scientifically-based research pertaining to reading strategies. The main components of literacy as stipulated by the NRP are alphabetics (including phonemic awareness and phonics), fluency, comprehension (including vocabulary and comprehension

strategies), teacher preparation, and computer technology (National Reading Panel, 2000). Given the fact that articles involving readers with disabilities were often excluded from the NRP analysis, the National Center on Severe and Sensory Disabilities (NCSSD) attempted to conduct a meta-analysis on scientifically-based literacy strategies for readers who were blind and visually impaired. Unfortunately, it was not possible to conduct a meta-analysis since there were only 20 scientifically-based research articles pertaining to literacy for students with visual impairments in kindergarten through $12^{th}$ grade, and each article covered a different aspect of literacy (Ferrell, Mason, Young, & Cooney, 2006). Thus, it is difficult to ascertain which practices used with braille readers are indeed considered best practice as defined by NCLB.

## Problem Statement

In spite of the lack of research supporting best practices, professionals in the field of blindness and visual impairment have promoted specific strategies for teaching braille. The recommended technique for reading braille involves using all fingers of both hands, except the thumbs, with emphasis on the index and middle fingers to lightly and smoothly scan halfway across a line of braille. At the midpoint, the left hand diagonally drops down to the beginning of the next line of text while the right hand finishes the current line. After the current line of text is read, the left hand begins reading the next line while the right hand drops down diagonally to where the left hand is currently reading (Castellano & Kosman, 1997; Caton, Pester, & Goldblatt, 1979; Koenig & Holbrook, 2000;

Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). However, just because this technique is supported by the experts and has been used over an extended period of time, it does not necessarily make it the most effective or efficient way of reading braille.

In fact, there is little research to adequately support this braille reading strategy as best practice. Furthermore, a small number of empirical studies have indicated that braille users read faster with their left hand and their middle finger, which contradicts the current practice of reading more with the right hand than the left and using both the index and middle fingers (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982; Wilkinson & Carr, 1987). Although there are only these few articles contradicting the current hand and finger usage practices of braille readers, these are the only empirical studies examining such braille mechanics in recent times.

A plausible explanation for these findings relates to the hemisphere specific functions of the human brain. Typically, language and reading processes occur in the left hemisphere while visual-spatial or tactual-spatial tasks occur in the right hemisphere (Gazzaniga, Ivry, & Mangun, 2008). Given the fact that each hemisphere of the brain controls the opposite side of the body, those braille readers predominantly engaging in phonological processes would read better with the right hand while those braille readers engaging in tactual-spatial processes would read better with the left hand (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982). Because braille is a tactual code comprised of

various spatial configurations of one to six dots within a braille cell, this explanation for faster left-handed reading warrants further investigation.

Hence, the purpose of this study was to conduct a constructive replication of Hermelin and O'Connor's (1971a, 1971b) research on hand and finger usage of braille readers in order to add to the scientifically-based research regarding braille mechanics. Specifically, hand and finger usage were analyzed in terms of their effect on the following fluency indicators: oral reading speed and oral reading accuracy. Given the role of the brain in learning, it was also important to analyze dominant hand preference as well as the age at which contracted braille was introduced, since there is often an indirect correspondence between letter-sound relationships (phonics) in contracted braille. Before making any monumental judgments regarding the efficacy of certain techniques, there needs to be multiple valid and reliable research studies in order to generalize the findings. This study was an attempt to get one step closer to establishing best practice in the area of increasing fluency through braille mechanics.

## Research Questions

The questions addressed in this study were as follows:

Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index + middle) resulted in the greatest degree of fluency?

Q2 Is there a relationship between handedness and/or dominant reading finger(s) and the hand and finger usage pattern that produced the greatest degree of fluency?

Q3 Is there a relationship between reading ability and the hand and finger usage pattern that produced the greatest degree of fluency?

Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, literacy modalities, educational setting, or instructional curriculum), participant characteristics (primary language, age vision lost, or presence of additional disabilities), and braille reading fluency?

## Delimitations

The limitations of this study were as follows:

1. Non Random Sampling: Given the fact that participation in research involving human subjects is required to be voluntary, it is not possible to obtain a list of qualifying braille readers and select every $n^{th}$ person as a participant (e.g., every $37^{th}$ person on the list) . Furthermore, time, money, and geographical constraints dictate the need for convenience sampling.

2. Non Random Assignment: Because students with visual impairments are an extremely heterogeneous population, it does not make sense to randomly assign participants to hand usage and finger usage conditions. Instead, all participants were tested under all conditions, with testing order randomized for each participant. Unfortunately, lack of a separate control group and a treatment group prevents this study from being a true experiment. While still considered rigorous research, it is quasi-experimental research.

3. Constructive Replication Study: Given the fact that the previous research regarding the topic at hand was conducted over 35 years ago, it was not possible to use the same assessment instruments. Furthermore, there were hand usage patterns and plausible confounding variables not investigated by the

original researchers that needed to be taken into consideration. Hence, this study was not an exact replication.

## Significance of the Study

With so many unanswered questions about braille, it might seem like a waste of time and resources to study a phenomenon that has already been studied. In addition, it might also seem frivolous to replicate an older study that has had no discernable impact on practice. In fact, it may even be deemed unwise to pay any attention whatsoever to a single-piece of research that contradicts prevailing practice.

The quality of research should not be judged on how much the results correspond to popular opinion or revered tradition. Instead, research needs to be evaluated on its reliability and validity. For instance, results obtained in one instance under one set of circumstances with one group of participants cannot necessarily be generalized to other people, settings, or times. Therefore, it is important to replicate research in order to determine its authenticity and applicability.

Professionals in the field of blindness and visual impairment cannot do the same things and expect different results. Reading rates of braille users are bound to remain the same if teaching methods do not change. Instead of dismissing research that supports nontraditional teaching techniques, professionals must use additional research to either discredit or validate these practices.

This research study serves to expand the existing research base. In fact, Ferrell (2007) has referred to the research base in the field of blindness and visual impairment as crumbling since it is comprised mostly of non-experimental, anecdotal, and single-subject research designs that have only been implemented once. Given the low-incidence of visual impairment and the extreme heterogeneity of this population combined with the limited numbers of university faculty available to conduct research, it is easy to see why there is a lack of scientifically-based evidence. In spite of these difficulties, professionals need to strive to increase the quality of this research base. Thus, this study attempted to strengthen the crumbling research base by either validating or refuting the best practice of reading braille using two hands with the left hand primarily serving the role of placeholder.

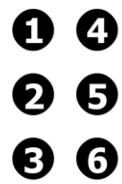
## Definition of Terms

Following are definitions of the key concepts used throughout this study:

**Blindness.** An uncorrectable condition of the visual system resulting in either no light perception or light perception (the ability to detect the presence or absence of light). These individuals are unable to see print and usually end up reading braille. This term specifically refers to a level of visual functioning experienced by those categorized as having a visual disability.

**Braille.** This code consists of various combinations of raised dots that correspond to letters, numbers, punctuation marks, letter combinations, and words. Braille is not a language; it is a code used to represent any given

language. The base unit of braille is referred to as a braille cell, and it is composed of six embossed dots arranged in a three-row-by-two-column configuration as pictured below.




Different braille symbols are created by using various spatial arrangements of the one to six dots. There are 63 possible braille symbols. Letter combinations or whole words can be represented by symbols occupying one or more cells.

**Braille Mechanics.** A set of skills needed to read braille efficiently. Specific skills include finger dexterity, hand movements, finger positioning, and tactual perception/discrimination.

**Contracted Braille.** This code (formerly known as Grade 2 Braille) refers to the 189 contractions unique to braille. These contractions include letters that represent words, symbols that denote words, abbreviations that represent words, and symbols that represent common letter combinations.

**Fluency.** The ability to read orally with sufficient accuracy, speed, and expression. The measurement of fluency in this study refers to reading speed and reading accuracy.

**Hand Dominance/Handedness.** The hand with which a person completes the majority of physical tasks. Someone can either be left handed, right handed, or ambidextrous.

**Hand Superiority.** The hand with which a braille user reads the most fluently. This may or may not be the reader's dominant hand.

**Phonics.** A method of teaching reading that emphasizes the understanding of letter-sound relationships.

**TSVI.** This acronym is used to refer to the teacher of students with visual impairments. This is a special education teacher who has been specially trained to instruct students who are blind and visually impaired in the Expanded Core Curriculum, which consists of disability specific skills.

**Uncontracted Braille.** This code (formerly known as Grade 1 Braille) refers to the symbols that represent the letters of the alphabet, numbers, and punctuation marks.

**Visual Impairment.** An uncorrectable condition of the visual system that adversely impacts a student's educational performance. It is often quantified as a visual acuity of 20/70 or less in the best eye with best correction and/or a visual field restricted to 20 degrees or less. Individuals who have residual vision and are capable of seeing print are often referred to as either visually impaired or legally blind. Visual impairment specifically refers to a level of visual functioning experienced by those categorized as having a visual disability.

## Summary

In order to produce braille readers who are capable of competing socially, academically, and vocationally with their sighted peers, more attention needs to be given to increasing fluency skills, especially braille reading speed and accuracy. Unfortunately, there is very little best practice supported by scientifically-based research to guide these efforts. Furthermore, some empirical research contradicts the current hand and finger usage patterns taught to braille readers. Thus, this study re-examined and constructively replicated previous research. The next chapter analyzes the research available on braille mechanics and how the brain functions in tactual reading. Chapter Three details the methodology implemented in this research study. Finally, chapters four and five share the results of the research and discuss the implications of the findings.

# CHAPTER 2

# LITERATURE REVIEW

Children who are blind and visually impaired are thought to be more similar to their sighted peers than they are different. Likewise the process of reading braille is believed to be more similar to reading print than it is different. In fact, Hampshire (1975) argues that "reading is primarily a cognitive process and that the cognitive processes involved in reading are essentially the same whether the incoming information is from the visual or tactual modality" (p. 146).

Even if the cognitive processes involved in reading print and braille are indeed similar, there are nevertheless significant differences between print and braille reading. The most obvious difference is that print is read visually with the eyes and braille is read tactually with the fingers. Furthermore, the braille code contains contractions for various letter combinations and words that are not contracted in print. Another important difference is that sighted readers are inundated with environmental print and hence, have more incidental learning opportunities related to literacy than the reader who is blind or visually impaired. Obviously, reading is an extremely complex process, and thus, it is presumptuous to assume that tactual reading involves the exact same processes as visual reading without a sufficient research base to demonstrate this. At best,

it can be argued that more research is needed in the field of blindness and visual impairment to explore the ways in which the processes of becoming literate are similar and different for braille readers.

Even though braille has been in existence since 1829, there are still many unanswered questions about the strategies involved in being an efficient and effective braille reader, especially in relation to braille mechanics. In order to better understand how various combinations of finger and hand usage affect the oral reading speed and accuracy of braille readers, this chapter will examine relevant research on this topic. To begin this analysis, current braille reading techniques hailed as best practice are described, and then the research on braille mechanics is reviewed. Particularly, research conducted by Hermelin and O'Connor (1971a, 1971b) is detailed since the intent of this dissertation is to constructively replicate one of their experiments. From there, the discussion turns to the research on cerebral processes involved in braille reading and how these processes impact hand and finger usage. Finally, the chapter concludes with an analysis of fluency, specifically related to the measurement of oral reading speed and accuracy in braille.

## Best Practice

Experts on braille literacy agree that the following techniques are used by the most fluent braille readers (Castellano & Kosman, 1997; Harley, Truan, & Sanford, 1997; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). The first characteristic possessed by good braille

readers involves the use of two hands This is deemed especially important during transitions between lines of text. The recommended procedure involves independent use of each hand as the left hand starts reading a new line of text while the right hand finishes reading the previous line. When the right hand is finished, it moves diagonally to the spot where the left hand is reading. At the midpoint of the current line of text, the left hand locates the next line as the right hand finishes the current line.

The second characteristic of good braille readers involves the use of at least four fingers during reading (Castellano & Kosman, 1997; Harley, Truan, & Sanford, 1997; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). The four fingers designated as most useful are the index and middle fingers of both hands. However, it is even more preferable to read with all fingers, except the thumbs. The reason for this is that it is believed that the use of all eight fingers helps the reader track across the same line of braille text without losing his/her place. However, the thumbs are not thought to have enough tactile sensitivity to be useful (Koenig & Holbrook, 2000).

The third characteristic of good braille readers involves the application of light pressure as the fingertips track in a continuous left-to-right direction across the dots in a smooth manner (Castellano & Kosman, 1997; Harley, Truan, & Sanford, 1997; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). Certain hand movements have been thought to contribute to inefficient reading. These include scrubbing (repetitive, up-and-

down movement of the finger over the same braille symbol) and retracing (backward movement over previously read text).

Although the aforementioned recommendations are very precise, the research pertaining to braille mechanics is complex and often contradictory. While the first experimental investigations regarding braille mechanics began in the early 1900s, modern-day researchers are still attempting to answer many of the same questions. Thus, this review of the literature will attempt to identify trends and holes in the existing body of research.

## Braille Mechanics

### Hand Usage

Some of the earliest research on braille mechanics occurred as a national committee, the Uniform Type Committee, was convened to gather evidence regarding the efficacy of various tactual codes. The Uniform Type Committee was assigned the specific task of deciding whether or not to adopt Standard English Braille Grade Two (now called contracted braille) as the official embossed code for American readers who are blind and visually impaired. In a summary of these findings, Maxfield (1925) concluded that the most efficient braille readers used two hands, since 579 of the 1200 participants (experienced braille readers) utilized this strategy, and 43% of these individuals were among the fastest readers. In another experiment involving 50 adult braille readers (some who read a little and some who read a lot; some with calloused hands and some without

calloused hands), Maxfield found that among the 25 fastest readers, only three were one handed readers as compared to 10 among the 25 slowest readers.

Halfway across the world in Germany, Burklen (1917/1932) published the results of a series of experiments that also showed that braille users read fastest when using two hands. Participants in these studies were blind and visually impaired braille readers between the ages of nine and eighteen. Interestingly, Burklen indicated that some of the students had enough residual vision to read braille better with their eyes than with their fingers. Participants were asked to read a series of characters, words, or sentences using their right hand, left hand, or both hands together. Braille was produced on metal strips, and the presentation order of the reading strips was randomized. Different experiments examined various hand or finger usage patterns on assorted reading tasks.

Whitby also found that 85% of a group of 80 braille readers between the ages of 10 and 16 read braille passages faster with both hands together than with either the left hand or the right hand alone (as cited in Wormsley, 1979). Likewise, Williams (1971) obtained similar results by analyzing survey data on reading rates and hand usage. Braille readers between the ages of 15 and 18 were classified as either slow (those who read fewer than 70 words per minute [WPM]), average (those who read 80 to 120 WPM), and fast (those who read over 130 WPM). Seventy percent of the fast readers and 60% of the slow readers used two hands to read braille. Data regarding average braille readers were not analyzed because the intent was to ascertain differences in braille

mechanics employed by good and poor readers. Whitby's results appear to be stronger than those found by Williams, which can probably be attributed to the experimental controls instituted by Whitby instead of the observational techniques employed by Williams.

In a study of 100 fourth graders (half in public schools and half in residential schools) and 100 eighth graders (half in public schools and half in residential schools), Lowenfeld, Abel, and Hatlen (1969) examined the reading behaviors of 106 males and 94 females who were both congenitally and adventitiously blinded with visual acuities of 5/200 or less. Students with additional disabilities were excluded from this study. Participants were asked to complete the reading portions of the *Sequential Tests of Educational Progress* and the *Stanford Achievement Tests* while their TSVIs recorded information about hand usage during the reading tasks. One hundred and forty three students read with both hands, with more students in public schools using both hands than students in residential schools. Although they did not find any statistically significant differences in reading rates based on the hand used, Lowenfeld, Abel, and Hatlen noted that more braille readers who used two hands scored in the upper quartile on the reading comprehension tests than in the lower quartile.

The results of a five-year longitudinal study, known as the Alphabetic Braille and Contracted (ABC) Braille Study, revealed a similar trend in support of two-handed braille reading (Wright, Wormsley, Kamei-Hannan, 2009).

Participants included 38 beginning readers from the United States and Canada whose only reading medium was braille. Fifteen boys and 23 girls between the ages of three and 11 with a visual acuity of light perception or less who had no additional disabilities were videotaped reading familiar passages for about five minutes each spring semester. A growth curve analysis revealed a statistically significant difference in the rate at which the reading speeds of two-handed braille readers increased over time as compared to participants who predominantly read using one hand.

Given the trend in the literature supporting the efficacy of two-handed braille reading, the next step is to explore research pertaining to how the hands are used in bimanual reading. By observing 164 blind and visually impaired braille users between the ages of ten and 23 at the Tokyo School for the Blind reading silently, Kusajima (1974) delineated four predominant patterns of hand usage. The first pattern involved using the left hand as a placeholder and the right hand as the reader. The second pattern entailed using both hands in a parallel manner so that the hands remained side-by-side while tracking across the braille text. The third pattern denoted the use of both hands together until the end of the line had almost been reached, at which time the left hand located the next line of text. The fourth pattern matched the style that is currently hailed as best practice, in which the left hand located the next line of text and began reading while the right hand finished reading the current line of text. The right hand then joined the left hand, and both hands read together until the midpoint

of the line was reached, at which time the left hand moved to the next line. In her observations of 63 braille users of average intelligence in grades three through 11 reading orally and silently, Eatman (1942) also noted an additional pattern in which one or both hands moved backward across the line of text just read and then traversed to the next line.

Even though these are the predominantly observed patterns of hand usage of braille readers as described throughout the literature, there is little agreement over which method is most efficient. Furthermore, there is considerable debate about the role that each hand plays. Nonetheless, the majority of researchers have concluded that the best braille readers use both hands independent of each other to read different portions of text simultaneously, as described in Kusajima's (1974) fourth method.

The research of Eatman (1942) and Fertsch (1946) corroborated the notion that independent hand usage is best. (It should be noted that Eatman and Fertsch are the same person; Fertsch is Eatman's maiden name, and she published before, during, and after her marriage.) She reached this conclusion by photographing the hand movements of braille users while reading. In order to capture the hand movements, she placed the camera in front of the reader and pointed it downward to focus on the braille text. Pictures were taken at four exposures per second. During data analysis, the braille was projected onto a screen and the film was fed through a projector and replayed frame-by-frame on the same screen, thereby making it possible to see the hand movements in

relation to the braille. The standardized timing of the photos also made it possible to calculate time taken to read selected passages. A comparison of hand movement styles and reading speed led Eatman/Fertsch to conclude that the independent use of both hands reduced reading times by six to seven percent.

In a synthesis of the research, Birns (1976) surmised that the fastest readers used both hands independently with the left hand reading the next line as the right hand finished the current line. Interestingly, the Uniform Type Committee found that only 15 out of 1200 braille readers used their hands independently. However, 12 of the 15 who used this technique were the fastest readers (Maxfield, 1925).

Wormsley (1979, 1981) also agreed that the most fluent braille readers were those who read different parts of the text simultaneously with each hand. In an attempt to measure the effects of a hand-movement, training program, Wormsley studied braille readers between the ages of six and 12 who attended either the residential school or a special program for the blind in Pennsylvania. Braille readers with additional motor impairments were excluded. Students were trained 15 minutes a day for 20 days in the independent use of both hands to read different portions of text simultaneously. While the hand movement training program did not appear to have a long-term impact on the continued use of this method, Wormsley noted that independent hand usage was the approach most often employed by the good braille readers.

In their comparison of fourth and eighth grade students in both residential and public schools, Lowenfeld, Abel, and Hatlen (1969) found that 70% of their sample read with both hands, but more of the eighth graders read using both hands independently, while more of the fourth graders tended to keep both hands together while reading. Likewise, Williams (1971) noted that 88% of the fast, two-handed readers read with both hands independently while only one of the slow readers demonstrated this skill. Even more support for independent use of the hands came from a survey of registered blind and visually impaired persons collected for the British Ministry of Health. Gray and Todd found that 41% of braille users who read over 100 WPM used both hands independently while only four percent of braille users who read less than 60 WPM used their hands in this manner (as cited in Wright, 2004).

In her aforementioned study of braille readers at the Texas School for the Blind, Eatman (1942)/Fertsch (1947) designated three classifications of simultaneous use of both hands: right dominant, left dominant, and hands equal. This classification was made by having participants silently read passages of equal length with both the left and right hands separately. If there was more than a 20% increase in reading times between the two hands, the hand with the fastest speed was labeled dominant. If there was less than a 20% difference in reading times between the hands, both hands were considered equal. These were the same criteria used by Graseman (Burklen 1917/1932). Based upon this classification system, Fertsch concluded that the fastest readers tended to have

equal hand dominance and used their hands independently with the right hand reading slightly more than the left hand.

Contrary to these findings, Kusajima (1974) postulated that the third method (parallel use of two hands until the last part of the line at which time the left hand located the next line) resulted in the best efficiency. This determination was made by having students read while wearing a sleeve on their reading fingers. A pencil was attached to the end of an arm that was connected to the sleeve. The pencil hung over the edge of the reader's index fingers and drew a line on a continuous paper roll affixed to a revolving drum. As the reader's fingers moved, corresponding lines were drawn. Since the drum revolved at a consistent rate, it was also possible to estimate reading rate. By analyzing these lines, Kusajima found that the smoother and shorter lines were affiliated with the third hand use pattern. In another experiment, Kusajima also found that braille readers had difficulty maintaining their typical reading rate while reading two different sentences at the same time. In fact, only three participants were able to read both sentences concurrently. The remaining nine participants entirely disregarded one of the sentences. These results were obtained by having brailled sentences scroll under each index finger held in a stationary position. Thus, these findings may have more to do with the fact that the fingers were not in motion. This topic will be discussed in further detail in the analysis of tracking research.

Upon closer examination of these issues, Millar (1987) found that reading tasks are divided between the two hands and that each hand takes turns fulfilling different functions. This theory contradicted the notion that each hand reads different parts of the text independently and simultaneously. Millar studied 10 braille readers between the ages of 14 and 20 who attended two high schools for the blind. However, only two-handed readers with high intelligent quotient scores were used in this investigation. Nevertheless, Millar discovered that instances in which the index finger of both hands touched text at the same time were rare. Typically, the reading finger touched a braille symbol while the non-reading finger was used as a placeholder in a blank cell. Furthermore, she found that when the left hand located the next line of text to be read, it moved slightly to the left of the line. Only after the right hand finished the current line of text did the left hand make contact with the first braille symbol on the new line. As the right hand moved to reconnect with the left hand, the fingers moved above the text so that the right hand was not feeling any dots as the left hand started to read the next line.

Such contradictions in research findings can be quite perplexing. Millar (1987) attributes the differences in her findings to the methods employed during data collection. While she was not the first to photograph or videotape the hand movements of braille readers, most of her predecessors recorded the hand motions from various positions above the desktop. Millar (1988) utilized a method for filming the hand and finger movements from below a transparent

desktop originally developed by Davidson, Wiles-Kettenmann, Haber, and Appelle (1980). This required brailling passages on transparent paper and darkening the indentations on the backside of the paper so that the braille configurations could easily be seen from below the glass tabletop. Since recording from the underside reverses the direction of the braille text, Millar aimed the video camera at an angled mirror mounted below the reading surface. The purpose of the mirror was to reflect an image as if recording were being done from above the reader's hands. However, recording from below gave the added advantage of being able to see the position of the reader's fingers in relation to the braille symbol(s) being touched. In previous cases, the position of the reader's fingers covered the actual braille symbols, and hence, only broad movement patterns were discernable.

The idea that different hands perform different functions forced researchers to contend with the different role each hand plays. Unfortunately, this added layer of research complicates the overall picture. In spite of the fact that this topic has been studied for the past 100 years and continues to be studied, there still is not enough available evidence to say that braille mechanic techniques are a best practice supported by scientifically-based research.

Even though Burklen (1917/1932) agreed that two-handed reading was the most efficient method, he, too, was intrigued by functional differences between the hands. In fact, his review of the literature revealed others who had conducted previous research on the topic. In particular, he discussed the findings

of Heller, Hocheisn, Gigerl, Zech, and Grasemann (as cited in Burklen). Around the turn of the century, Heller proposed that the primary purpose of the left hand is to analyze the braille while the main function of the right hand is to synthesize the braille. Basically, this means that the left hand decodes individual shapes of braille symbols while the right hand previews the upcoming text to help the left hand piece together the information. Hocheisn agreed that the left hand acted as the decoder, but he viewed the purpose of the right hand as a word and line locator. Zech concurred that the left is responsible for decoding while the right is responsible for tracking. However, Gigerl believed that the left index finger checks what the right index recognizes. Given the fact that these studies are summarized in Burklen's review of the research, there are not extensive details provided about the research methodology and procedures employed to reach these conclusions.

Burklen (1917/1932) was especially interested in Grasemann's finding that braille users read faster with their left hand. Consequently, Burklen had Grasemann write a chapter in his book on this original study. Unfortunately, Grasemann does not provide a description of the participants used in this study other than the fact that seven were two-handed braille readers, 15 were left-handed braille readers, and 9 were right-handed braille readers. It is important to note that 30 of the 31 participants read with both hands, but when the hands were tested separately, those classified as left-handed read at least 20% faster with this hand than with the right hand. For those classified as two-handed,

there was less than a 20% difference in reading rates between the two hands. In this experiment, all participants were timed as they read the first page of a passage with both hands, the second page with the left hand, and the third page with the right hand. Thus, it is possible that there might be an unintended order effect. When Burklen replicated Grasemann's study, he also found that 75% of his participants read German braille, which is uncontracted, faster with the left hand alone than with the right hand alone.

Hermelin and O'Connor (1971b) found that 14 beginning braille readers between the ages of eight and 10 read unrelated sentences significantly faster and more accurately using only the left hand than only the right hand. A similar study involving 15 adult braille readers between the ages of 25 and 65 who read columns of random letters significantly more accurately with the right hand alone than with the left hand alone. In spite of the differences between the two experiments, a distinct advantage was found for accurate decoding of braille using the left hand. It should be noted that the majority of participants in both these studies were right handed.

Wilkinson (1979, 1982) and Wilkinson and Carr (1987) built on the work of Hermelin and O'Connor (1971a, 1971b). Using 16 right-handed, female braille readers and 17 right-handed, male braille readers between the ages of 10 and 20 at the Michigan School for the Blind, Wilkinson (1979) found that only females showed a significant improvement in reading speed for reading braille paragraphs with the left-hand. However, the same effect in females was not

observed for reading braille letters. Furthermore, those who indicated a preference for the left hand performed better with the left hand, but those who indicated a preference for the right hand did not necessarily perform better with the right hand. Participants in this study completed a handedness questionnaire and a history of blindness questionnaire. Six participants were excluded for being left-handed due to the inability to run statistical analyses on this small group. During the testing session, participants were asked to read lists of words arranged vertically in order to minimize any left-to-right motor scanning bias. Participants were then given passages from the *Gates-MacGintie Reading Test*. This test was used to measure both reading speed and accuracy. In the control condition, participants read three paragraphs silently and then three paragraphs orally using their preferred hand usage pattern, and then they answered comprehension questions. In the experimental conditions, participants read 12 paragraphs silently and 12 paragraphs orally with either the right or the left index finger, and then they read the remaining 12 paragraphs silently and orally with the opposite index finger. Once again, participants had to answer comprehension questions regarding the reading material.

Sampio and Philip (1995) also found similar results. In a sample of 38 adults between the ages of 19 and 62 who became blind before learning to read and write, females read faster with the left hand than the right hand. A similar trend was also found in regard to hand preference.

In a follow-up study, Wilkinson (1982) and Wilkinson and Carr (1987) studied 34 male and 29 female, congenitally blind braille readers between the ages of 11 and 70. Participants were obtained from five residential schools, disabled student services at Michigan State University, and the Michigan Association of the Blind. As in her previous study, each participant was tested for handedness using a questionnaire, and a personal and literacy history was obtained through a questionnaire. A baseline was established by having the braille users read a paragraph employing their typical mechanics style. They then read four additional paragraphs with the preferred hand alone and then the non-preferred hand alone using the index finger alone and then the middle finger alone. The interesting twist in this study was that readers were asked to read lists of letters and words that felt similar or different and that sounded similar or different. The results indicated that those who processed sound similarities and differences better tended to prefer the right hand for braille reading while those who processed tactual similarities and differences better tended to prefer the left hand for braille reading. These findings will be discussed further when exploring cerebral processing. In addition, it was found that participants read both words and paragraphs significantly faster with the left hand.

Also intrigued by the work of Hermelin and O'Connor (1971b), Mommers (1980) tested similar hypotheses using 25 Dutch braille readers between the ages of seven and 12. All participants were totally blind and right handed (as determined by a modified handedness test). Each child was asked to read lists of

numbers and lists of words for one to two minutes each using their natural reading style, the left index-finger only, the right index-finger only, the left middle-finger only, and the right middle-finger only. In order to avoid fatigue, students were tested over three sessions by the same experimenter. Reading speed (number of words read) and accuracy (number of mistakes) were recorded. While a slight left-hand advantage was noted when reading unrelated words, the difference between the hands was not found to be statistically significant.

In a summary of research, Kozel (1995) concurred that an emerging pattern of left-hand superiority in the accurate decoding of braille had been established, and he pointed to a similar phenomenon in children learning to read braille. Rudel, Denckla, and Spalten (1974) taught 40 sighted males and 40 sighted females, all of whom were right-handed, to read isolated braille symbols by touch. Participants were in the second, fourth, sixth and eighth grades. They, too, found a left-hand advantage. In a similar study, Rudel, Denckla, and Hirsch (1977) also found that sighted participants ten years or older demonstrated a left-hand superiority for decoding braille symbols.

Just as some research shows a left-hand superiority, there is also research that shows a right-hand advantage. Holland and Eatman (as cited in Wright, 2004) photographed the hands of students between the third and 11$^{th}$ grades as they read braille. Two braille readers were taken from every grade except the 10$^{th}$ grade. As students read passages, their hand movements were

photographed at five exposures per second. Their analysis of the pictures revealed that two-handed braille users read a greater proportion of text with their right hand than with their left hand.

Multiple researchers have described an interesting finding. Fertsch (1947) noted that braille users who displayed left-hand dominance were the slowest and poorest readers and had difficulty using both hands in an independent manner. Millar (1984) described a similar pattern. Using congenitally blind braille readers between the ages of seven and 13 from two different residential schools for the blind, she actually sought out students with average intelligence and those who had an intelligent quotient (IQ) at least 18 months lower than their chronological age. She then had participants read lists of letters with each hand separately and both hands together while she recorded reading speed and accuracy. Millar found that only poor readers showed better reading speeds with the left hand. Hence, both of these researchers speculated that hand dominance may be related to braille proficiency. However, this finding has not been supported sufficiently by research. As Kusajima (1974) observed, beginning braille readers tended to predominantly use their right hands alone whereas advanced readers used two hands.

Right hand braille reading has also been correlated with different reading styles. Kusajima (1974) asserted that the aforementioned beginning braille readers also tended to read letter-by-letter as indicated by their uneven reading lines. However, Maxfield (1928) advocated that right handed reading is best,

especially when word recognition strategies are employed versus letter recognition strategies. This conclusion was based on the findings of the Uniform Type Committee as well as survey results in which a majority of TSVIs indicated that they taught braille using word recognition strategies.

Millar (1975) also suggested that less experienced braille readers tended to pay more attention to the tactual features of the braille code while more experienced braille readers tended to pay more attention to the phonological features of language. To reach this conclusion, Millar studied 48 congenitally blind braille readers who had no additional disabilities. Participants were 24 female and 24 male students at two residential schools for the blind who had only minimal light perception. Participants were given lists of words to read and had to engage in matching tasks involving words that felt or sounded similar and different. Beginning readers were better at matching based on tactual similarities whereas the experienced readers were better at matching based on phonological similarities.

After years of researching braille reading phenomenon, Millar (1997) concluded that whether readers decode braille letter-by-letter or word-by-word depends on their proficiency level as well as on the type of reading task. This suggests that braille readers may be more prone to rely on the left hand when they have not yet acquired proficiency in the braille code or are engaged in tasks that require identification of isolated letters or words. Support for this position was provided by Bradshaw, Nettleton, and Spehr (1982) who did not find any

differences between the hands when congenitally blind braille readers between the ages of 28 and 57 were asked to find words in lists that related to a designated sound or meaning (both of which required phonological processing).

Although this review of the literature on hand usage has revealed a trend suggesting that the most efficient and effective braille users read with both hands, the research suggests that each hand may fulfill a different function in the reading process. In an attempt to discern the role of each hand, a strand of research has emerged that has found instances in which the left hand allows for more accurate and more efficient braille reading. However, a closer analysis suggests that this left-hand superiority may only be applicable to beginning and struggling braille readers. Differences in hand use have also been noted in relation to different reading tasks. This has led some researchers to conclude that hand use in braille reading may be quite dependent upon the reading task and the reader's familiarity with the task.

**Finger Usage**

Since the fingers are the part of the body that maintains direct physical contact with braille, there is also a substantial amount of research on this topic. As discussed earlier, the use of two to four fingers on each hand has been deemed best practice. For the purpose of this literature review, the body of research on finger usage in relation to efficient and effective braille mechanics will be analyzed.

While there was almost unanimous support for two-handed braille reading in the literature, there seems to be less consistency on finger usage, perhaps because there are eight different fingers as compared to only two different hands. In fact, a survey of teacher practices indicated that most TSVIs do not specifically teach any particular finger usage pattern (Lowenfeld, Abel, & Hatlen, 1969). Basically, it is left up to the students to personally decide which fingers are most effective. However, questionnaires completed by 520 TSVIs (390 from public schools and 130 from residential schools) revealed an interesting trend showing that residential schools usually recommended the use of the index finger while public schools usually recommended the use of other finger combinations (Lowenfeld, Abel, & Hatlen). Unfortunately, a search of the literature revealed that there were not any new data on teacher practices regarding effective finger usage because most research on braille literacy that gathered data from TSVIs has been concerned with teacher attitudes about braille and perceptions regarding the efficacy of pre-service preparation to teach braille (Ferrell, Mason, Young, & Cooney, 2006).

In a study of adult braille readers who had 29 to 62 years of experience reading braille, Foulke (1964) tested each finger on each hand separately, excluding the thumbs, to discern the ability of individual fingers to read braille. While all fingers were able to discriminate various braille letters, the index finger was the most sensitive followed by the middle finger. Although the ring and pinky fingers were able to accurately discriminate braille symbols, their

effectiveness was noticeably less as indicated by a statistically significant reduction in reading speed and accuracy. Furthermore, no differences between the fingers of each hand were observed. Eatman (1942) agreed that there was no difference in tactile sensitivity between the index fingers of the two hands as indicated by reading accuracy. Finally, Mommers (1980) demonstrated that reading speeds were higher for index fingers alone than for middle fingers alone among elementary Dutch braille reading students.

As is the case with two-handed reading, there is research that supports the efficacy of using both the index and middle fingers when reading braille. Burklen (1917/1932) found that good braille readers between the ages of nine and 18 used more than just their index fingers while reading. More specifically, reading rates and comprehension have been shown to be better for braille users who read with multiple fingers of each hand (Lowenfeld, Abel, & Hatlen, 1969; Williams, 1971). However, Lowenfeld, Abel, and Hatlen found that the majority of the children in their study read with just their index fingers and the next largest group read with both their index and middle fingers. In spite of these ambiguities, there seems to be no doubt that the index finger plays a major role in braille reading.

In order to prevent practice effects from biasing their research findings, researchers interested in hand dominance have tested the index and middle fingers of each hand separately. Their findings indicated that the index fingers are superior to the middle fingers (Hermelin & O’Connor, 1971a; 1971b;

Wilkinson, 1979, 1982; Wilkinson & Carr, 1987). However, it is important to note that performance differences (reading speed and accuracy) between the two hands on a variety of reading tasks were more pronounced for the middle finger than the index finger.

Determining the role and function of the individual fingers has traditionally been a difficult task, and has often produced conflicting results. For instance, Kusajima (1974) found that reading speeds did not differ between the left and right index fingers. However, Eatman (1942) discovered that the fastest readers used both index fingers to read, but when forced to use only one finger, the right finger produced the fastest reading rates. Millar (1988, 1997) sheds a new light on this subject when she recorded the hand movements of braille users reading text brailled on transparent paper and placed on a glass tabletop. This method allowed her to see the finger(s) to which the reader applies pressure. When pressure is applied, the braille flattens the fingertip and produces a light colored area of the finger that Millar (1997) refers to as the reading patch. As discussed earlier, Millar (1987, 1997) found that there were few instances in her studies on braille reading in which multiple fingers displayed a reading patch. Further research analyzing the reading patch has the potential to resolve these discrepancies because specific instances in which one reading finger is predominantly used can be analyzed.

Although research has shown that the index, middle, ring, and pinky fingers are capable of discriminating braille accurately, the research suggests

that it is practical to use only the index and middle fingers for reading. Even when the middle and index fingers are deployed for reading tasks, the index finger is believed to be the primary reading finger. Just as the research on hand use favored bimanual reading, the limited research in this area suggests that the use of both index fingers is desirable. However, there is little consensus on the role and function of the left versus the right index finger. At this juncture, it is safe to presume that finger usage and dominance patterns are closely related to hand dominance and hand usage patterns.

**Tracking**

The final area of braille mechanics to be covered in this analysis is the movement of the hands across lines of braille text, and it is referred to as tracking. Sometimes this term is often used in a more global sense in reference to all the braille mechanics skills, but in this study, tracking refers strictly to hand movements across the same line of text. Issues pertaining to hand movements between lines of text were covered in the section on hand usage.

Best practices regarding tracking highlight the importance of smooth movements across the braille in which light pressure is applied to the dots. Another important component involves movement in a continuous, left-to-right progression. Hence, retracing and scrubbing are undesirable as they temporarily impede the left-to-right movement. Research related to these aspects of tracking will now be analyzed to see if current practices are supported with evidence.

In the first book on teaching braille, Maxfield (1928) describes the importance of light and smooth finger movements. Initial studies on tracking involved having braille readers wear a sleeve or a ring with an attached stylus or pencil. As the readers moved their hands across the braille, the stylus or pencil marked a corresponding line on a sheet of paper. As a result, Burklen (1917/1932) analyzed the lines made by braille users and found that the best readers produced the straightest lines. Likewise, Kusajima (1974) noted that reading lines of good braille readers contained very few zig-zag motions, which indicated that good braille readers do not tend to engage in scrubbing motions.

Holland (as cited in Wright, 2004) measured the pressure exerted during silent braille reading by 17 fourth through tenth graders. Prior to testing, participants were classified as either fast or slow readers. A trend found amongst both groups of readers was that pressure is greatest at the beginning of the line of a new line of text and lessened as the fingers progressed across the line. However, slow readers exerted more pressure than the fast readers. Lowenfeld, Abel, and Hatlen (1969) also reported that smooth reading patterns were positively correlated with fast reading speeds and good reading comprehension.

Much of the research on tracking has focused on scrubbing and retracing. A strong relationship has demonstrated that poor readers engage in more of these behaviors than good readers. However, these behaviors have been observed in all types of readers. For example, the Uniform Type Committee

discovered that 90% of the readers studied engaged in scrubbing (Maxfield, 1928).

Furthermore, Davidson, Wiles-Kettenmann, Haber, and Appelle (1980) noted that all 18 of the adolescent braille users with light perception or less engaged in retracing or rechecking individual braille symbols while reading passages. However, regressions involving multiple symbols were observed more frequently amongst the less proficient readers. In another study of 16 life-long braille readers in high school at the New York School for the Blind who received braille instruction from the same teacher, Davidson, Appelle, and Haber (1992) found that the left index finger was the one that typically scrubbed or retraced, especially in proficient readers. Similarly, Eatman (1942) noted that good readers tended to make any needed regressions with the left index finger while poor readers employed either the right index finger alone or both index fingers together. Williams' (1971) survey data indicated that scrubbing was only reported in the group of slow readers.

As can be seen from this review of the literature, the use of light pressure, continuous left-to-right movement, and minimal scrubbing and retracing are associated with effective and efficient braille reading. A faint pattern has emerged that reinforces the notion that the left hand may serve the purpose of checking uncertainties or correcting decoding errors. However, more research is needed to confirm this phenomenon.

## Hermelin and O’Connor

As indicated in the previous review of research on braille mechanics, Hermelin and O’Connor are not the only investigators to have studied this topic. However, a recent synthesis of the research on braille literacy between the years of 1963 and 2003, discovered that a study conducted by Hermelin and O’Connor (1971b) was the only peer-reviewed, scientifically-based research available on this topic (Ferrell, Mason, Young, & Cooney, 2006). Since the intent of this dissertation is to test these findings in order to increase the availability of evidence-based practice, it is essential to provide an in-depth description of their research on hand dominance. Unfortunately, the published reports on Hermelin and O’Connor’s research provide only a minimal amount of detail.

Their initial study involved 14 braille readers between the ages of eight to 10. Twelve of the participants were right handed and two were ambidextrous. Most of the participants usually were two handed readers, but interestingly, three of the children were unable to read with only the right hand. Fearing that this may have compromised the results, Hermelin and O’Connor (1971a) conducted additional research on this topic. When summarizing the data from the previous experiment, two extra participants seem to have been added. Thus, the results will be detailed again in this analysis for clarity. Fourteen participants were right handed and two were ambidextrous. Hand dominance was established through a series of tasks in which hand use was recorded. No data were given on hand usage patterns typically employed by the participants during

braille reading. Nevertheless, reported results still indicated that left-handed reading was faster and more accurate than right-handed reading on four unrelated, age-appropriate sentences.

Hermelin and O'Connor (1971a) then went on to conduct a similar experiment with 15 adults (seven males and eight females) between the ages of 25 and 65. Nine participants were congenitally blind and six were recently blinded. While those with congenital blindness had received formal instruction in braille, many of those with adventitious blindness were self-taught. Twelve of the individuals were right handed, one was left handed, and two were ambidextrous. However, nine typically read with their left hand, and six typically read with their right hand. Participants were asked to read vertical columns of random letters. Once again, a left-hand advantage was found. However, unlike the experiment with the children, a significant difference in the use of the left hand was found only in the number of errors made.

Although Hermelin and O'Connor's research on braille reading children met the minimum criteria for scientifically-based research, it still leaves a lot to be desired. As indicated by this review, there are some discrepancies between published research reports. It is very difficult to figure out such discrepancies because the authors did not provide sufficient details regarding their research methodology. Furthermore, the extent of the experiment seems limited in two respects. First of all, they only tested differences between the left and right index fingers and middle fingers alone, instead of testing other combinations used by

braille readers. Secondly, participants only completed short reading tasks. Thus, while Hermelin and O'Connor made an interesting and noteworthy contribution to the research on braille mechanics, further replication is needed in order to validate or refute their findings.

## Cerebral Processing

Hermelin and O'Connor (1971a, 1971b) attributed their findings to the distinct role of the left and right hemispheres of the brain. Language processes occur predominantly in the left hemisphere while spatial processes occur predominantly in the right hemisphere of the brain. Research has shown that this is true for 96% of humans irrespective of hand dominance. It is also well known that the left hemisphere generally controls the right side of the body while the right hemisphere generally controls the left side of the body (Gazzaniga, Ivry, & Mangun, 2008).

Unfortunately, research in this area is extremely limited. A very recent systematic search for articles published in the ProMed database on braille reading and cerebral processes revealed a mere three studies related to hand use and tactile reading. Moreover, the majority of these studies either included sighted participants or involved reading raised letters instead of braille symbols (Hannan, 2006). Contrary to the patterns revealed throughout this literature review, Bradshaw, Nettleton, and Spehr (1982) studied twelve braille readers and concluded that hand superiority is nonexistent and that hand dominance does not affect braille reading.

As Millar (1997, 2008), Gizewski, Timmann, and Forsting (2004), and Geschwind (1972) point out, braille reading involves both the left and right hemispheres of the brain, and hence, hand superiority should not be an inherent aspect of braille reading. Since braille consists of spatial arrangements of raised dots, it is natural to deduce right hemisphere/left hand involvement. However, language processes are inherently involved in reading as well, and thus, it is equally rational to assume left hemisphere/right hand involvement. Therefore, the ultimate focus needs to be on understanding the role that each hand plays and how that affects the learning of braille and the development of fluent reading.

Traditionally, tactile processing was thought to occur only in the somatosensory cortex, which is located in the parietal cortex. The parietal lobe is a mid-brain structure that extends into both the left and right hemispheres. Both language and spatial processing occur within the parietal cortex. Reading processes also occur in the occipital lobe, which is primarily responsible for visual processing (Hannan, 2006). Therefore, it was surprising to find research that determined that the visual cortex is activated during braille reading in congenitally blind, braille readers (Sadato et al., 1996). Functional magnetic resonance imaging (fMRI), an advanced form of brain scanning, revealed that braille reading activates more of the occipital cortex than the somatosensory cortex (Sedato & Hallet, 1999). However, it should be noted that this study contained only one participant, and thus, may or may not be a common

occurrence in braille readers. Using fMRI, another study revealed that congenitally blind, braille readers had higher levels of activation in the visual cortex than adventitiously blind participants and that cerebral activation was contralateral (opposite side) to the braille reading hand in congenitally blind participants, whereas hemispheric activation was ipsilateral (same side) for adventitiously blind participants (Burton, Snyder, Conturo, Akbudak, Olinger, & Raichle, 2002).

Once again, the issue of hand use in braille reading has resurfaced. Since contralateral processing has been demonstrated in braille readers who are congenitally blind, this subject demands further investigation. A pattern of left-hand superiority in beginning and struggling readers may indeed be indicative of a primary reliance on right-hemisphere, spatial processing. However, the National Reading Panel (2000) strongly recommends phonics instruction for beginning readers. Phonological processes are language based, and hence rely more on left-hemisphere processing. This may potentially pose problems for braille readers who are acquiring literacy, and this is not a possibility that can be dismissed given the fact that braille readers have not attained the same levels of fluency as their sighted peers (Millar, 1997).

## Fluency

Another piece of this complex puzzle relates to the low levels of fluency exhibited by braille readers. The first step in solving this puzzle requires a review of the relevant literature on braille reading rates. The discussion will then turn to

the issues related to the measurement of oral reading speed and oral reading accuracy, especially in reference to informal reading inventories (IRIs).

*Braille Reading Rates*

Unfortunately, consistent data are not available on the reading rates of braille readers. However, this seems to have been an issue as long as professionals have been conducting research on braille literacy. Burklen (1917/1932) concluded that sighted readers obtained speeds three to four times faster than that of the average braille reader. Estimates of average reading speed have ranged from 70 through 80 WPM (Caton, Pester, & Goldenblatt, 1979) to 90 through 110 WPM (McBride, 1974). Millar (1997) estimated the braille reading rate to be between 100 and 150 WPM and indicated that the average reading rate of print readers is 250 WPM. Average reading rates of beginning braille readers in elementary school range from 34 to 62 WPM as compared to average reading speeds of 53 WPM to 123 WPM for beginning print readers (Emerson, Holbrook, & D’Andrea, 2009). Reading rates of braille readers in the upper elementary grades range from 50 to 67 WPM (Caton, Pester, & Goldenblatt) while the reading rates of print readers in the upper elementary grades ranges from 131 to 174 (Johns, 2008). Thus, any of these estimates of braille reading rate are considerably below average.

*Informal Reading Inventories*

Reading speed and accuracy are the most commonly assessed forms of fluency (Rasinski, Blachowicz, & Lems, 2006; Strecker, Roser, & Martinez, 2005).

While these are not the sole components of fluency, these are the only ones that were addressed in this particular study. The reason for this decision relates to the theory that reading prosody (expression) is contingent upon the ability to chunk phrases of text together instead of reading word-by-word (Kuhn, 2003; Rasinski, Blachowicz, & Lems, 2006; Samuels, 2002; Strecker, Roser, & Martinez, 2005). Unfortunately, this skill may not be emphasized when teaching braille because tactile readers can only "see" what is under the fingertip(s) (Rex, Koenig, Wormsley, & Baker, 1994). Since instruction in prediction cannot be accurately measured, measures of prosody were not part of the assessment instrument.

There are two widely used approaches to assess oral reading speed and accuracy. The two methods are curriculum-based measurement (CBM) and the informal reading inventory (IRI). Curriculum-Based Measurement entails having a student orally read a passage in a textbook from the school's curriculum for one minute (Rasinski, Blachowicz, & Lems, 2006). However, the investigator decided that CBM is not appropriate for this study because participants were expected to come from a variety of school districts using a variety of curriculum-based materials. Thus, it would have been extremely time consuming to prepare testing instruments ahead of time. Furthermore, it would also have been very difficult to pick reading passages from these materials that are unfamiliar to the student but do not contain information that is contingent upon prerequisite knowledge since the researcher has not personally worked with the participants. Given the fact

that repeatedly reading the same text has shown to increase fluency (Kuhn, 2003; National Reading Panel, 2000; Rasinski, Blachowicz, & Lems, 2006; Samuels, 2002; Strecker, Roser, & Martinez, 2005), using passages that participants have had previous exposure to could seriously jeopardize the results of this experiment.

In spite of the current political emphasis on formal, standardized assessment, informal assessments can still provide valuable information. This is especially true in light of the fact that standardized assessments are typically not normed on students with visual impairments and that changing administration procedures has the potential to affect the test's reliability and validity (Rex, Koenig, Wormsley, & Baker, 1994). Therefore, IRIs serve as a viable alternative for gathering information about the reading behaviors of individuals who are blind or visually impaired (Koenig & Holbrook, 1995; Wormsley & D'Andrea, 1997). IRIs are of particular interest to this researcher because they are designed to be administered by teachers, and they assess both oral reading speed and oral reading accuracy through the use of grade-level word lists and grade-level reading passages.

## Implications

### Historical Changes

The research examined in this literature review spanned a 100 year period. Given the advancements that have occurred in the past century, previous research is not necessarily applicable to current circumstances. Thus, this section

presents the factors that need to be considered when interpreting research on braille literacy.

The most obvious issue relates to the changes in the braille code within the past 75 years. Studies conducted prior to the adoption of Grade 2 Braille by the Uniform Type Committee in 1932 (Rex, Koenig, Wormsley, & Baker, 1994) were most likely conducted in either Grade 1 or Grade 1½ Braille (Lowenfeld, Abel, & Halten, 1969). Care must also be taken when interpreting findings that involve the use of foreign language braille because these codes are typically written in uncontracted braille.

Another significant change that has the potential to complicate the results of the available research is the recent emphasis on visual efficiency, the use of residual vision. Prior to the 1970s, all children who were blind or visually impaired were taught as if they had no vision. The rationale for this former practice involved the belief that residual vision would deteriorate if the eyes were strained, and thus, educational interventions focused on saving sight (Hatlen, 2000). However, Barraga (1963) demonstrated that students could be taught to effectively and safely use their vision. As a result, the majority of children with visual impairments are now print readers, using either large print, regular print, or regular print with optical aids (American Printing House for the Blind, 2010). Since the majority of studies do not provide information on visual acuities or visual conditions, the use of residual vision has the potential to affect the manner in which braille mechanics are utilized. For example, if a braille reader has

enough vision to see the lines of braille, (s)he may not feel inclined to use one hand to locate the next line of text, and thus, may actually prefer to read with one hand.

Hand and finger usage patterns observed throughout the research may be the result of instruction in braille mechanics rather than contralateral cerebral processes (Fertsch, 1947). Furthermore, it is also possible that the first patterns learned become the predominant hand and finger usage style (Millar, 1997). As Lowenfeld, Abel, and Halten (1969) found, different techniques are often taught in different educational settings. There is also no guarantee that a beginning braille reader will have the same braille teacher during the process of acquiring the braille code, and consequently, (s)he may be exposed to numerous techniques. Therefore, without an instructional history, it is hard to determine what aspects of hand and finger usage can be attributed to nature versus nurture.

Finally, the increased availability of various assistive technologies may have an impact on braille fluency and braille mechanics (Lowenfeld, Abel, & Hatlen, 1969). First of all, there has been an increase in the availability of braille materials over the last 100 years. On the other hand, braille readers are now honing their literacy skills using various modalities, and thus, they may not be reading braille as much as they once were. Braille users may also be using new tools that change the manner in which hands and fingers were previously used. For example, students long ago relied primarily on the slate and stylus to write.

In this style of writing, the stylus is held in the right hand. Thus, tasks involving copying required the braille user to read with the left hand while writing with the right hand (Burklen, 1917/1932). In current times, braille users often read materials on a refreshable braille display, and hence do not necessarily need to use the left hand as a line locator since there is only one line of text to be read. Since it is unknown what technologies are utilized by students, it is hard to determine how the use of assistive technology has affected braille mechanics.

**Current Needs**

In spite of 100 years of research on the topic of braille mechanics, further inquiry is warranted due to discrepancies in the professional literature. These contradictions can be attributed primarily to the participants studied and the methodologies utilized. In designing the current study, it was important to evaluate these gaps and incorporate specific strategies to address these shortcomings.

The majority of research on braille focuses on a very small segment of the population of children who are blind. Participant selection criteria in the research reviewed tended to focus on those who were congenitally blind, who had no additional disabilities, and who attended residential schools. Samples used in the aforementioned studies are not representative of the true population since most vision loss is adventitiously acquired, over half the students with visual impairments are estimated to have additional disabilities, and less than 10% of

students who are blind attend residential schools (American Printing House for the Blind, 2010; Tuttle & Tuttle, 2004).

Although several research studies explored the difference between good and poor readers, most studies included only those whose intelligence fell within the normal range. However, a trend has been demonstrated suggesting that fluent and struggling braille readers utilize different braille mechanics and different cerebral processes. Thus, in order to better assess this connection, it will be important for future researchers to avoid placing limitations on intelligence.

While some studies did pool participants from both residential and public schools, the majority of research was conducted using students who were blind in residential placements. Moreover, participants usually were not randomly selected from all residential schools, but instead, residential schools were selected based on geographical proximity. Although this is understandable given the expenses involved in conducting research, it would be better to sample students who are blind from both public and residential schools in the same geographic region.

The inclusion of participants from different educational settings is vital because the intensity of braille instruction is thought to be greater in residential placements. Furthermore, residential schools may relegate the responsibility of teaching braille to one TSVI while school districts often employ rotating, itinerant TSVIs to provide braille instruction to students who are blind and visually

impaired. While it is not known if differences still exist in the braille mechanics taught in public schools versus residential schools, this possibility needs to be considered when conducting research. Given these confounding factors, it is important that research extend across and account for differences in educational placements.

Another complicated factor involving participants involves the fact that there are several disorders of the visual system that result in the reduction or absence of vision. Not all students who read braille evidence the same etiology, and even those who do share the same eye condition may function very different visually. However, research reports published in peer reviewed journals that were examined in this literature review often failed to report sufficient information on participants' visual functioning. Thus, it is essential that researchers gather and report details about a student's visual functioning as indicated by visual acuities and visual fields.

When adding to the existing research base, it is also important to examine the methodologies implemented by other investigators. This has become a necessity as a result of the legislatively mandated call for scientifically-based evidence (No Child Left Behind Act, 2002). Therefore, current researchers have the task of analyzing previous research in order to increase the rigor of the current state of research.

There are many lessons to be learned from the previous research about the study of braille mechanics. First of all, specific aspects of braille mechanics

have been studied in isolation on tasks that are minimally related to everyday literacy. Some studies included in this literature review utilized standardized assessments to measure dependent variables. However, these instruments are typically not normed on individuals who are blind and visually impaired. While this does not necessarily mean that standardized assessments cannot and should not be used on this population, comparisons to sighted peers based on these assessments must be made with caution. Hence, research variables need to be assessed in a manner that provides meaningful data specific to braille literacy.

Previous studies have measured reading speed and reading accuracy among braille readers. With time, the measurement of these skills has become more sophisticated. Oftentimes, researchers in the first half of the last century had to utilize techniques in which reading times and errors were estimated instead of directly measured, especially when silent reading was assessed. Although oral reading has been shown to be slower than silent reading (Holland & Eatman as cited in Wright, 2004; Johns, 2008; Koenig & Holbrook, 1995), research measuring only silent reading misses the opportunity to evaluate the types of reading errors made. Furthermore, when calculating accuracy, many researchers have failed to take into account whether or not errors are significant (i.e., change the intended meaning of the text). Just because a student reads faster using a certain combination of hands and fingers does not necessarily mean that students are reading in a manner that is conducive to comprehension. Therefore, current research needs to examine the types of errors made as well

as the number of errors made. Furthermore, it would be beneficial to analyze errors in relation to their effect on reading speed.

The final methodological consideration that needs to be discussed involves the assessment of hand and finger movements. The majority of previous research summarized in this literature review relied on self-report or observation. Viewing hand movements from above the reading surface allows the observer to notice gross motor movements, but it does not allow for the evaluation of individual fingers in direct relation to specific braille symbols. Even when projections of braille reading passages are placed beneath projections of filmed hand movements, it is still not possible to see the different pressure being exerted by the various fingertips. Thus, it is important that the method of videotaping from below a transparent surface be implemented in the continued study of finger and hand movements (Breidegard, Jonsson, Fellenius, & Stromqvist, 2006; Davidson, Wiles-Kettenmann, Haber, & Appelle, 1980; Millar, 1988).

The overall factors that need to be taken into consideration when researching braille mechanics are as follows: Given the fact that there might be a link between hand usage and reading level, the practice of excluding participants based on IQ needs to be re-evaluated. Furthermore, both students with congenital and adventitious blindness need to be studied in regards to their braille reading techniques. Participants also need to be assessed while engaging in authentic literacy tasks, not on scrambled words or unrelated strings of words.

This will also allow for an analysis of errors that takes into account their effect on reading comprehension and reading speed. Research designs that increase the availability of scientifically-based evidence also need to be implemented in the study of braille mechanics. In order to better understand the role and function of the hand and fingers in braille reading, especially as they relate to contralateral cerebral processing, mechanical movements need to be observable in direct relation to the braille text.

## Summary

The research regarding the hand and finger usage patterns of braille readers can best be synthesized by the following statement made by Wilkinson (1979):

> In summary, the studies of blind braille readers generally demonstrate that braille reading skills are acquired in stages that vary with ability and can change with practice, experience, or training; yet there may be constraints on the ability to progress through learning levels and to recall verbal and nonverbal features, constraints that are related to the task, the type of hand movements, and the cognitive processes used (p. 16).

The methodology delineated in the next chapter is intended to address these concerns. The intent of this research was to attempt to replicate the results obtained by Hermelin and O'Connor (1971a, 1971b). However, it is neither feasible nor desirable to replicate their exact study. First of all, practices have evolved over time, and thus, research useful to the practitioner reflects current

needs. Furthermore, this review of the literature has revealed many trends and holes in the previous research that need to be addressed. After years of research on the topic of hand and finger usage of braille readers, Millar (1997) urges, "Further studies of the development of hand use in braille would be of interest, especially with designs that systematically vary stimulus, task, and contextual factors at different levels of braille reading" (p. 73). This particular study followed these guidelines by systematically varying hand and finger usage conditions across different reading tasks (symbols, words, and sentences) that involved several types of decoding (spatial, phonological, and contextual).

CHAPTER 3

# METHODOLOGY

## Overview

In order to increase best practices supported by scientifically-based evidence, this study constructively replicated a previous experiment on the hand and finger usage patterns of braille readers that produced the best oral reading speed and reading accuracy. Constructive replication requires the current researcher to devise his/her own methods for testing the findings of the original researchers (Gall, Gall, & Borg, 2007; Lykenn, 1968). Given the 40 year lapse between the original study and this research, it was deemed best to use procedures that addressed and reflected the current needs of and practices in the field of blindness and visual impairment.

The remainder of this chapter is devoted to discussing the methodology used in this investigation. This includes details about the research design (including the independent and dependent variables), participants, procedures (including sampling, data collection, and piloting), instrumentation, and data analysis (including statistical assumptions). Before delving into specific methods, a review of the questions addressed by this study is helpful. They were as follows:

Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index + middle) resulted in the greatest degree of fluency?

Q2 Is there a relationship between handedness and/or dominant reading finger(s) and the hand and finger usage pattern that produced the greatest degree of fluency?

Q3 Is there a relationship between reading ability and the hand and finger usage pattern that produced the greatest degree of fluency?

Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, literacy modalities, educational setting, or instructional curriculum), participant characteristics (primary language, age vision lost, or presence of additional disabilities), and braille reading fluency?

## Research Design

The research design used in this study was a counterbalanced, repeated measures experiment with one within-subjects factor and three between-subjects factors. Basically, there were nine treatment variables, and all participants received all treatment conditions presented in random order. Furthermore, each participant's performance was measured across all treatment conditions (Gall, Gall, & Borg, 2007; Huck 2011; Mertens, 2009).

### Independent Variables

The treatment variables in this study included hand usage and finger usage. Three conditions were examined regarding hand usage: reading with the left hand only, reading with the right hand only, and reading with both hands. During two-handed conditions, participants were allowed to use their normal tracking patterns. Finger usage involved the following three conditions: index finger(s) only; middle finger(s) only; and middle and index fingers. While reading

under these conditions, participants were instructed to have only the designated finger(s) in contact with the braille text.

Besides the treatment variables, there were also differences among the participants that needed to be accounted for because of their potential impact on the dependent variable. These included reading ability, handedness, and dominant reading finger(s). Students were classified as being proficient readers (those whose instructional reading level was at or above their current grade level) and struggling readers (those whose instructional reading level was below their current grade level). Handedness referred to being either left handed, right handed, or ambidextrous. Dominant reading finger, on the other hand, was defined as the finger(s) that were used the most to decode braille characters and recheck what was read. More information on how participants were assigned to each of these groups is provided in the instrumentation section of this chapter.

**Dependent Variables**

The dependent measure in this study was fluency. Technically, fluency includes oral reading speed, oral reading accuracy, and oral reading expression (National Reading Panel, 2000; Rasinski, Blachowicz, & Lems, 2006). However, for the purpose of this study, expression was not an analyzed component of fluency. Moreover, oral reading speed and oral reading accuracy were condensed into a single measure to prevent someone from obtaining fast speeds as a result of omitting portions of text.

Fluency was assessed by recording both the types of errors, also known as miscues, and the number of errors made while reading a designated selection aloud. A miscue is defined as saying something different from what appears in the reading passage (Applegate, Quinn, & Applegate, 2004; Johns, 2005, 2008; Woods & Moe, 1999; Wormsley & D'Andrea, 1997). There are several different types of miscues, which include substitutions, omissions, insertions, reversals, mispronunciations, repetitions, hesitations, punctuation oversights, and self-corrections (Flynt & Cooter, 2004; Johns, 2005, 2008; Leslie & Caldwell, 2006; Roe & Burns, 2007; Stieglitz, 2002; Woods & Moe, 1999; Wormsley & D'Andrea, 1997). Definitions of the aforementioned miscues are provided in Table 1. When calculating the overall number of miscues, errors were classified as either significant (those that had potential to change intended meaning) or insignificant (those that did not have potential to change intended meaning). Since repetitions, mispronunciations, hesitations, punctuation oversights, and self-corrections are usually considered insignificant miscues (Applegate, Quinn, & Applegate, 2004; Flynt & Cooter, 2004; Johns, 2005, 2008; Koenig & Holbrook, 1995; Leslie & Caldwell, 2006; Roe & Burns, 2007; Shanker & Ekwall, 2000; Silvaroli & Wheelock, 2004; Stieglitz, 2002; Wormsley & D'Andrea, 1997), they were classified as such for the purpose of this study. All other miscues were classified as significant. The same miscue appearing repeatedly, multiple attempts to correct the same miscue, or subsequent miscues resulting from the

Table 1

*Types and Descriptions of Reading Miscues*

| **Miscues** | **Definitions** |
|---|---|
| Substitutions | Saying a different word or part of a word than appears in the original text. |
| Omissions | Leaving out a word or phrase that appears in the original text. |
| Insertions | Adding a word or phrase that does not appear in the original text. |
| Reversals | Changing the order of one or more words in a phrase or a sentence. |
| Repetitions | Saying a word or phrase more than once. |
| Mispronunciations | Incorrectly pronouncing all the phonemes (smallest units of sound) in a word (National Reading Panel, 2000; Rasinski, Blachowicz, & Lems, 2006) and are affected by dialects (Johns, 2005, 2008; Leslie & Caldwell, 2006; Stieglitz, 2002) |
| Hesitations | Pauses in reading at the end of a word or line of text that last for more than 5 seconds |
| Punctuation Oversights | Failing to pause for punctuation |
| Self-Corrections | Fixing a mistake without any prompts |

first miscue were only counted once (Applegate, Quinn, & Applegate, 2004; Wormsley & D'Andrea, 1997).

To obtain an overall indicator of oral reading fluency, a score known as correct words per minute (CWPM) was calculated by subtracting the total number of significant miscues from the total number of words in the passage, multiplying that number by 60, and dividing this figure by the amount of seconds it took to read the passage (Leslie & Caldwell, 2006). CWPM allows scores to be compared among individuals as well as across an individual's performance (Fuchs & Fuchs, 1999; Fuchs, Fuchs, Hosp, & Jenkins, 2001). Table 2 provides a summary of the variables to be measured in this experimental study.

## Participants

### Selection Criteria

The target population for this research was congenitally blind, contracted braille users in grades kindergarten through twelve who had functional use of both hands and whose instructional reading level was at or above the fourth grade. Those who lost their sight by the age of three were considered congenitally blind, and those who had little to no measurable visual acuity were considered blind. Given the geographic dispersion of this population, obtaining a national sample was cost and time prohibitive. Furthermore, it was not feasible to obtain a random sample because institutional policies required participation to be voluntary and child confidentiality laws prevented the procurement of a list of qualified participants from which to recruit. Thus, a convenience sample of braille

Table 2

*Overview of Variables*

| **Independent Variables** | |
|---|---|
| Within-Subjects Factors | Between-Subjects Factors |
| • Hand Usage | • Reading Ability |
| ○ Left hand | ○ Proficient |
| ○ Right hand | ○ Struggling |
| ○ Both hands | • Handedness |
| • Finger Usage | ○ Left hand |
| ○ Index finger(s) only | ○ Right hand |
| ○ Middle finger(s) only | ○ Both hands |
| ○ Index + middle fingers | • Reading Finger Dominance |
| **Dependent Variables** | |
| • Fluency = CWPM | |

readers in close proximity to Kentucky was utilized since this is where the researcher resided during the study. A convenience sample is defined as a nonprobability sampling technique in which participants are recruited on the basis of availability (Gall, Gall, & Borg, 2007; Huck, 2011; Mertens, 2009; Mertens & McLaughlin, 2004).

Participant criteria in this study differed from those used by Hermelin and O'Connor (1971a, 1971b). Hermelin and O'Connor utilized braille readers who ranged in age from eight to 10 years. There were a couple of reasons for altering

this aspect of the original study. First of all, most braille readers are still acquiring the contracted braille code through the third grade (Wormsley & D'Andrea, 1997). This is important because each assessment contained a wide variety of contractions, and thus, it was not possible to use reading materials that contained only the contractions a given student had learned. Second, as suggested in the literature review, there may be a link between left-hand superiority in braille reading and reading ability (Bradshaw, Nettleton, and Spehr, 1982; Fertsch, 1947; Holland and Eatman as cited in Wright, 2004; Millar, 1975, 1984, 1997). Therefore, it was important to include students who had learned contracted braille but were reading below grade level.

**Participant Demographics**

In order to run the appropriate statistical tests for this research design, it was recommended that a minimum sample of 10 to 20 participants be secured (Dr. Daniel Mundfrom, personal communication, Fall 2006; Dr. Jamis Perrett, personal communication, Fall 2006; Dr. John Young, III, personal communication, Fall 2006; Dr. Susan Hutchinson, personal communication, Fall 2006). Of the 17 students who agreed to participate in this study, two were disqualified—one because she was not congenitally blind and the other because a significant cognitive impairment interfered with her ability to sustain attention during the required tasks. Eight of the 15 participants were male and seven were female. They ranged in age from 11 to 19 years ($\bar{x}$ = 16.2) and were in grades five through 12 ($\bar{x}$ = 9.33).

All participants lost their vision before the age of three ($\bar{x}$ = 0.55 years). Nine had light perception while six had no light perception. The most common cause of vision loss was retinopathy of prematurity (n = 5), followed by glaucoma (n = 2), Leber's Congenital Amaurosis (n = 2), and optic nerve hypoplasia/septo-optic dysplasia (n = 2). One participant had disconnected optic nerves and another detached retinas. One student was diagnosed with anophthalmia. Finally, one participant reported having albinism.

Three students had disabilities in addition to visual impairment, which included cerebral palsy, hormone deficiencies, and learning disabilities. All were receiving instruction in the general education curriculum, but six were also receiving instruction in functional academics and/or life skills. Although all the participants were currently attending a school for the blind and visually impaired, only seven had attended nothing but a residential school.

Even though all the participants were braille readers, not all of them preferred tactual learning as their primary literacy modality. In actuality, the primary literacy modality was tactual for 13 students and auditory for two. Participants had been reading braille for as little as three years and as much as 15 ($\bar{x}$ = 10.63), and braille was introduced between the ages of two through 12, ($\bar{x}$ = 4.8.). It is important to note that one student was completely illiterate until she immigrated to the United States when she was twelve. In the three years in which she had received a formal education for the first time in her life, she became proficient in English and had attained an instructional reading level at

the sixth grade, which was only three years below grade-level. Two students were initially instructed in contracted braille while all the other participants began learning contractions one to five years after they were introduced to braille. The average time between the introduction to braille and introduction to braille contractions was 2.71 years.

The majority of the participants were Caucasian (n = 11) and just spoke English (n = 13). Two students were African American, one was Asian, and one was Hispanic/Latino. While all participants were proficient speakers of English, one student's primary language was Mandarin/Cantonese while another's was Spanish. The extent of English proficiency for these two participants is not known since the researcher did not have access to oral and written language test scores.

It was also recommended that the participants be equally distributed across the different levels of the graded assessments for purposes of statistical analysis. Unfortunately, it was not practical for the researcher to obtain a large enough sample to engineer this type of distribution. Therefore, distribution across the grade-leveled assessments was uneven as one third of the participants (n = 5) were tested at the fifth grade level (all of whom were struggling readers) and another third (n = 5) were tested at the ninth grade level (all of whom were proficient readers). The remaining participants were tested as follows: one proficient reader took the fourth grade test, one struggling reader took the sixth grade test, one struggling reader took the seventh grade

test, and two participants (one a struggling reader and one a proficient reader) took the eighth grade test.

**Comparison Group Demographics**

Given the fact that reading, and in particular braille reading, is a complex process, it was important to examine the participant demographics in relation to a variety of factors. Because the population of learners with visual impairments is heterogeneous, it was also important to present detailed information about the participant attributes and instructional characteristics that have a potential impact on braille reading. This information will be useful when examining the findings presented in the next chapter, and thus, pertinent demographics of the between-subjects comparison groups is discussed in-depth.

Ideally, the between-subjects comparison groups needed to be the same size. Due to difficulty securing participants, it was not possible to select students whose attributes were evenly distributed across the various comparison groups. However, equal size was practically achieved for the characteristic of reading ability. Equal distribution was not attained for handedness or reading finger dominance.

**Reading ability.** There were seven participants reading at or above grade level as determined by the pre-test (see the Instrumentation section of this chapter) who were placed in the proficient readers' group and eight participants reading below grade level who were placed in the struggling readers' group. Sixty-three percent ($n = 5$) of the males were classified as struggling

readers as compared to only forty-three percent (n = 3) of the females. Proficient readers ranged in age from 11 to 18, ($\bar{x}$ = 14.86) whereas struggling readers ranged in age from 15 to 19, ($\bar{x}$ = 17.38). The proficient readers were in fifth through eleventh grade and had an average instructional reading level at the ninth grade ($\bar{x}$ = 9.13). On the other hand, the struggling readers were in eighth through twelfth grade and had an average instructional reading level at the sixth grade ($\bar{x}$ = 6.75).

Most of the participants across both groups had light perception—57% (n = 4) of the proficient readers and 63% (n = 5) of the struggling readers. The age at which proficient readers lost their vision ranged from zero to two years ($\bar{x}$ = 0.29), and the age at which struggling readers lost their vision ranged from zero to three years ($\bar{x}$ = 0.78). Given the fact that a large proportion of children born with retinopathy of prematurity have additional disabilities (Ferrell, 1998), it was surprising that only 13% (n = 1) of the struggling readers had retinopathy of prematurity as compared to 57% (n = 4) of the proficient readers. However, 25% (n = 2) of the struggling readers had another disability whereas only 14% (n = 1) of the proficient readers had other disabilities.

The proficient readers had been reading braille for six to 15 years ($\bar{x}$ = 10.43), and the struggling readers had been reading braille for three to 14 years ($\bar{x}$ = 10.81) One hundred percent (n = 7) of the proficient readers indicated that tactual was their primary literacy modality as compared to only 75% (n = 6) of the struggling readers. Proficient readers were introduced to braille between the

ages of two through six ($\bar{x}$ = 4.0), and struggling readers were introduced to braille between the ages of three through 12 ($\bar{x}$ = 5.5). [None of the proficient readers and 29% (n = 2) of the struggling readers were taught contractions at the same time they were introduced to braille.] The age at which contractions were introduced to proficient readers ranged from six to eight years ($\bar{x}$ = 7.29), and the age at which contractions were introduced to struggling readers ranged from three to 12 ($\bar{x}$ = 7.57). The only two students to be introduced to contractions at the same time that braille was introduced were in the struggling readers' group.

Fifty-seven percent (57%, n = 4) of the proficient readers had always attended schools for the blind whereas 63% (n = 5) of the struggling readers had attended both public and residential schools. Eighty-six percent (n = 6) of the proficient readers had been educated in only the general education curriculum while 63% (n = 5) of the struggling readers had also received instruction in functional academics and/or life skills.

Eighty-six percent of the proficient readers were Caucasian (n = 6) as compared to 63 percent (n = 5) of the struggling readers. There was one proficient reader for whom English was a second language as well as one struggling reader. This struggling reader (who had also been completely illiterate) had been making incredible progress since immigrating to the United States three years earlier, and thus, generalizations about these bilingual students should be avoided.

**Handedness.** The majority of the participants were right handed (n = 11). Three were ambidextrous, and only one was left handed. Eighty-eight percent (88%, n = 7) of the males were right handed, and all the ambidextrous students were female (n = 3). The left handed student was also male. Eighty-six percent (n = 6) of the proficient readers were right handed as compared to 63% (n = 5) of the struggling readers. The left handed reader was a struggling reader. Interestingly, all of the participants who were ethnically diverse were right handed, and the participants with additional disabilities (n = 3) were equally spread across each handedness group.

**Reading finger dominance.** In spite of the fact that most of the participants were right handed, the majority used their left index finger predominantly during braille reading (n = 9). There were five students whose right index finger was dominant and only one student who demonstrated equal preference for the left index and right index fingers. Surprisingly, the student who preferred both index fingers was not ambidextrous. Another interesting trend is that 86% percent (n = 6) of the females placed more emphasis on their left index fingers while reading as compared to only 38% (n = 3) of the males. All of the students with additional disabilities (n = 3) used their left index finger the most, and the second language learners were equally divided among the left-index-finger group (n = 1) and the right-index-finger group (n = 1).

In terms of educational experiences, 56% (n = 5) of the participants with a dominant left index finger had always attended residential schools as compared

to 40% (n = 2) of the participants whose right index finger was dominant. Likewise, 56% (n = 5) of those who showed a preference for the left index finger were educated in the general education curriculum as well as a functional academics and/or life skills curriculum while only 20% (n = 1) of the readers who used their right index finger the most were educated in the core and expanded core curriculum. Nevertheless, there was little difference in instructional reading levels between the groups (left index finger: $\bar{x}$ = 7.89 and right index finger: $\bar{x}$ = 8). Furthermore, the students who preferred the auditory modality (n = 2) were equally divided between the left index dominant group and right index dominant group. However, participants who demonstrated left-index-finger dominance had been reading for fewer years ($\bar{x}$ = 9.83) than their right-index-finger dominant counterparts ($\bar{x}$ = 11.4). In addition, those who relied most on their left index finger had been introduced to both the braille code and braille contractions later than students who relied most on their right index finger. The average age at which those with a dominant right index finger were taught braille was 4.4 years as compared to 5 years for those with a dominant left index finger. An even bigger difference is seen in relation to the age at which students were introduced to braille contractions (right index finger: $\bar{x}$ = 6.4 and left index finger: $\bar{x}$ = 8.25). Demographics for all participants and each of the comparison groups has been summarized in Table 3.

Table 3

*Summary of Participant Demographics by Comparison Groups*

| | All Participants | Handedness Groups | | | Dominant Reading Finger Groups | | | Reading Ability Groups | |
|---|---|---|---|---|---|---|---|---|---|
| | | Left Handed | Right Handed | Ambidextrous | Left Index | Right Index | Both Indexes | Proficient | Struggling |
| Gender | | | | | | | | | |
| Female | n = 7 | n = 0 | n = 4 | n = 3 | n = 6 | n = 1 | n = 0 | n = 4 | n = 3 |
| Male | n = 8 | n = 1 | n = 7 | n = 0 | n = 3 | n = 4 | n = 1 | n = 3 | n = 5 |
| Age | $\bar{x}$ = 16.2 | x = 19 | $\bar{x}$ = 16 | $\bar{x}$ = 16 | $\bar{x}$ = 16.11 | $\bar{x}$ = 15.8 | x = 19 | $\bar{x}$ = 14.86 | $\bar{x}$ = 17.38 |
| Grade | $\bar{x}$ = 9.33 | x = 11 | $\bar{x}$ = 9.18 | $\bar{x}$ = 9.33 | $\bar{x}$ = 9 | $\bar{x}$ = 9.4 | x = 12 | $\bar{x}$ = 8.14 | $\bar{x}$ = 10.38 |
| Ethnicity | | | | | | | | | |
| Caucasian | n = 11 | n = 1 | n = 7 | n = 3 | n = 8 | n = 3 | n = 0 | n = 6 | n = 5 |
| Other | n = 4 | n = 0 | n = 4 | n = 0 | n = 1 | n = 2 | n = 1 | n = 1 | n = 3 |
| Primary Language | | | | | | | | | |
| English | n = 13 | n = 1 | n = 9 | n = 3 | n = 8 | n = 4 | n = 1 | n = 6 | n = 7 |
| Other | n = 2 | n = 0 | n = 2 | n = 0 | n = 1 | n = 1 | n = 0 | n = 1 | n = 1 |
| Additional Disabilities | n = 3 | n = 1 | n = 1 | n = 1 | n = 3 | n = 0 | n = 0 | n = 1 | n = 2 |
| Age Vision Lost | $\bar{x}$ = .55 | x = 0 | $\bar{x}$ = .48 | $\bar{x}$ = .67 | $\bar{x}$ = .44 | $\bar{x}$ = .25 | x = 3 | $\bar{x}$ = .29 | $\bar{x}$ = .66 |
| Visual Acuities | | | | | | | | | |
| Light Perception | n = 9 | n = 1 | n = 2 | n = 6 | n = 5 | n = 3 | n = 1 | n = 4 | n = 5 |
| No Light Perception | n = 6 | n = 0 | n = 1 | n = 5 | n = 4 | n = 2 | n = 0 | n = 3 | n = 3 |
| Educational Settings | | | | | | | | | |
| Always Residential | n = 7 | n = 1 | n = 5 | n = 1 | n = 5 | n = 2 | n = 0 | n = 4 | n = 3 |
| Public and Residential | n = 8 | n = 0 | n = 6 | n = 2 | n = 4 | n = 3 | n = 1 | n = 3 | n = 5 |
| Educational Curriculum | | | | | | | | | |
| Core | n = 9 | n = 1 | n = 7 | n = 1 | n = 4 | n = 4 | n = 1 | n = 6 | n = 3 |
| Core + Functional Skills | n = 6 | n = 0 | n = 4 | n = 2 | n = 5 | n = 1 | n = 0 | n = 1 | n = 5 |
| Instructional Reading Level | $\bar{x}$ = 7.87 | x = 8 | $\bar{x}$ = 8 | $\bar{x}$ = 7.33 | $\bar{x}$ = 7.89 | $\bar{x}$ = 8 | x = 7 | $\bar{x}$ = 9.14 | $\bar{x}$ = 6.75 |
| Primary Literacy Modality | | | | | | | | | |
| Auditory | n = 2 | n = 0 | n = 2 | n = 0 | n = 1 | n = 1 | n = 0 | n = 0 | n = 2 |
| Tactual | n = 13 | n = 1 | n = 9 | n = 3 | n = 8 | n = 4 | n = 1 | n = 7 | n = 6 |
| Age Braille Introduced | $\bar{x}$ = 4.8 | x = 5 | $\bar{x}$ = 5 | $\bar{x}$ = 4 | $\bar{x}$ = 5 | $\bar{x}$ = 4.4 | x = 5 | $\bar{x}$ = 4 | $\bar{x}$ = 5.5 |
| Age Contracted Braille Introduced | $\bar{x}$ = 7.43 | x = 9 | $\bar{x}$ = 7.18 | $\bar{x}$ = 8 | $\bar{x}$ = 8.25 | $\bar{x}$ = 6.4 | x = 6 | $\bar{x}$ = 7.29 | $\bar{x}$ = 7.57 |
| Years Spent Reading Braille | $\bar{x}$ = 10.57 | x = 12 | $\bar{x}$ = 10.73 | $\bar{x}$ = 9.83 | $\bar{x}$ = 9.83 | $\bar{x}$ = 11.4 | x = 14 | $\bar{x}$ = 10.43 | $\bar{x}$ = 10.81 |

# Procedures

Conducting research is a complex process, and safeguards must be taken to ensure the safety of all participants. Thus, all procedures used in this experiment were approved by the Internal Review Board (IRB) at the University of Northern Colorado (UNC). Appendix A contains the narrative that was submitted to the UNC IRB committee and the approval letter. In addition, the following section details the procedures used in this particular experiment, including details about the pilot study conducted to test the procedures for use in the official research.

## Sampling

In order to maintain consistent testing environments, it was decided that regional testing centers would be established at nearby schools for the blind. Thus, voluntary participants were solicited by electronically sending a written description of the study and qualifications for participation to superintendents and principals of nearby residential schools and itinerant TSVIs for whom the researcher had e-mail addresses. These individuals were asked to determine which of their students met the participation requirements. The researcher then sent packets containing a flyer, parental consent form, and a student demographic questionnaire to the vision professionals who responded to the researcher's initial query about how many students they had that qualified for the study. These liaisons then sent the packets home to parents, who then returned the signed consent form and student demographic questionnaire to the

researcher in the provided self-addressed and stamped envelope. In order to entice volunteers, participants were offered 25 dollars for completing the testing session. A copy of the student questionnaire can be found in Appendix B. Upon receipt of the signed consent/assent forms and completed demographic questionnaires, individual testing sessions were arranged at each participating school for students who are blind and visually impaired.

**Data Collection**

During the individual testing sessions, which took 90 to 120 minutes, participants were first given an assent form in braille. After reading the form, they were permitted to ask any questions before verbally indicating whether or not they wished to participate in the study. Students were then given a pre-test consisting of grade-level words to determine which reading assessments should be administered.

The first reading test to be given was a baseline assessment in which students could use their typical hand and finger patterns. The baseline consisted of 63 randomly ordered braille symbols preceded by a full cell of braille to facilitate orientation; a paragraph of 10 unrelated, grade-level words; and a grade-level reading passage. Starting with the baseline and occurring throughout the remainder of the session, students were asked to execute a simple physical task (to determine handedness) after each test (refer to Appendix C to see specific tasks). Participants completed the baseline condition and three to four treatment conditions during the first testing session. During the second testing

session, students were asked to give verbal assent indicating whether or not they wanted to continue to participate in the study, and then they completed the remainder of the treatment conditions.

The order of the nine treatment conditions were implemented in a pre-determined random order. Table 4 provides a matrix of the experimental conditions. For each condition, participants were asked to read seven randomly selected braille symbols (also presented in conjunction with a full cell of braille for orientation); a paragraph of 10 unrelated, grade-level words; and a grade-level passage. In another attempt to minimize reading fatigue, participants were given one minute to read the braille symbols, one minute to read the word lists, and two minutes to read the reading passages contained on each test (Mommers, 1980). Participants were provided with a verbal description of the hand and finger technique to be used and were asked to show the researcher the assigned fingers. Each testing session was videotaped so that data on braille reading fluency and reading finger dominance could be coded later.

**Pilot Study**

In order to refine the procedures to be used in this experiment, a pilot study was conducted. Given the small number of braille users reading between the fourth and ninth grades, it was not advisable to tap into the limited sample pool that exists. Thus, adults with congenital visual impairments who read contracted braille were used to pilot the procedures to be followed in the data collection process. Since the intent was merely to refine the testing protocol, the

Table 4

*Experimental Treatment Conditions*

| | | **Hand Conditions** | | |
|---|---|---|---|---|
| | | **Left** | **Right** | **Both** |
| **Finger Conditions** | **Index** | Condition LI<br>Left Index | Condition RI<br>Right Index | Condition LI-RI<br>Left Index &<br>Right Index |
| | **Middle** | Condition LM<br>Left Middle | Condition RM<br>Right Middle | Condition LM-RM<br>Left Middle &<br>Right Middle |
| | **Index + Middle** | Condition LIM<br>Left Index &<br>Left Middle | Condition RIM<br>Right Index &<br>Right Middle | Condition LIM-RIM<br>Left Index &<br>Left Middle +<br>Right Index &<br>Right Middle |

desired sample size was between three to five participants. Unfortunately, it was not feasible to gain enough participants in the pilot study to conduct reliability and validity on the testing instrument because it is recommended that there be three to six times as many participants as there are variables (Cattell, 1978). Using this formula, a minimum of 15 to 30 participants would be needed in order to assess the reliability and validity of the testing instrument. Given the fact that there were only about 3,000 contracted, braille reading students in the entire

United States (American Printing House for the Blind, 2010), it was too difficult to obtain 15 to 30 participants for a pilot study and another 10 to 20 participants for the actual experiment.

Voluntary participants were solicited through disability support services at Heartland Community College, Illinois State University, Illinois Wesleyan University, and Lincoln College as well as acquaintances of the researcher. These sampling techniques yielded three participants, all of whom were female, Caucasian, English-only speakers. They ranged in age from 20 to 54 years ($\bar{x}$ = 33) and had been reading braille 16 to 47 years ($\bar{x}$ = 28.33). Two preferred to read tactually while one preferred to read auditorally. (The auditory reader was the participant who had no useable vision.) One participant had no light perception, one had light perception, and one had acuities measured as 1/250 O.S. (left eye) and 1/300 O.D. (right eye). All the participants lost their vision within the first year of life. One participant had multiple sclerosis.

After conducting the pilot, procedures were modified as necessary. This entailed pairing down the testing script to reduce the amount of time required to complete the experiment (refer to Appendix D for a copy of the final testing script). Furthermore, modifications to the reading stand were required. The camera had to be moved below the reading surface to reduce glare from the transparent, Plexiglas surface and the camera mount had to be changed to prevent the camera from overheating. See the portion of the next section titled Braille Reading/Recording Stand for specific details.

# Instrumentation

## Reliability and Validity of Informal Reading Inventories

In spite of the popularity of informal reading inventories (IRI) there are concerns regarding the reliability and validity of these instruments (Klesius & Homan, 1985; Spector, 2005). Reliability refers to the consistency of the data yielded from the assessment across different administrations. Validity, on the other hand, evaluates the accuracy of how well the instrument measures what it purports to measure (Huck, 2011). Specific concerns relate to inter-observer reliability, passage length, and content validity. All of these issues were taken into consideration when developing the instruments used in this research.

As for passage length, previous studies have recommended a length of at least 125 words because it has been found that there are significantly more word recognition errors in passages shorter than this (Stuever, 1969). Given the fact that 12 reading passages were needed at each grade-level, it was necessary to use all available inventories, especially at the middle and high school levels. However, when there were passages that exceeded the minimum threshold, longer passages were given priority.

The concern regarding content validity, which had the greatest potential to affect this study, pertained to the readability estimates of the grade-level word lists and reading passages. Different inventories tend to use different readability formulas. In addition, there are sometimes leaps in difficulty between school years that are greater than one year (Gerke, 1980). Given the fact that

participants were only assessed on passages that corresponded to their independent reading level, there was no need to worry about difficulty between levels. However, to prevent different level of difficulties between passages, especially between different inventories, from confounding the experimental conditions, test forms were treated as a random variable. In order to control for the effects of a random variable, the order in which test forms are administered was randomized. Thus, grade-level word list and reading passages were not affiliated with any particular experimental condition. Likewise, there were three different forms for the baseline assessment so that these forms could also be randomly assigned to each participant. Nevertheless, each grade-level passage used in this experiment was evaluated using the Flesch-Kincaid readability formula, which accounts for both word and sentence length, to determine a grade-level readability estimate. As indicated by the Microsoft Word Help document titled, *Testing Your Document's Readability*, the specific formula is 0.39 (total words ÷ total sentences) + 11.8 (total syllables ÷ total words) – 15.9 = grade level. Table 5 provides the average readability of all the grade-level assessments used in this research.

When IRIs are used to make diagnoses and placement decisions, extra special care must be given to the aforementioned reliability and validity issues. However, the purpose for using IRIs in this study is to have a consistent way of assessing oral reading speed and oral reading accuracy. Because multiple inventories were used, it was not possible to follow several different

Table 5

*Passage Readability Levels*

| Grade Levels | Flesch-Kincaid Grade-Level Ranges | Flesch-Kincaid Grade-Level Means |
|---|---|---|
| 4th | 1.9 - 5.2 | 3.9 |
| 5th | 3.4 - 7.2 | 5.1 |
| 6th | 3.1 – 8.2 | 5.8 |
| 7th | 5.4 – 8.1 | 6.6 |
| 8th | 5.8 – 10.2 | 7.9 |
| 9th | 6.8 – 10.8 | 9.2 |

administration procedures. Since the administration procedures were altered, combined with the fact that the IRIs were not normed on braille readers, reliability and validity was compromised. While reliability and validity have been reported for the various IRIs, the general consensus is that these types of assessments typically demonstrate the minimum requirements in these domains (Paris & Carpenter, 2003).

**Protocol Development**

**Reading tests.** Each reading test for each grade-level for each treatment condition was created and brailled by the researcher and then proofread by an experienced braille reader. Materials for the assessments were obtained from the *Seven Line Braille Chart* and various published IRIs (only the graded word lists and graded reading passages were used). Multiple IRIs were used because no single instrument contained enough different grade-level word lists and passages

to cover all of the treatment conditions. Detailed information on the specific inventories selected can be found in Table 6, including the limited information available on reliability and validity.

Student assessment packets were assembled for individual students after participation had been secured. Each student assessment packet at each grade level contained 10 different randomly selected assessments. Although the baseline assessment was always the first test, one of three different grade-level versions of this instrument was randomly assigned to each participant.

Random assignment was achieved by using a random numbers generator to label each separate unit (braille symbol, grade-level word, grade-level reading passage), and then a Table of Random Numbers was consulted to determine which units were assigned to which form. Words occurring across grade-levels were deleted from the master grade-level word list. When base-words appeared with different endings, the base-word at the lowest grade-level was retained and all others removed from the master list. This prevented duplicate or similar words from appearing on different forms of the grade-level word portion of the tests.

There were only nine experimental tests created for each grade level. Each completed form was assigned a random number and then randomly assigned to the different treatment conditions for each participant by using a Table of Random Numbers. When using the Table of Random Numbers, the starting point was determined by blindly pointing to a spot on the page. The

Table 6

*Description of Informal Reading Inventories*

| Grade Levels | Oral Reading Inventory Forms | Passage Length for 4th-9th Grade | Readability Formulas | Validity | Reliability |
|---|---|---|---|---|---|
| Analytical Reading Inventory (6th ed.) – 1999 | | | | | |
| P-9th grade | Graded Word Lists & Graded Passages (5 forms): narrative, expository, science, & social studies | N/A | Revised Spache, Powers Formula, & Flesch | N/A | N/A |
| Bader Reading and Language Inventory (4th ed.) – 2002 | | | | | |
| PP-8th grade, 9/10 grade, & 11/12 grade | Graded Word Lists & Graded Passages (2 forms) | 149-213 words | Harrison-Jacobson & Fry | .93 (construct) | .80 (alternate form) |
| Basic Reading Inventory (9th ed.) – 2005 | | | | | |
| PP-12th grade | Graded Word Lists & Graded Passages (5 forms): narrative, expository, short, & long | 100-255 words | A readability computer program | N/A | .80 (alternate form) |
| Classroom Reading Inventory (10th ed.) – 2004 | | | | | |
| PP-8th grade | Graded Word Lists & Graded Reading Passages (2 forms) | 121-268 words | N/A | N/A | N/A |

Table 6, continued

| Grade Levels | Oral Reading Inventory Forms | Passage Length for 4th-9th Grade | Readability Formulas | Validity | Reliability |
|---|---|---|---|---|---|
| The Critical Reading Inventory – 2004 | | | | | |
| PP-6th grade, junior high, & high school | Graded Word Lists & Graded Reading Passages (2 forms): narrative & informational | 221-497 words | Flesch-Kincaid | N/A | .98 (inter-observer) |
| Ekwall/Shanker Reading Inventory (4th ed.) – 2000 | | | | | |
| PP-9th grade | Graded Word Lists & Graded Reading Passages (2 forms) | 141-202 words | Harris-Jacobson & Revised Dale-Chall | N/A | .80 (inter-observer) |
| Qualitative Reading Inventory (4th ed.) – 2006 | | | | | |
| PP-6th grade, upper-middle school, & high school | Graded Word Lists & Graded Reading Passages (6 forms): narrative & expository | 254-591 words | Harris-Jacobson, Spache, Wheeler and Smith, Fry, Readability Estimator (computer program), & Dale Chall | | .98 (inter-observer) .80 (alternate form) |
| Reading Inventory for the Classroom (5th ed.) – 2004 | | | | | |
| PP-12th grade | Graded Reading Passages (4 forms): narrative | 249-510 words | Fry & Harris-Jacobson | N/A | N/A |

Table 6, continued

| **Grade Levels** | **Oral Reading Inventory Forms** | **Passage Length for $4^{th}$-$9^{th}$ Grade** | **Readability Formulas** | **Validity** | **Reliability** |
|---|---|---|---|---|---|
| | | Roe/Burns Informal Reading Inventory ($7^{th}$ ed.) – 2007 | | | |
| PP-$12^{th}$ grade | Graded Word Lists & Graded Reading Passages (4 forms): fiction & nonfiction | 131-244 words | Spache & Fry | N/A | N/A |
| | | Stieglitz Informal Reading Inventory ($3^{rd}$ ed.) – 2002 | | | |
| PP-$9^{th}$ grade | Graded Word Lists & Graded Reading Passages (2 forms): narrative | N/A | Spache & Fry | N/A | .80 (alternate form) |

*Note.* PP = preprimer; P = primer

random assignment of participants and test protocols to the baseline and treatment conditions has been summarized in Table 7. In addition, Appendix E contains a list of the specific braille symbols, word lists, and reading passages associated with each form. Due to copyright infringement issues, it was not possible to include an actual copy of the coding sheets in this dissertation. Thus, Appendix F includes a sample miscue coding forms without any of the actual text to be read by participants.

**Pre-test.** Since braille users of varying reading abilities participated in this experiment, it was important to develop a pre-assessment instrument that

Table 7

*Randomized Order of Treatment Conditions and Testing Protocols*

| | Order of the Experimental Conditions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| **P1G5** | BL 3 | RI 5 | LM-RM 9 | LIM-RIM 3 | RM 8 | RIM 2 | LI 4 | LM 7 | LIM 1 | LI-RI 6 |
| **P2G9** | BL 2 | LI 9 | LM 3 | RI 1 | RIM 7 | LM-RM 5 | LIM-RIM 8 | LI-RI 2 | RM 4 | LIM 6 |
| **P3G8** | BL 2 | LIM 3 | LM-RM 2 | LI 6 | RM 1 | RIM 4 | LI-RI 8 | LM 9 | RI 7 | LIM-RIM 5 |
| **P4G9** | BL 3 | LM-RM 8 | LI-RI 5 | LI 3 | LM 6 | LIM-RIM 2 | RIM 1 | RM 7 | LIM 9 | RI 4 |
| **P5G5** | BL 1 | LM 5 | RIM 9 | LIM 8 | LI-RI 4 | RI 3 | LI 2 | LIM-RIM 1 | RM 6 | LM-RM 7 |
| **P6G5** | BL 2 | RM 3 | LM-RM 4 | LIM-RIM 7 | RI 9 | LM 2 | LIM 5 | RIM 6 | LI-RI 1 | LI 8 |
| **P7G9** | BL 1 | LIM 4 | RM 5 | LI-RI 3 | LM 1 | LM-RM 6 | RI 2 | LI 7 | LIM-RIM 9 | RIM 8 |
| **P8G8** | BL 2 | RI 8 | LM-RM 3 | RIM 5 | RM 2 | LM 4 | LIM 7 | LIM-RIM 6 | LI-RI 9 | LI 1 |
| **P9G5** | BL 1 | LM 4 | LIM-RIM 9 | LM-RM 6 | LIM 8 | LI-RI 3 | RM 5 | RIM 7 | LI 1 | RI 2 |
| **P10G5** | BL 3 | RM 6 | LIM 8 | LI-RI 4 | LIM-RIM 1 | LM-RM 7 | LI 2 | RI 3 | RIM 9 | LM 5 |
| **P11G7** | BL 1 | LI 3 | RI 4 | LM 6 | LIM 9 | LIM-RIM 2 | LI-RI 5 | RM 7 | LM-RM 8 | RIM 1 |
| **P12G9** | BL 3 | LIM-RIM 7 | LM-RM 1 | RI 9 | LM 2 | LI 8 | RM 3 | LI-RI 4 | RIM 6 | LIM 5 |
| **P13G4** | BL 1 | LIM 4 | RI 8 | RIM 5 | LI 7 | LI-RI 9 | LM 1 | LIM-RIM 6 | LM-RM 3 | RM 2 |
| **P14G9** | BL 3 | LI-RI 8 | LIM-RIM 5 | LM 9 | LM-RM 2 | LIM 7 | RIM 4 | RM 1 | RI 3 | LI 6 |
| **P15G6** | BL 2 | RIM 3 | LI 5 | RI 6 | LIM-RIM 4 | RM 9 | LIM 2 | LM 8 | LI-RI 7 | LM-RM 1 |

*Note: P = participant number; G = grade-level tests; BL = baseline condition; number = test instrument number; and letters = experimental condition*

would help match participants to their appropriate grade-level reading tests. Like other IRIs, this was done through the creation of grade-level word lists. All the

grade-level words that were not used as part of the reading tests were compiled into grade-level master lists, and each word was assigned a random number using a random numbers generator. Twenty words from each grade level were then selected using a Table of Random Numbers. Before administering the baseline or experimental conditions, participants were asked to read the word lists aloud, starting with the fourth grade list and continuing to the point where they missed two or more words (not including self-corrections). This established each student's estimated instructional reading level. In accordance with administration procedures for the *Basic Reading Inventory* (Johns, 2008), the grade-level reading tests one level below each student's estimated instructional reading level were administered. Given the fact that participants were asked to use hand and finger combinations that would make braille reading more difficult than usual, it was important to assess them at a level they could read comfortably and independently. The pre-assessment protocols are included in Appendix G.

**Handedness test.** In order to assess hand dominance (whether someone is left handed, right handed, or ambidextrous), participants were asked to complete a series of simple, physical tasks. These included 10 everyday activities that are normally done with just one hand (e.g., throwing a small ball, brushing teeth, and picking up a cup). The researcher recorded the hand with which the participant executed these tasks, and then the number of tasks completed with each hand was tallied. In cases where there was a two-point

difference or less between the left hand and right hand totals, the participants were labeled ambidextrous. A copy of the handedness assessment has been included in Appendix C.

**Reading finger dominance.** When assessing braille mechanics, it is common to videotape the hand movements of braille readers. Typically, the video-camera is placed either above and/or across from the reader. While such positioning allows the hand movements of the reader to be tracked, it is not possible to detect finger position in relation to braille symbols because the fingers are covering the braille. Furthermore, these recording angles do not allow the observer to determine if the fingers contacting the braille are exerting enough pressure to be decoding the braille. In order to address these issues, three different sets of researchers devised a method for recording the hand movements of braille readers from below a transparent surface (Breidegard, Jonsson, Fellenius, & Stomqvist, 2006; Davidson, Wiles-Kettenmann, Haber, & Appelle, 1980; Kilpatrick, 1985; Millar, 1988, 1997). This level of detail is important in this study to address the equality of finger use when readers are required to use multiple fingers.

To detect any reading finger dominance, the researcher captured video screen shots every five seconds whenever participants were reading braille symbols, words, and passages. These screen shots were then analyzed to see if any of the assigned fingers displayed a reading patch as evidenced by a flattened and/or whitened fingertip (Millar, 1997). Since the reading patch was either not

visible or was observed on fingers that were not actively engaged in the reading process, the researcher (using the screen shots) then coded which fingers were actively reading the text (i.e., fingers that were aligned with the row of text currently being read). While this yielded information about which fingers served as decoders and which served as placeholders, it did not provide information regarding the subtle differences between the left reading finger(s) versus the right reading finger(s). Thus, another level of analysis was completed where the researcher tallied the number of times each finger engaged in rechecking (i.e., retracing and scrubbing). The total tally for each of the reading finger(s) was added to the total tally for each of the rechecking finger(s). The finger with the highest tally was ranked as the top preference. All other scores were then compared with the top-ranked finger (or fingers in case of a tie). If there was less than a 33% difference between the top-ranked finger and a lower-ranked finger, the participant was labeled as having multiple dominant fingers. This procedure was completed for each section of each test for each baseline and treatment condition that involved the use of multiple fingers. For ease of analyzing this variable, means scores were calculated for all of the multi-finger conditions to determine an overall finger dominance. This protocol is housed in Appendix C.

**Inter-Observer Reliability**

Using the data from the pilot study, the lead researcher trained the assistant researchers by jointly coding the videotape data on the first participant.

The researchers then independently coded the remaining data, and the coding was reviewed to ensure that there was at least 80% inter-observer agreement. When there was more disagreement than this, the researchers jointly reviewed the footage and discussed the ratings until an acceptable level of agreement had been reached. In cases where at least 80% agreement, but not 100% agreement, was attained, the scores of the researchers were averaged.

After this initial training session, the lead researcher coded all participant data while the assistant researchers coded one randomly-selected testing protocol for every participant. When agreement fell below 80%, the same procedures as before were implemented. As necessary, retraining on the pilot data occurred until satisfactory inter-observer reliability was regained. By following these procedures, the research team demonstrated 96.04% agreement on fluency scores, 93.33% on dominant reading-finger scores, and 95.62% on dominant rechecking-finger scores.

**Braille Reading/Recording Stand**

The video recording station was recreated using detailed information provided by Millar (1988; 1997). However, alterations were made to reduce construction costs as well as to enhance portability. The reading table resembled a student desk with a storage area beneath the tabletop. It stood approximately 30 inches tall, and the tabletop surface measured 33 inches high by 24 inches wide. A removable, transparent piece of Plexiglas was inserted in the tabletop. The bottom portion of the Plexiglas measured 11 inches high by 11.5 inches

wide, the same size as a sheet of braille paper. The top portion of the Plexiglas measured eight inches by eight inches and served as a viewing window. A Panasonic GS400 video camera was inverted and mounted in a stand below the tabletop. The video camera was aimed downward at an 11 inch by 11.5 inch mirror. The mirror was positioned at a 45 degree angle and mounted at the front of the desk, facing away from the reader. Two battery-operated florescent lights flanked the underside of the Plexiglas reading panel. The storage box located below the reading surface was three inches deep at the front of the desk and angled downward to a point where the box was 12.5 inches deep. A 23 inch wide by eight inch high access panel was cut out of the underside of the storage box that provided easy access to the mirror and lights. To eliminate shadowing from overhead lights, a white lap desk was placed above the transparent reading surface. Figure 1 provides a view of the tabletop while Figure 2 includes a view of the inside of the storage box.

Since the researcher needed to bring the reading station to each individual testing site, the station was designed to be portable. When in transit, the Plexiglas was removed, covered in a pillow case, and placed in the storage box. The table legs were also unscrewed and placed in the storage box. Finally, the lights and video camera mount were un-Velcroed®, placed in a bag, and added to the storage box. The storage box was then stood on end with the front edge of the desk sitting on the ground. Casters were attached to the front edge of the desk and a handle carved into the underside of the storage unit so that

Figure 1

*Braille Reading/Recording Stand*


Figure 2

*Internal Components of the Braille Reading/Recording Stand*

the reading station could be wheeled like a piece of luggage. Figure 3 contains a view of the unassembled reading stand. In addition to the reading stand, the researcher needed to bring an adjustable chair and a foot stool so that the reader maintained proper reading posture with his/her elbows at table height and feet flat on the ground (Wormsley & D'Andrea, 1997).

Figure 3

*Portability of the Braille Reading/Recording stand*

During the experiment, braille produced on polycarbonate, transparent paper was placed on the bottom portion of the Plexiglas. This is the same plastic utilized by the American Printing House for the Blind in their print/braille books.

Because the Plexiglas was sunken into the tabletop, a lip was provided that prevented the braille paper from sliding out of the camera's view. Due to the excess pressure applied by some participants, it also became necessary to secure the pages to the reading surface with double-sided tape. In order to make the braille highly visible, the indentations on the reverse side of the paper were manually colored in with a black marker. If the video camera was simply aimed at the braille placed on the transparent reading surface, the reading image would be recorded backwards. By inverting the video camera and having it film the mirror reflection of the reading surface, the hand movements of the reader in relation to the braille were recorded in a left-to-right and top-to-bottom orientation. This eliminated the need for the data coders to read backwards. Figure 4 shows the braille as it appears from different recording angles from below the transparent surface.

While the assessments were brailled on transparent plastic to maximize visibility of the reader's hand movements, plastic is typically used just for short reading tasks. In order to prevent the braille readers' fingers from becoming numb as a result of prolonged reading on plastic, participants were asked to notify the researcher if this occurred. In addition, participants were given physical tasks to complete between readings to help prevent numbing and reading fatigue from occurring as a direct result of extended reading sessions.

Image from Below (text is right to left)

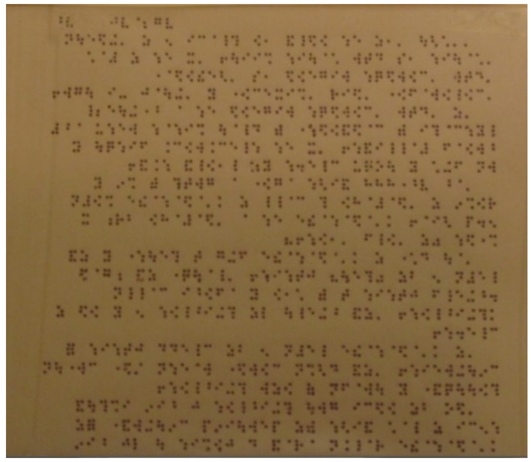


Image from Mirror (text is right to left and upside down)

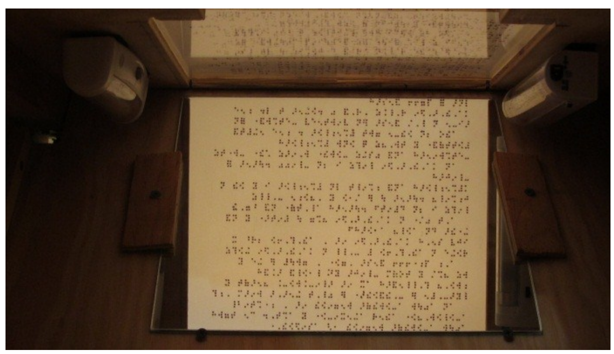


Image from Inverted Camera (text is left-to-right and right side up)

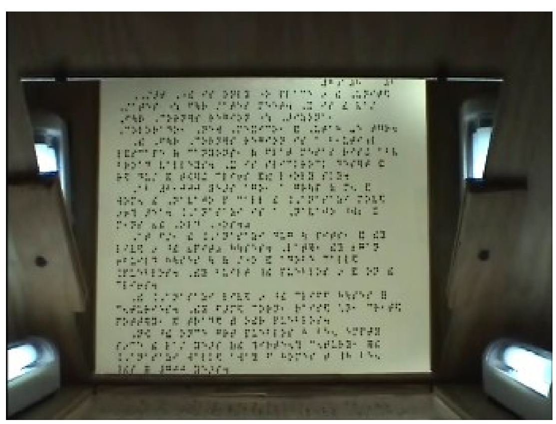


Figure 4

*The Braille Image*

## Data Analysis

Video footage for each treatment condition was analyzed independently by the primary researcher and coded (using the aforementioned testing protocols) to determine CWPM, handedness, and dominant reading finger(s). The assistant researchers independently coded select video footage. Data were then entered into a spreadsheet and exported into SPSS (a computerized statistics program) where preliminary analyses were conducted. The following descriptive statistics were included in the initial analysis in order to evaluate the distribution of scores: mean, standard deviation, skewness, and kurtosis. As a result of the small sample size in comparison with the number of different assessment instruments used in this study, it was not possible to statistically assess reliability and validity of the assessment protocols.

The statistical test used to answer research questions one through three was a repeated measures, mixed-design, Analysis of Variance (ANOVA). This procedure discerns differences between one or more independent variables (at least one of which is a between-subjects factor plus at least one within-subjects factor) and a dependent variable (Huck, 20011; Mertens & McLaughlin, 2004; Rutherford, 2001). In this study, it was utilized to detect differences in braille reading fluency between the independent groups (categorizations based on reading ability, handedness, and reading finger dominance) during the various experimental, treatment conditions (including the baseline). Since there were three different fluency measures per treatment condition (one for symbols, one

for words, and one for passages), separate ANOVAs were run for each of these scores. Although Multivariate Analysis of Variance (MANOVA) is capable of handling multiple dependent variables, it was not used because of the complexities involved in having a repeated measures design combined with a small sample that is not normally distributed.

As a result of the small size of this study's sample, it was not possible to run ANOVA on the full model because the 2 X 3 X 3 (reading ability x handedness x dominant reading finger) factorial design consumed all the degrees of freedom. Thus, the model was simplified by first running one set of ANOVAs for the between-subjects factors of reading ability and handedness to answer research question two. Because there were no main effects or interaction effects for handedness, it was then possible to substitute dominant reading-finger for the handedness factor in order to answer research question three. Given the fact that there were significant findings for this ANOVA, these results were also used to address the within-subjects factor pertaining to effecient hand and finger-usage patterns, which is the core component of research question one.

Since this particular study is a constructive replication of Hermelin and O'Connor's (1971a, 1971b) research, an ANOVA was also run using only the experimental conditions implemented in the original study and the fluency measure that best approximated their dependent variable. These treatment conditions included the following four hand and finger combinations: left index

finger, right index finger, left middle finger, and right middle finger. Fluency for their participants was assessed on a series of unrelated sentences, which is most similar to the passage fluency variable in this study.

In order for this statistical test to perform as intended, the assumption of sphericity needs to be met whenever an ANOVA is conducted (Huck, 2011; Rutherford, 2001). Sphericity ensures that the differences between groups on the same variables should be minimal. If sphericity is violated, the chances of committing a Type I Error are great, and this would result in a false-positive result. To test this assumption, the Mauchly sphericity test was utilized. In instances when the Mauchly test yielded a statistically significant result, the Greenhouse-Geisser correction was referenced, which produced a conservative F-value.

Post hoc analyses to further explore statistically significant differences were conducted by comparing the least squares means (sometimes referred to as the marginal means) of the variable(s) for which there was either a main effect or an interaction effect. Due to the variability in the mean scores of the participants, it was not appropriate to rely on the mathematical average as it can be skewed by outliers. The least squares means is an estimation procedure in which the best fit for the data model is calculated using a regression line. The differences between the actual means and the best fit means are accounted for and then adjusted accordingly to account for differences between the observed and predicted values (Huck, 2011; Rutherford, 2001). Furthermore, effect sizes

were also calculated for statistically significant results in order to determine the magnitude of the relationship between these variables (Gall, Gall, & Borg, 2007). SPSS computed partial eta squared as the effect size statistic, which has the tendency to overestimate the effect—especially when the sample is small. Furthermore, partial eta squared is not comparable to commonly reported effect-size statistics (Bakeman, 2005). As a result, generalized eta squared ($\eta_G^2$) was reported instead. Using guidelines established by Cohen (1988), .02 to .12 constituted a small effect; .13 to .25 constituted a medium effect; and .26 and above constituted a large effect.

Research question four was answered using Multiple Linear Regression. This statistical procedure is used to ascertain relationships between one dependent variable and multiple independent variables (Gall, Gall, & Borg, 2007; Huck, 2011). For this question, the dependent variable was still fluency, but the independent variables were characteristics of braille instruction and participant traits. As a result of the small sample size, it was only possible to use one set of fluency scores for one treatment. Given the fact that the students had not practiced any of the experimental techniques, it was deemed more appropriate to use baseline fluencies to assess these relationships, especially since the baseline was typically one of the conditions in which the participants demonstrated the highest fluencies. As was the case with the ANOVAs, three separate Multiple Linear Regressions were performed, one each for symbols,

words, and passages. Furthermore, the predictor variables were not entered into these models in a pre-determined order.

When employing Multiple Linear Regression as an analytical tool, it is important that the following assumptions are met: normality, linearity, homoscedasticity, and reliability (Huck, 2011; Osborne & Waters, 2002). Normality means that the dependent variables should be normally distributed within groups. Non-normally distributed variables, such as substantial outliers, can distort relationships and significance tests. Normality was assessed by examining skewness and kurtosis. Skewness indicates whether a distribution is asymmetrical (i.e., not normally distributed) because the majority of scores fall either in the lower half of the distribution (i.e., a positively skewed distribution) or in the upper half of the distribution (i.e., a negatively skewed distribution). Kurtosis, on the other hand, detects whether a distribution is abnormally peaked as compared to the bell curve because an unusually large number of scores fall in the center of the distribution. A leptokurtic distribution is overly peaked while a platykurtic distribution is flatter than normal. The linearity assumption stipulates that there be a known relationship between the independent and dependent variables. Linearity was tested through the generation of scatter plots. The scatter plots were also visually inspected to evaluate homoscedasticity, which refers to the construct that error variances should be the same for all the independent variables. Unfortunately, it was not possible to assess reliability, and thus, the results for this question have to be interpreted

with caution so as not to make a Type I Error (a false-positive result) or Type II Error (a false-negative result).

Effect sizes were also calculated for the Multiple Linear Regressions. SPSS provided $R^2$, which tends to overestimate effect size. Since the adjusted $R^2$ adjusts for this tendency, it was used to compute Cohen's $f^2$, which allows for comparison to commonly reported effect sizes. An effect was considered small if Cohen's $f^2$ registered between .02 and .14; medium if it registered between .15 and .34; and large if it registered at .35 or larger (Cohen, 1988). The effect size scales used in this experiment are provided in Table 8.

Table 8

*Effect Size Scales*

| **Statistical Procedure** | **Effect Size Statistic** | **Small Effect** | **Medium Effect** | **Large Effect** |
|---|---|---|---|---|
| ANOVA | $\eta_G^2$ | .02 | .13 | .26 |
| Multiple Linear Regression | $f^2$ | .02 | .15 | .35 |

## Summary

Even though this research was intended to be a replication study, the methodology employed by Hermelin and O'Connor (1971a, 1971b) was expanded because of the different motives for investigating this issue (brain function versus instructional methodology). Hence, this study is considered a constructive replication. When comparing the results of this study to the findings

obtained by Hermelin and O'Connor, these differences need to be kept in mind. They have been summarized in Table 9.

Table 9

*Methodological Differences*

| | **Hermelin & O'Connor** | **This Study** |
|---|---|---|
| Age of Participants | 8-10 years | 11-19 years |
| Handedness | No left handed participants | 1 right handed participant |
| Braille Experience | Beginning readers | Experienced readers |
| Other Disabilities | None | Learning disabilities, cerebral palsy, & hormone deficiencies |
| Languages Spoken | English | English, Spanish, & Mandarin Chinese |
| Experimental Conditions | LI, RI, LM, & RM | LI, RI, LM, RM, LI-RI, LM-RM, LIM, RIM, LIM-RIM, & Baseline |
| Reading Tasks | 1 unrelated, age-appropriate sentence per experimental condition | 7 braille symbols, 10 grade-level words, & a grade-level passage per experimental condition |
| Measures | Reading speed, number of errors, & handedness | Correct words per minute, handedness, dominant reading finger, & reading ability |

This chapter provided an extensive overview of the methodology used in this mixed design experiment. The purpose of this study was to determine which

hand and finger usage patterns of braille readers are most effective as determined by the highest oral reading speeds and the greatest oral reading accuracy. Specific procedures were delineated that the researcher believed would answer the research questions in the most objective manner possible. This involved specifying the research design as well as operationally defining the variables in the study. Then, participant criteria and procedures for obtaining the sample were described. Details were also provided about the development of the assessment protocols used to measure the variables and the pilot study conducted to refine experimental procedures. Finally, this chapter also provided information on the procedures used to collect and analyze the data.

# CHAPTER 4

# RESULTS

Fluency data were gathered on 15 congenitally blind, contracted braille users who read a series of braille symbols, words, and passages using randomly assigned hand and finger combinations. Given the multitude of factors involved in the process of reading with one's fingers, data were also collected on handedness, dominant reading finger(s), reading ability, participant demographics, and characteristics of instruction (particularly braille instruction). These variables were analyzed in SPSS using either ANOVA or Multiple Linear Regression, and the results are presented in this chapter.

Since this research constituted a constructive replication of a previous study, findings are presented first concerning only the hand and finger conditions employed by Hermelin and O'Connor (1971a, 1971b). Each research question is then answered in relation to the different type of reading tasks (symbols, words, or passages) completed by the participants. Finally, the overall findings of this study are summarized.

## Hermelin and O'Connor Constructive Replication

Hermelin and O'Connor (1971a, 1971b) had participants read a series of unrelated sentences in braille using their left-index-finger alone, right-index-

finger alone, left-middle-finger alone, and right-middle-finger alone. Their research showed a left hand and a middle finger advantage, which contradicts the perceived best-practice of reading with the index and middle fingers of both hands. Thus, this constructive replication added two-handed and two finger treatment conditions and different types of reading tasks to see how the findings of Hermelin and O'Connor compared to that which TSVIs believed to be best practice.

Before delving into the research questions using the expanded experimental conditions, it was important to first compare apples to apples. Thus, all multi-hand and multi-finger variables added to the constructive replication were removed from this preliminary analysis. Since the reading tasks instituted by Hermelin and O'Connor (1971a, 1971b) differed from those used by this researcher, fluency scores obtained during the reading of passages were utilized as this was the closest approximation to sentence reading. Like the original research, this analysis also included the handedness variable.

Thus, a repeated measures ANOVA for the within-subjects factor of original treatment conditions and the between-subjects factor of handedness was conducted. The Greenhouse-Geisser correction was referenced because Mauchly's Test of Sphericity was violated ($W$ = .342, $\chi^2$ (5) = 11.509, $p$ = .043). A statistically significant interaction effect between treatment conditions and handedness was found ($F$(4.273, 25.635) = 3.314, $p$ = .024). The summary of this ANOVA can be found in Table 10.

Table 10

*ANOVA Summary for Original Treatment Conditions and Handedness*

| Source | SS | df | MS | F | p | $\eta_G^2$ |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| Original Conditions | 3172.050 | 2.136 | 1484.851 | 5.015 | .013 | .105 |
| * Handedness x Original Conditions | 4192.113 | 4.273 | 981.173 | 3.314 | .024 | .155 |
| Error | 7590.532 | 25.635 | 296.097 | | | |
| Between-Subjects Factor | | | | | | |
| Handedness | 211.563 | 2.000 | 105.781 | .084 | .920 | .008 |
| Error | 15057.874 | 12.000 | 1254.823 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

Post hoc analysis of the least squares means and profile plot of this interaction showed that the left handed and right handed participants were most fluent when reading with their right index finger followed by their left index finger. Ambidextrous participants, on the other hand, achieved the highest fluency with their left index finger followed by their left middle finger. While the left handed and the right handed students read best using their index fingers, a handedness advantage was found when they were required to use only their left middle finger or their right middle finger. Left handed participants did better with their left middle finger than with their right middle finger. Likewise, right handed participants performed better with their right middle finger than with their left middle finger. Table 11 provides the least square means while Figure 5 plots these means to visually demonstrate this interaction.

Table 11

*Least Squares Means for Original Conditions x Handedness*

| Handedness | Original Conditions | Least Squares Mean | Standard Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Left | LI | 40.000 | 22.438 | -8.889 | 88.889 |
| | RI | 44.300 | 25.891 | -12.113 | 100.713 |
| | LM | 31.360 | 16.478 | -4.543 | 67.263 |
| | RM | 11.660 | 21.023 | -34.146 | 57.466 |
| Right | LI | 40.634 | 6.765 | 25.893 | 55.374 |
| | RI | 51.531 | 7.807 | 34.522 | 68.540 |
| | LM | 23.980 | 4.968 | 13.155 | 34.805 |
| | RM | 28.755 | 6.339 | 14.944 | 42.565 |
| Ambidextrous | LI | 67.963 | 12.955 | 39.737 | 96.190 |
| | RI | 29.323 | 14.948 | -3.247 | 61.893 |
| | LM | 43.860 | 9.514 | 23.131 | 64.589 |
| | RM | 17.603 | 12.138 | -8.843 | 44.049 |

Unlike Hermelin and O'Connor (1971a, 1971b), this research did not find an overarching left-hand advantage when analyzing only the data pertaining to their original experiment. Both left and right handed participants in this study attained the highest fluency when using their right index fingers. Only the ambidextrous participants showed a left-hand advantage. Furthermore, when reading with either middle fingers, an ipsilateral tendency was observed.

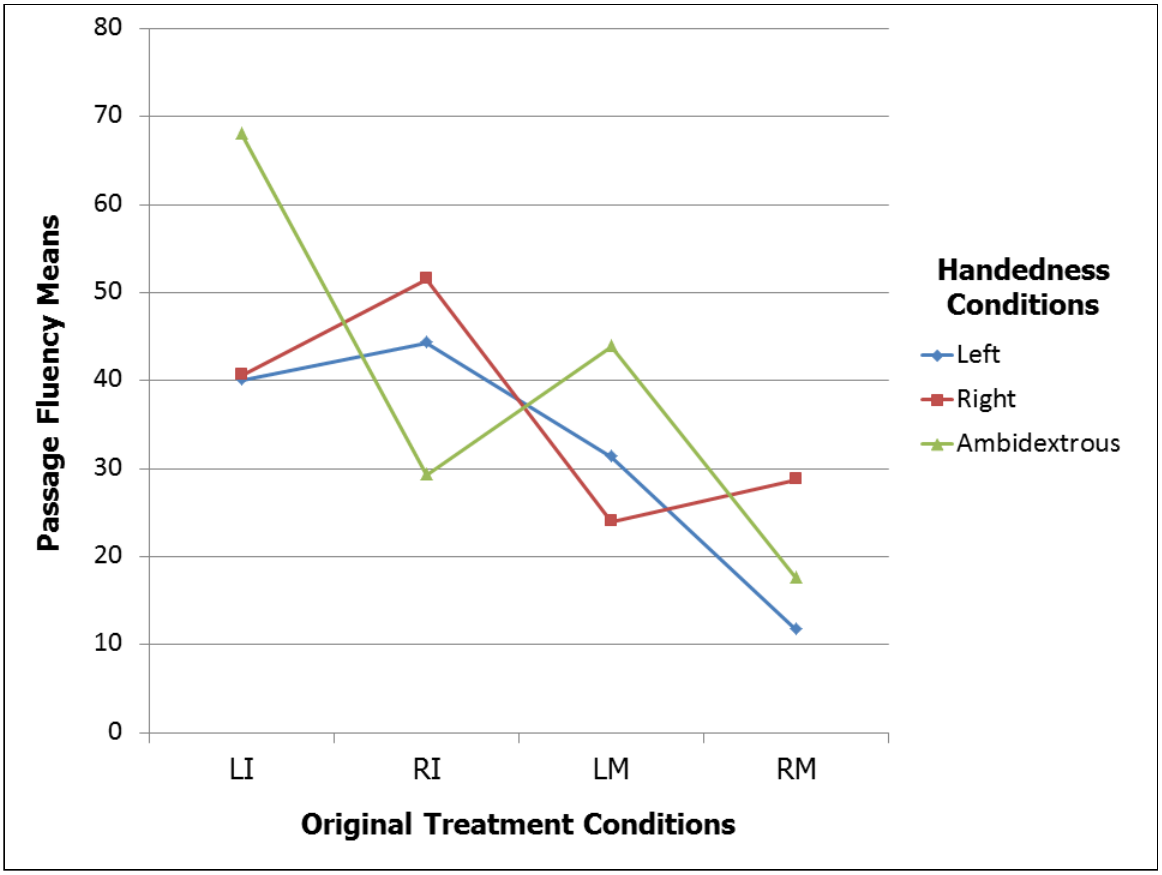



Figure 5

*Profile Plot for Original Conditions x Handedness*

## Research Questions

Given the fact that a significant body of research, most of which is correlational, supports two-handed reading, it was important to test the findings of Hermelin and O'Connor in relation to common hand and finger usage patterns using experimental controls. The primary goal of this study was to ascertain which hand and finger combination(s) produced the greatest reading fluency on a variety of reading tasks (symbols, words, and passages). Confounding variables (such as handedness, dominant reading finger(s), reading ability,

participant attributes, and instructional factors) were also explored to determine if they had any impact on the hand and finger usage patterns that resulted in the best fluency across the different reading tasks.

**Q1: Hand/Finger Pattern(s) and Fluency**

Research question one asked the following:

Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index + middle) resulted in the greatest degree of fluency?

Preliminary analyses of the fluency distributions for each treatment condition according to reading task were analyzed for normality using skewness and kurtosis coefficients. The distribution data for symbols, words, and passages are displayed in Tables 12-14 respectively.

Where symbol fluency is concerned, all conditions were normally distributed except for Condition LI, which was only slightly positively skewed (skewness coefficient = 1.144) because there was a slightly larger cluster of scores below the middle of the distribution than above it. Once again, all conditions were normally peaked for symbol reading except Condition LI (kurtosis coefficient = 2.643), which was leptokurtic. The histogram of scores for symbol fluency during Condition LI can best be described as a three-step staircase with the top of the staircase starting at the lower end of the distribution and descending in the direction of the upper end of the distribution. In essence, most of the participants received low fluency scores while decoding symbols with their left index finger.

Table 12

*Distribution of Symbol Fluency Scores for All Treatment Conditions*

| | **Baseline** | **Condition LI** | **Condition RI** | **Condition LI-RI** | **Condition LM** | **Condition RM** | **Condition LM-RM** | **Condition LIM** | **Condition RIM** | **Condition LIM-RIM** |
|---|---|---|---|---|---|---|---|---|---|---|
| n | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Missing | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Mean | 15.20 | 17.50 | 19.93 | 19.99 | 13.24 | 15.51 | 15.57 | 16.55 | 18.10 | 18.35 |
| Standard Deviation | 8.86 | 11.94 | 9.10 | 10.50 | 9.35 | 9.90 | 8.64 | 10.84 | 9.80 | 7.53 |
| Skewness | .87 | 1.14 | -.30 | .86 | .97 | .21 | .58 | .89 | .28 | -.09 |
| Standard Error of Skewness | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 |
| Kurtosis | 1.87 | 2.64 | -.74 | .10 | .24 | -.69 | .13 | .40 | -.25 | -.51 |
| Standard Error of Kurtosis | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |
| Minimum Score | 2.17 | .00 | 4.28 | 7.61 | 1.14 | .00 | 1.83 | 2.50 | 2.56 | 4.52 |
| Maximum Score | 37.70 | 49.18 | 34.48 | 42.65 | 33.18 | 32.82 | 32.43 | 38.89 | 38.01 | 31.37 |

Table 13

*Distribution of Word Fluency Scores for All Treatment Conditions*

| | Baseline | Condition LI | Condition RI | Condition LI-RI | Condition LM | Condition RM | Condition LM-RM | Condition LIM | Condition RIM | Condition LIM-RIM |
|---|---|---|---|---|---|---|---|---|---|---|
| n | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Missing | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 | .00 |
| Mean | 24.95 | 17.14 | 17.29 | 22.01 | 11.15 | 8.74 | 16.16 | 17.02 | 14.00 | 22.21 |
| Standard Deviation | 9.986 | 10.24 | 9.06 | 9.96 | 6.61 | 7.21 | 10.63 | 8.40 | 8.24 | 10.96 |
| Skewness | .27 | .39 | -.52 | .45 | .21 | .52 | .73 | -.27 | .07 | .72 |
| Standard Error of Skewness | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 |
| Kurtosis | -.88 | -.67 | -1.02 | .55 | -1.20 | -1.32 | -.27 | -.82 | -1.32 | .57 |
| Standard Error of Kurtosis | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |
| Minimum Score | 10.34 | 2.85 | .91 | 8.05 | 1.67 | .31 | 4.01 | .76 | .46 | 7.40 |
| Maximum Score | 43.04 | 38.07 | 28.37 | 44.74 | 22.40 | 21.12 | 38.76 | 30.33 | 26.87 | 47.24 |

Table 14

*Distribution of Passage Fluency Scores for All Treatment Conditions*

| | Baseline | Condition LI | Condition RI | Condition LI-RI | Condition LM | Condition RM | Condition LM-RM | Condition LIM | Condition RIM | Condition LIM-RIM |
|---|---|---|---|---|---|---|---|---|---|---|
| n | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 | 15.00 |
| Missing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Mean | 73.97 | 46.06 | 46.61 | 73.06 | 28.45 | 25.38 | 45.53 | 47.09 | 49.27 | 70.14 |
| Standard Deviation | 33.27 | 23.67 | 25.65 | 26.69 | 17.32 | 20.35 | 22.63 | 26.46 | 27.83 | 26.07 |
| Skewness | .62 | .39 | .00 | .07 | .33 | .95 | .48 | .65 | .36 | .29 |
| Standard Error of Skewness | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 | .58 |
| Kurtosis | .10 | .41 | -.33 | -1.51 | -.93 | .45 | -.81 | .17 | -.55 | -.87 |
| Standard Error of Kurtosis | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |
| Minimum Score | 24.29 | 2.90 | .00 | 36.71 | 3.19 | .00 | 18.54 | 6.74 | 1.30 | 26.92 |
| Maximum Score | 144.08 | 93.47 | 95.63 | 114.92 | 59.26 | 73.29 | 89.39 | 103.57 | 96.61 | 115.01 |

The skewness coefficients of the distributions for word fluency scores revealed that all conditions were symmetrical. However, the kurtosis coefficients indicated that Conditions RI (-1.018), LM (-1.2), RM (-1.319), and RIM (-1.316) were platykurtic. A visual inspection of the histograms for conditions involving only the right hand (Conditions RI, RM, and RIM) showed that similar numbers of participants scored in the lower third, middle third, and upper third of the distribution of scores. The histogram for the left middle finger (Condition RM) depicted a spike in the number of participants who scored just above and just below the mean.

As for passage fluency, all treatment conditions were distributed symmetrically. However, Condition LI-RI was slightly platykurtic as the kurtosis coefficient was -1.506. While the scores peaked just above and just below the mean, the frequency of scores in the middle of the distribution was similar to those at both ends of the distribution.

In order to ascertain if there were statistically significant differences among experimental conditions (including the baseline) while reading symbols, words, and passages, three independent, repeated measures ANOVAs were computed. These ANOVAs included the within-subject factor of treatment conditions and the between-subject factors of reading ability and dominant reading finger. As a result of possible interactions between the within-subjects factor and the between-subjects factors, the full model had to be run for symbols, words and passages. Thus, models in which a statistically-significant

main-effect was present for only treatment conditions will be discussed in relation to research question one.

Although the Baseline Condition was treated like the other treatment conditions in the ensuing analyses, it is important to understand that this condition was not rigorously controlled like all the other treatments. Participants were allowed to read using whatever combination of hands and fingers they normally used. During the baseline assessments, eight of the participants read primarily using their left and right index and middle fingers while five read primarily with their left and right index fingers. One participant read primarily with the left index and middle fingers while another primarily used the right index and middle fingers. Thus, 87% of the participants utilized a natural reading pattern that involved the use of two hands, and all participants used multiple fingers during reading.

The repeated measures ANOVA representing symbol fluency was tested for normality using Mauchly's Test of Sphericity. Since sphericity was not violated ($W$ = .000, $\chi^2$ (44) = 54.125, $p$ = .266), no correction was necessary. Although there was a statistically significant main effect for treatment conditions, it was explained by an interaction with dominant reading fingers. Thus, this particular finding will be discussed in relation to research question two. In addition, there was a statistically significant interaction between dominant reading finger(s) and reading ability, which will be addressed in relation to question three. All the results for this ANOVA are exhibited in Table 15.

Table 15

*ANOVA Summary for Symbol Fluency*

| Source | SS | df | MS | F | p | $\eta_G^2$ |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| Treatment Conditions | 570.127 | 9 | 63.347 | 2.535 | .012 | .047 |
| * Treatment Conditions x Reading Finger(s) | 1566.363 | 18 | 87.020 | 3.482 | .000 | .135 |
| Treatment Conditions x Reading Ability | 161.434 | 9 | 17.937 | .718 | .691 | .014 |
| Treatment Conditions x Reading Finger(s) x Reading Ability | 233.455 | 9 | 25.939 | 1.038 | .417 | .020 |
| Error | 2249.081 | 90 | 24.990 | | | |
| Between-Subjects Factors | | | | | | |
| Reading Finger(s) | 870.661 | 2 | 435.331 | 1.614 | .247 | .075 |
| Reading Ability | 533.106 | 1 | 533.106 | 1.977 | .190 | .046 |
| * Reading Finger(s) x Reading Ability | 3264.891 | 1 | 3264.891 | 12.107 | .006 | .282 |
| Error | 2696.617 | 10 | 269.662 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

The only main effect for treatment conditions was discovered through the repeated measures ANOVA examining word fluency. Since Mauchly's Test of Sphericity indicated that the normality assumption had been violated ($W$ = .000, $\chi^2$ (44) = 74.346, $p$ = .009), the Greenhouse-Geisser correction was implemented. The main effect for treatment conditions was statistically significant ($F$(2.978, 29.778) = 6.055, $p$ = .002). Post hoc analysis of the least squares means for all the treatment conditions revealed that participants achieved the highest fluency scores on the Baseline Condition (LSM = 24.990), Condition LI-RI (LSM = 20.557), and Condition LIM-RIM (LSM = 20.538).

Participants attained the lowest fluency scores on Condition RM (LSM =8.600) and Condition LM (LSM = 9.738). Basically, participants did better on the two-handed conditions involving the index fingers and worst on those conditions involving the use of each middle finger in isolation, particularly the right middle finger. All the results of this ANOVA are listed in Table 16, and the least squares means for treatment conditions are provided in Table 17.

Table 16

*ANOVA Summary for Word Fluency*

| **Source** | **SS** | **df** | **MS** | **F** | **p** | **$\eta_G^2$** |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| * Treatment Conditions | 2317.857 | 2.978 | 778.386 | 6.055 | .002 | .176 |
| Treatment Conditions x Reading Finger(s) | 1075.810 | 5.956 | 180.640 | 1.405 | .246 | .099 |
| Treatment Conditions x Reading Ability | 344.354 | 2.978 | 115.641 | .900 | .452 | .032 |
| Treatment Conditions x Reading Finger(s) x Reading Ability | 151.707 | 2.978 | 50.947 | .396 | .755 | .014 |
| Error | 3827.972 | 29.778 | 128.551 | | | |
| Between-Subjects Factors | | | | | | |
| Reading Finger(s) | 342.270 | 2 | 171.135 | .570 | .583 | .032 |
| Reading Ability | 703.772 | 1 | 703.772 | 2.346 | .157 | .065 |
| Reading Finger(s) x Reading Ability | 1417.302 | 1 | 1417.302 | 4.724 | .055 | .130 |
| Error | 3000.312 | 10 | 300.031 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

Like the previous ANOVAs, this repeated measures ANOVA on passages was tested for normality using Mauchley's Test of Sphericity. The normality

Table 17

*Least Squares Means for Word Fluencies*

| Conditions | Mean | Standard Error | 95% Confidence Interval Lower Bound | Upper Bound |
|---|---|---|---|---|
| Baseline | 24.990 | 2.922 | 18.479 | 31.501 |
| LI | 16.172 | 3.142 | 9.171 | 23.173 |
| RI | 19.621 | 2.158 | 14.812 | 24.431 |
| LI-RI | 20.557 | 3.246 | 13.325 | 27.788 |
| LM | 9.738 | 1.539 | 6.309 | 13.168 |
| RM | 8.600 | 1.969 | 4.213 | 12.987 |
| LM-RM | 14.841 | 3.089 | 7.957 | 21.724 |
| LIM | 15.042 | 1.956 | 10.684 | 19.400 |
| RIM | 13.364 | 1.691 | 9.595 | 17.132 |
| LIM-RIM | 20.538 | 2.507 | 14.952 | 26.124 |

assumption was not violated ($W$ = .000, $\chi^2$ (44) = 63.137, $p$ = .075), and therefore, there was no adjustment required. No main effects were found, but multiple interaction effects were found. The first interaction occurred between treatment conditions and dominant reading finger(s). This finding will be discussed during the presentation of results for research question two. Both the interaction between treatment conditions and reading ability as well as the one between dominant reading finger(s) and reading ability will be analyzed in respect to research question three. The complete results of this ANOVA are given in Table 18.

As a result of interaction effects, there was very little information available on treatment conditions alone. Thus, it was not possible to answer the first research question in relation to all the different reading tasks. However, there was a statistically significant difference between treatment conditions when

Table 18

*ANOVA Summary for Passage Fluency*

| Source | SS | df | MS | F | p | $\eta_G^2$ |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| Treatment Conditions | 23082.528 | 9 | 2564.725 | 14.997 | .000 | .226 |
| * Treatment Conditions x Reading Finger(s) | 7493.945 | 18 | 416.330 | 2.434 | .003 | .095 |
| * Treatment Conditions x Reading Ability | 3079.491 | 9 | 342.166 | 2.001 | .048 | .039 |
| Treatment Conditions x Reading Finger(s) x Reading Ability | 1876.800 | 9 | 208.533 | 1.219 | .293 | .024 |
| Error | 15391.326 | 90 | 171.015 | 15391.326 | | |
| Between-Subjects Factors | | | | | | |
| Reading Finger(s) | 8606.821 | 2 | 4303.411 | 2.289 | .152 | .109 |
| Reading Ability | 5732.118 | 1 | 5732.118 | 3.049 | .111 | .072 |
| * Reading Finger(s) x Reading Ability | 18222.312 | 1 | 18222.312 | 9.694 | .011 | .230 |
| Error | 18797.979 | 10 | 1879.798 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

reading words. Further analysis of the least squares means supported hand and finger combinations involving two hands and use of at least the index fingers or the index and middle fingers.

## Q2: Handedness/Reading Finger Dominance and Fluency

Research question two sought to discern the following:

Q2 Is there a relationship between handedness and/or dominant reading finger(s) and the hand and finger usage pattern that produced the greatest degree of fluency?

While the ideal would have been to run both handedness and reading finger dominance in the same model so as to detect any interactions between these

two factors, this was not possible due to the small sample size. Thus, repeated measures ANOVAs were first run for symbol fluency, word fluency, and passage fluency with treatment conditions being the within-subjects factor and handedness and reading ability being the between-subjects factors. Then three, similar, repeated measures ANOVAs were conducted substituting dominant reading finger(s) for handedness.

All three handedness ANOVAs were examined for normality using Mauchly's Test of Sphericity, which was violated as indicated by the following results: symbols ($W$ = .000, $\chi^2$ (44) = 70.398, $p$ = .005), words ($W$ = .000, $\chi^2$ (44) = 76.952, $p$ = .005), and passages ($W$ = .000, $\chi^2$ (44) = 81.634, $p$ = .002). Therefore, the Greenhouse-Geisser correction was utilized. Given the fact that there were no statistically significant main or interaction effects specific to handedness, the dominant-reading-finger(s) factor was substituted for the handedness factor and used to answer research questions one through three. Nevertheless, the complete results of the handedness ANOVAs are presented in Appendix H.

Unlike handedness, there were several interaction effects pertaining to dominant reading finger(s) for both symbol and passage fluency. Interactions between dominant finger(s) and reading ability will be addressed in relation to research question three. Thus, only those interactions between reading finger(s) and treatment conditions will be presented here.

The ANOVA pertaining to symbol fluency, which was previously summarized in Table 15, revealed a significant interaction between treatment conditions and dominant reading finger(s) ($F(18, 90) = 3.482$, $p = .000$). Post hoc analysis of the least squares means indicated that those participants whose dominant reading finger was their left index finger performed best on Conditions LIM (LSM = 21.908) and LI (LSM = 21.165) and worst on Condition RM (LSM = 13.585). Those whose right index finger was dominant read most fluently during Conditions RI (LSM = 28.569) and LI-RI (LSM = 26.120) and least fluently on Conditions LIM (LSM = 11.564) and LM (LSM = 12.069). These results demonstrated that participants received the highest scores on some, but not all, of the conditions that included the use of their dominant reading finger while performing poorly on conditions that involved the middle finger on the non-dominant hand. Furthermore, readers who used their left index finger did best on left hand only conditions while readers who used their right index finger also did well when using the index fingers of both hands. The data supporting these trends are conveyed in Table 19 and visually depicted in the profile plot contained in Figure 6.

Analysis of the ANOVA results for passage fluency, as previously summarized in Table 18, also demonstrated a statistically significant interaction between treatment conditions and dominant reading finger ($F(18, 90) = 2.434$, $p = .003$). Inspection of the least squares means indicated that those whose left index finger was most dominant attained the highest scores on the Baseline

Table 19

*Least Squares Symbol Means for Reading Finger(s) x Conditions*

| Dominant Reading Fingers | Conditions | Mean | Standard Error | 95% Confidence Interval | |
|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound |
| Left Index Finger | Baseline | 15.877 | 2.770 | 9.705 | 22.048 |
| | LI | 21.165 | 3.253 | 13.917 | 28.413 |
| | RI | 16.225 | 1.466 | 12.958 | 19.492 |
| | LI-RI | 19.271 | 2.768 | 13.103 | 25.438 |
| | LM | 16.278 | 1.827 | 12.208 | 20.348 |
| | RM | 13.585 | 2.193 | 8.699 | 18.471 |
| | LM-RM | 15.201 | 2.205 | 10.288 | 20.113 |
| | LIM | 21.908 | 2.393 | 16.576 | 27.241 |
| | RIM | 20.716 | 1.792 | 16.723 | 24.709 |
| | LIM-RIM | 20.320 | 2.373 | 15.034 | 25.607 |
| Right Index Finger | Baseline | 17.483 | 3.769 | 9.084 | 25.881 |
| | LI | 16.054 | 4.427 | 6.191 | 25.917 |
| | RI | 28.569 | 1.996 | 24.123 | 33.015 |
| | LI-RI | 26.120 | 3.767 | 17.727 | 34.513 |
| | LM | 12.069 | 2.486 | 6.531 | 17.608 |
| | RM | 23.437 | 2.984 | 16.787 | 30.086 |
| | LM-RM | 20.029 | 3.000 | 13.344 | 26.714 |
| | LIM | 11.564 | 3.257 | 4.308 | 18.821 |
| | RIM | 18.875 | 2.439 | 13.441 | 24.309 |
| | LIM-RIM | 18.095 | 3.229 | 10.901 | 25.289 |
| Left Index + Right Index Fingers | Baseline | 6.170† | 8.258 | -12.229 | 24.569 |
| | LI | 6.120† | 9.698 | -15.489 | 27.729 |
| | RI | 15.060† | 4.372 | 5.319 | 24.801 |
| | LI-RI | 8.100† | 8.252 | -10.287 | 26.487 |
| | LM | 3.130† | 5.446 | -9.004 | 15.264 |
| | RM | 3.080† | 6.538 | -11.488 | 17.648 |
| | LM-RM | 6.820† | 6.573 | -7.826 | 21.466 |
| | LIM | 3.320† | 7.135 | -12.578 | 19.218 |
| | RIM | 4.290† | 5.343 | -7.615 | 16.195 |
| | LIM-RIM | 9.030† | 7.074 | -6.731 | 24.791 |

*†Note: Results are not discussed in the narrative because they are based on one participant, and thus, it is not appropriate to draw conclusions about these data.*

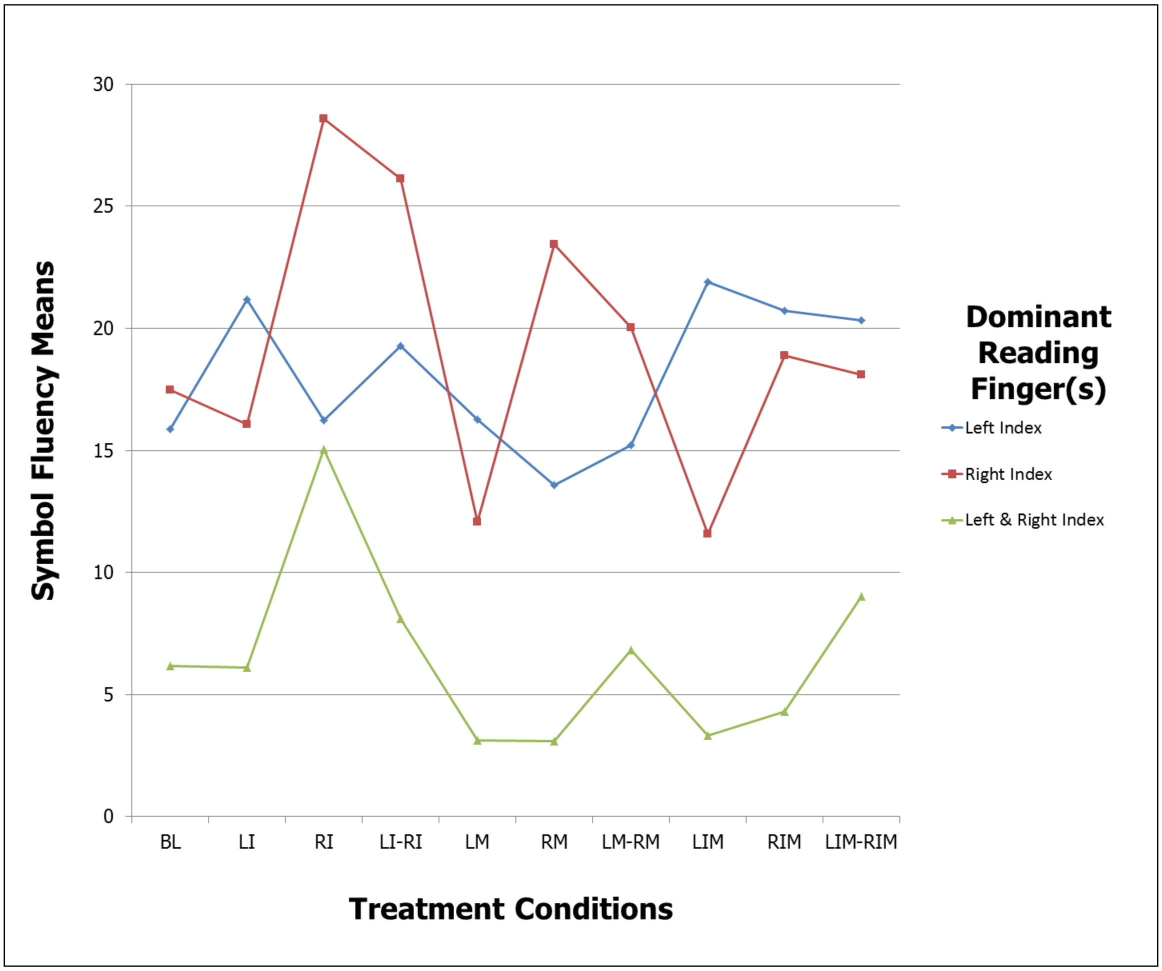



Figure 6

*Profile Plot of Least Squares Symbol Means for Reading Finger(s) x Conditions*

Condition (LSM = 83.568), Condition LIM-RIM (LSM = 82.018), and Condition LI-RI (LSM = 81.238). This group obtained the lowest fluency scores on Condition RM (LSM = 25.017). Those participants whose right index finger was the dominant reading finger performed best on Condition LI-RI (LSM = 69.148) and the Baseline Condition (LSM = 68.151). This group performed worst, by far, on Condition LM (LSM = 15.622). To summarize, participants did best on the two-handed conditions that included the use of their dominant reading finger during

passage reading. Furthermore, both groups did worst on the conditions that required the use of the middle finger on the non-dominant hand while reading passages. These results correspond to those for symbol fluency. All the mean fluency scores for passage reading are assembled in Table 20 and visually plotted in Figure 7.

According to these findings, there is no statistically significant relationship between handedness and the greatest degree of fluency. However, there is a statistically significant relationship between dominant reading finger and fluency during symbol and passage reading. Post hoc analysis showed an advantage for use of two-handed conditions that included the use of the dominant reading finger. Furthermore, the most inefficient condition was shown to be the use of the middle finger on the non-dominant hand.

**Q3: Reading Ability and Fluency**

The previously-referenced repeated measures ANOVAs that included the within-subjects factor of treatment conditions and the between-subjects factors of dominant reading finger(s) and reading ability were used to answer the following question:

> Q3 Is there a relationship between reading ability and the hand and finger usage pattern that produced the greatest degree of fluency?

This section will focus on main effects or interaction effects involving reading ability. To see the full results of these ANOVAs, refer to Table 15 for symbol fluency data, Table 16 for word fluency data and Table 18 for passage fluency data.

Table 20

*Least Squares Passage Means for Reading Finger(s) x Conditions*

| Dominant Reading Fingers | Conditions | Mean | Standard Error | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|
| Left Index Finger | Baseline | 83.568 | 9.150 | 63.179 | 103.957 |
| | LI | 59.275 | 5.547 | 46.915 | 71.636 |
| | RI | 45.361 | 6.521 | 30.832 | 59.890 |
| | LI-RI | 81.238 | 6.416 | 66.942 | 95.534 |
| | LM | 38.894 | 4.122 | 29.709 | 48.078 |
| | RM | 25.017 | 6.068 | 11.496 | 38.537 |
| | LM-RM | 54.219 | 6.069 | 40.696 | 67.741 |
| | LIM | 63.805 | 4.123 | 54.619 | 72.991 |
| | RIM | 53.512 | 6.124 | 39.868 | 67.156 |
| | LIM-RIM | 82.018 | 6.426 | 67.699 | 96.337 |
| Right Index Finger | Baseline | 68.151 | 12.452 | 40.406 | 95.896 |
| | LI | 30.152 | 7.549 | 13.331 | 46.972 |
| | RI | 59.365 | 8.873 | 39.594 | 79.136 |
| | LI-RI | 69.148 | 8.731 | 49.693 | 88.602 |
| | LM | 15.622 | 5.609 | 3.123 | 28.120 |
| | RM | 31.389 | 8.258 | 12.990 | 49.789 |
| | LM-RM | 37.508 | 8.259 | 19.106 | 55.910 |
| | LIM | 26.884 | 5.610 | 14.384 | 39.385 |
| | RIM | 49.361 | 8.333 | 30.794 | 67.928 |
| | LIM-RIM | 57.801 | 8.745 | 38.315 | 77.286 |
| Left Index + Right Index Fingers | Baseline | 45.630† | 27.281 | -15.157 | 106.417 |
| | LI | 29.190† | 16.539 | -7.662 | 66.042 |
| | RI | 25.630† | 19.441 | -17.687 | 68.947 |
| | LI-RI | 58.200† | 19.129 | 15.578 | 100.822 |
| | LM | 11.140† | 12.289 | -16.243 | 38.523 |
| | RM | 14.600† | 18.092 | -25.711 | 54.911 |
| | LM-RM | 24.820† | 18.094 | -15.497 | 65.137 |
| | LIM | 26.420† | 12.292 | -.967 | 53.807 |
| | RIM | 36.040† | 18.257 | -4.639 | 76.719 |
| | LIM-RIM | 44.340† | 19.160 | 1.649 | 87.031 |

*†Note: Results are not discussed in the narrative because they are based on one participant, and thus, it is not appropriate to draw conclusions about these data.*

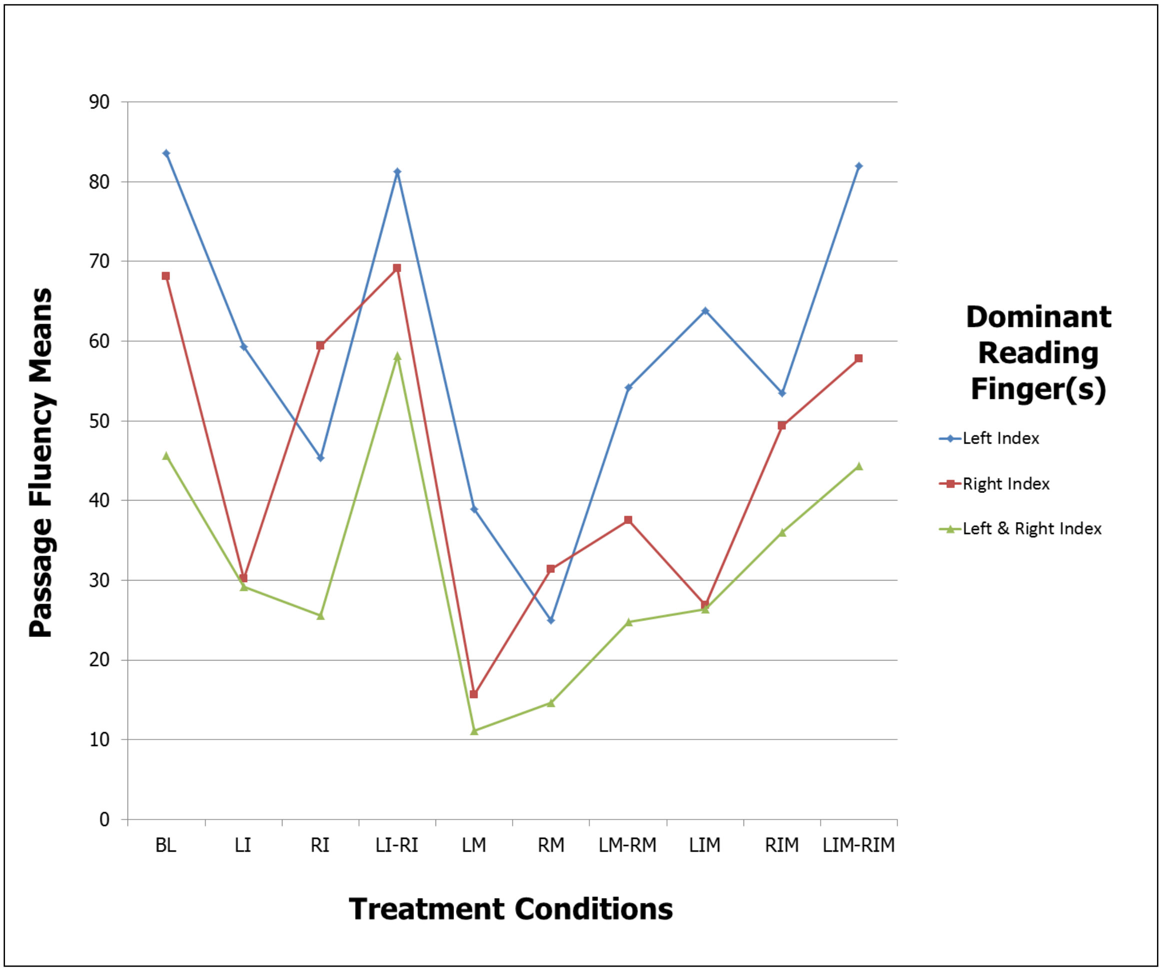



Figure 7

*Profile Plot of Least Squares Passage Means for Reading Finger(s) x Conditions*

The repeated measures ANOVA pertaining to symbol fluency found a statistically significant interaction effect between reading ability and dominant reading finger(s) ($F$(1, 10) = 12.107, $p$ = .006). Further analysis of the least squares means revealed that struggling readers whose right index finger was the dominant reading finger attained higher fluency scores (LSM = 22.279) than proficient readers whose right index finger was the dominant reading finger (LSM = 16.180). Likewise proficient readers whose left index finger was the dominant

reading finger attained higher fluency scores (LSM = 25.240) as compared to struggling readers whose left index finger was the dominant reading finger (LSM = 10.869). Moreover, proficient readers demonstrated better fluency when reading symbols predominantly with the left index finger (LSM = 25.240) than with their right index finger (LSM = 16.180), and struggling readers demonstrated better fluency when reading symbols with the right index finger (LSM = 22.279) than with the left index finger (LSM = 10.869). Thus, these data revealed a left index finger advantage for proficient readers and a right index finger advantage for struggling readers. The least squares means that support this interaction are supplied in Table 21 and the data are plotted in Figure 8.

Table 21

*Least Squares Symbol Means for Reading Ability x Dominant Reading Finger(s)*

| **Dominant Reading Fingers** | **Reading Ability** | **Mean** | **Standard Error** | **95% Confidence Interval** | |
|---|---|---|---|---|---|
| | | | | **Lower Bound** | **Upper Bound** |
| Left Index Finger | Proficient | 25.240 | 2.596 | 19.455 | 31.025 |
| | Struggling | 10.869 | 2.322 | 5.695 | 16.044 |
| Right Index Finger | Proficient | 16.180 | 2.998 | 9.500 | 22.860 |
| | Struggling | 22.279 | 3.672 | 14.097 | 30.461 |
| Left Index + Right Index Fingers | Proficient | N/A† | N/A | N/A | N/A |
| | Struggling | 6.512† | 5.193 | -5.058 | 18.082 |

*†Note: Results are not discussed in the narrative because they are based on one participant, and thus, it is not appropriate to draw conclusions about these data.*

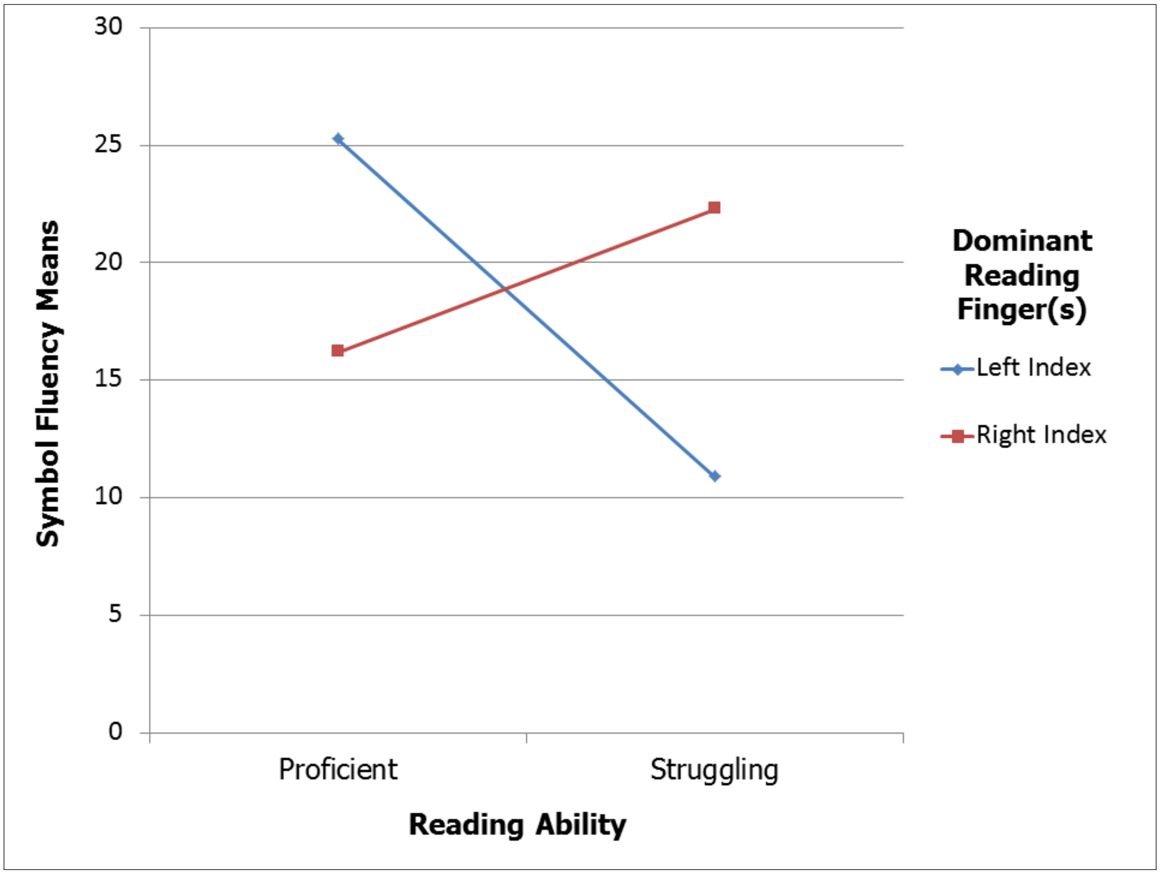



Figure 8

*Profile Plot of Least Squares Symbol Means for Reading Ability x Finger(s)*

Examination of the repeated measures ANOVA results for passage fluency, as previously reported in Table 18, revealed two different, statistically significant, interaction effects—one between reading ability and treatment conditions ($F(9, 90) = 2.001$, $p = .048$) and the other between reading ability and dominant reading finger(s) ($F(1, 10) = 9.694$, $p = .011$). The least squares fluency means pertaining to the interaction between reading ability and treatment conditions during reading passages demonstrated that participants who were proficient readers scored higher on all treatment conditions than did struggling readers.

Specific means are provided in Table 22, and the profile plot visually depicting this interaction is presented in Figure 9.

Table 22

*Least Squares Passage Means for Reading Ability x Conditions*

| | | | | 95% Confidence Interval | |
|---|---|---|---|---|---|
| **Reading Ability** | **Conditions** | **Mean** | **Standard Error** | **Lower Bound** | **Upper Bound** |
| Proficient | Baseline | 88.743 | 10.418 | 65.530 | 111.957 |
| | LI | 46.948 | 6.316 | 32.875 | 61.021 |
| | RI | 57.065 | 7.424 | 40.523 | 73.607 |
| | LI-RI | 76.509 | 7.305 | 60.232 | 92.785 |
| | LM | 27.504 | 4.693 | 17.047 | 37.961 |
| | RM | 35.940 | 6.909 | 20.546 | 51.334 |
| | LM-RM | 54.737 | 6.910 | 39.341 | 70.133 |
| | LIM | 48.845 | 4.694 | 38.387 | 59.304 |
| | RIM | 67.320 | 6.972 | 51.785 | 82.854 |
| | LIM-RIM | 80.337 | 7.317 | 64.034 | 96.640 |
| Struggling | Baseline | 57.194 | 11.857 | 30.775 | 83.612 |
| | LI | 38.049 | 7.188 | 22.033 | 54.066 |
| | RI | 40.317 | 8.449 | 21.491 | 59.143 |
| | LI-RI | 68.651 | 8.314 | 50.127 | 87.175 |
| | LM | 21.721 | 5.341 | 9.820 | 33.622 |
| | RM | 18.510 | 7.863 | .991 | 36.030 |
| | LM-RM | 32.933 | 7.864 | 15.411 | 50.456 |
| | LIM | 36.702 | 5.342 | 24.799 | 48.605 |
| | RIM | 35.716 | 7.935 | 18.036 | 53.395 |
| | LIM-RIM | 54.434 | 8.327 | 35.880 | 72.988 |

Just like symbol reading, the interaction between reading ability and dominant reading finger(s) during passage reading showed that struggling readers whose right index finger was the dominant reader attained higher fluency scores (LSM = 49.847) than proficient readers whose right index finger

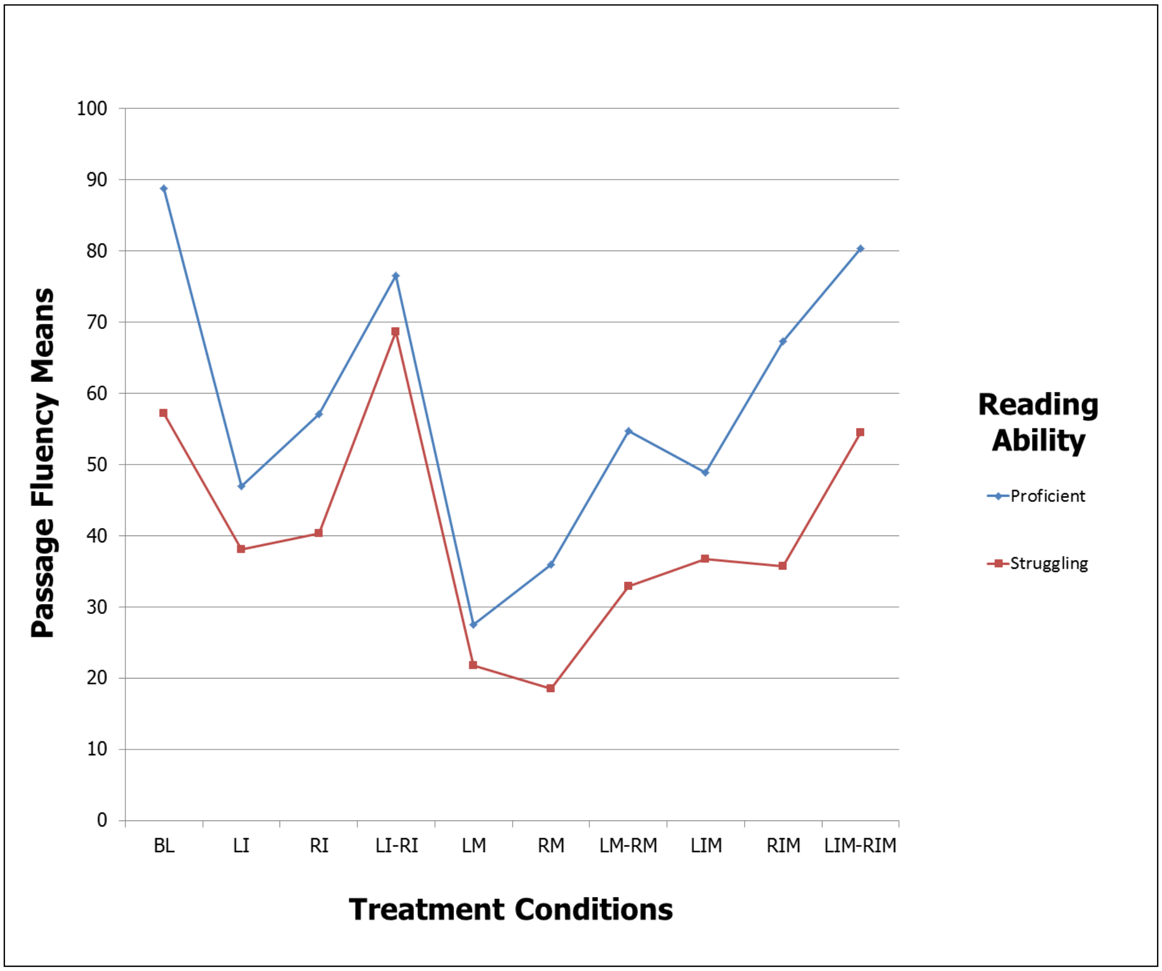



Figure 9

*Profile Plot of Least Squares Passage Means for Reading Ability x Conditions*

was the dominant reader (LSM = 39.229). Similarly, proficient readers whose left index finger was the dominant reader attained higher fluency scores (LS Mean = 77.561) as compared to struggling readers whose left index finger was the dominant reader (LS Mean = 39.820). Furthermore, proficient readers whose left index finger was the dominant reader were more fluent (LSM = 77.561) than proficient readers whose right index finger was the dominant reader (LSM =

39.229). Likewise, struggling readers whose right index finger was the dominant reader were more fluent (LSM = 49.847) than struggling readers whose left index finger was the dominant reader (LSM = 39.820). This interaction further supports the previous finding that suggested a left index finger advantage for proficient readers and a right index finger advantage for struggling readers. Least squares means are given in Table 23, and the corresponding profile plot is displayed in Figure 10.

Table 23

*Least Squares Passage Means for Reading Ability x Dominant Reading Finger(s)*

| **Dominant Reading Fingers** | **Reading Ability** | **Mean** | **Standard Error** | **95% Confidence Interval** | |
|---|---|---|---|---|---|
| | | | | **Lower Bound** | **Upper Bound** |
| Left Index Finger | Proficient | 77.561 | 6.855 | 62.286 | 92.835 |
| | Struggling | 39.820 | 6.132 | 26.158 | 53.482 |
| Right Index Finger | Proficient | 39.229 | 7.916 | 21.591 | 56.867 |
| | Struggling | 49.847 | 9.695 | 28.246 | 71.448 |
| Left Index + Right Index Fingers | Proficient | N/A† | N/A | N/A | N/A |
| | Struggling | 31.601† | 13.711 | 1.052 | 62.150 |

*†Note: Results are not discussed in the narrative because they are based on one participant, and thus, it is not appropriate to draw conclusions about these data.*

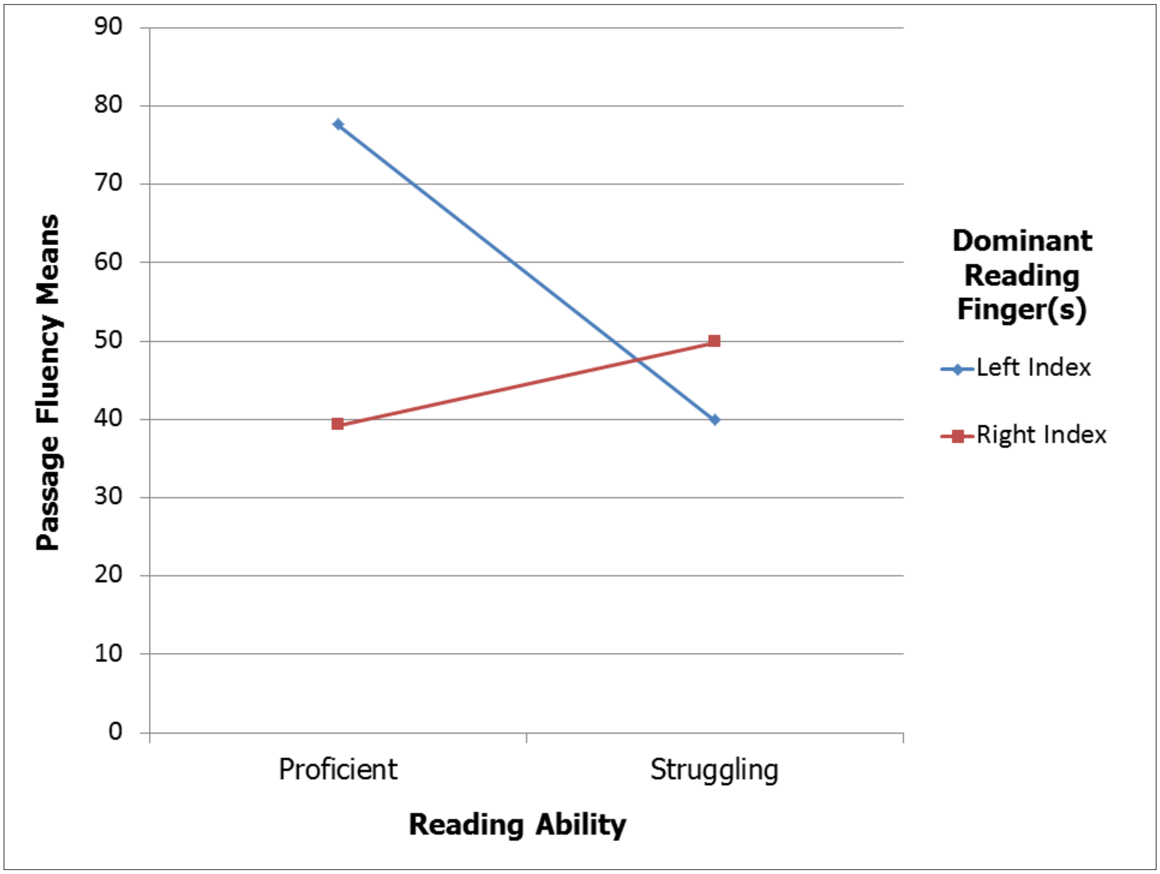



Figure 10

*Profile Plot of Least Squares Passage Means for Reading Ability x Finger(s)*

Through the use of three, repeated measures ANOVAs for various reading tasks (symbols, words, and passages), it was discovered that there was indeed a relationship between reading ability and reading fluency. Not surprisingly, these results showed that proficient readers performed better on all treatment conditions while reading passages than did those who were struggling readers. In addition, results for both symbol fluency and passage fluency revealed a connection linking efficient reading among proficient readers to a dominant left

index finger and efficient reading among struggling readers to a dominant right index finger.

**Q4: Participant Attributes, Instructional Characteristics, and Fluency**

Finally, research question four queried about the following:

Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, literacy modalities, educational setting, or instructional curriculum), participant characteristics (primary language, age vision lost, or presence of additional disabilities), and braille reading fluency?

This query was answered using Multiple Linear Regression. Once again, a series of Multiple Linear Regressions were run for each reading task (one for symbol reading, one for word reading, and one for passage reading). The dependent variable was fluency scores. Because it was not possible to conduct this analysis using fluency scores from all the treatment conditions given the small size of the sample, only the Baseline Condition was used in this portion of the analysis. Since the participants did not get any training or practice in the use of the experimental conditions, it was not problematic to use only baseline scores, especially since participants performed very well on this condition. The predictor variables used in these Multiple Regressions were the aforementioned participant attributes and instructional characteristics.

Like the ANOVAs, statistically significant results were not found for all the reading tasks. In fact, the entire model pertaining to symbol fluency and all its coefficients was not statistically significant as indicated by an adjusted $R^2$ of -.218 ($F(7, 14) = .643$, $p = .713$). Specific results of the symbol fluency Multiple

Linear Regression are presented in Table 24. The remainder of this section will detail the findings of the word fluency and passage fluency models.

Table 24

*Regression Analysis Summary for Symbol Fluency*

| **Variables** | **B** | **Standard Error B** | **β** | **t** | **p** |
|---|---|---|---|---|---|
| Years Spent Reading Braille | -.524 | 1.072 | -.230 | -.489 | .640 |
| Primary Literacy Modality | -4.042 | 9.441 | -.161 | -.428 | .681 |
| Educational Placement* | -4.906 | 5.958 | -.286 | -.823 | .437 |
| Age of Onset | 1.464 | 2.943 | .165 | .497 | .634 |
| Additional Disabilities | -3.701 | 7.521 | -.173 | -.492 | .638 |
| Curriculum* | -6.383 | 6.305 | -.365 | -1.012 | .345 |
| Primary Language* | -.425 | 11.427 | -.017 | -.037 | .971 |

* Note: Factors that are statistically significant are marked with an asterisk.

Before describing specific findings, the tests conducted to address the Multiple Linear Regression assumptions of normality, linearity, and homoscedasticity must first be discussed. In order to assess normality, skewness and kurtosis coefficients were analyzed for the relevant fluency scores. Given the fact that the predictor variables used in this part of the analysis were nominal variables, it was not possible to assess normality on them. However, the skewness coefficients for baseline word fluency (.267) and baseline passage fluency (.619) indicated that these variables were normally distributed. Kurtosis coefficients for word fluency (-.878) and passage fluency (.095) also confirmed

normality. In order to assess linearity, the residual plots for the word fluency regression and the passage fluency regression were visually inspected to see if the data were symmetrically arranged along a diagonal line. In the case of word fluency, the data were arranged in a slight s-shaped pattern around the diagonal line. The residual plot for passage fluency followed the diagonal line closely with a little bowing on both the upper half and lower half of the line. Finally, homoscedasticity was evaluated by visually examining the scatterplots for these two regressions to make sure the data appear to be scattered randomly rather than clustered together in patterns. Both scatterplots revealed sufficiently random scatter patterns. Since linearity was not met for word fluency, care must be taken when interpreting and generalizing the results for that regression.

Participant attributes and characteristics of braille instruction produced an adjusted $R^2$ of .874 ($F$(7, 14) = 14.884, $p$ = .001) for the prediction of word fluency. Basically, this means that these predictor variables accounted for 87% of the variance among word fluency scores. The five, statistically significant, predictor variables in order of importance were presence of additional disabilities (β = -.805), educational placement (β = -.725), primary language (β = -.670), primary literacy modality (β = -.545), and curriculum (β = .349). Students without additional disabilities who had always attended a school for the blind, whose primary language was English, who preferred learning through the tactual modality, and who had received instruction in both the general education curriculum and a functional life skills curriculum attained the highest word

fluency scores than those with additional disabilities who had attended both public and residential schools whose secondary language was English, who preferred learning through the auditory modality, and who had received instruction in only the general education curriculum. The complete findings of this Multiple Linear Regression are shown in Table 25.

Table 25

*Regression Analysis Summary for Word Fluency*

| Variables | B | Standard Error B | β | t | p |
|---|---|---|---|---|---|
| Years Spent Reading Braille | -.610 | .389 | -.237 | -1.570 | .161 |
| Primary Literacy Modality* | 15.461 | 3.422 | .545 | 4.518 | .003 |
| Educational Placement* | -14.029 | 2.160 | -.725 | -6.496 | .000 |
| Age of Onset | .089 | 1.067 | .009 | .083 | .936 |
| Additional Disabilities* | -19.421 | 2.726 | -.805 | -7.125 | .000 |
| Curriculum* | 6.875 | 2.285 | .349 | 3.008 | .020 |
| Primary Language* | -19.008 | 4.142 | -.670 | -4.589 | .003 |

* Note: Factors that are statistically significant are marked with an asterisk.

For the explanation of passage fluency, characteristics of braille instruction and participant attributes resulted in an adjusted $R^2$ of .609 ($F(7, 14) = 4.117$, $p = .041$). Hence, these predictor variables explained 61% of the variance among passage fluency scores. Four of the seven predictor variables were statistically significant, and they are presented in order of importance as follows: primary literacy modality (β = -.762), primary language (β = -.724), presence of

additional disabilities (β = -.639), and educational placement (β = -.535). Tactual learners, whose primary language was English, who did not have additional disabilities and who had always attended a residential school for the blind attained higher fluency scores during passage reading than those who were auditory learners, whose secondary language was English, who had additional disabilities, and who had attended both public and residential schools. All the results of this Multiple Linear Regression are posted in Table 26.

Table 26

*Regression Analysis Summary for Passage Fluency*

| **Variables** | **B** | **Standard Error B** | **β** | **t** | **p** |
|---|---|---|---|---|---|
| Years Spent Reading Braille | -2.093 | 2.281 | -.244 | -.917 | .389 |
| Primary Literacy Modality* | 72.014 | 20.085 | .762 | 3.585 | .009 |
| Educational Placement* | -34.485 | 12.676 | -.535 | -2.720 | .030 |
| Age of Onset | -5.152 | 6.262 | -.155 | -.823 | .438 |
| Additional Disabilities* | -51.376 | 16.000 | -.639 | -3.211 | .015 |
| Curriculum | 11.017 | 13.414 | .168 | .821 | .439 |
| Primary Language* | -68.489 | 24.311 | -.724 | -2.817 | .026 |

* Note: Factors that are statistically significant are marked with an asterisk.

## Summary

This study questioned the reliability and validity of one of the few scientifically-based research studies conducted in the last fifty years because it

contradicted hand and finger usage patterns during braille reading deemed to be best practice. Given the fact that theories on the most effective braille mechanics are predominantly based on observational and correlational research, it was important to constructively replicate the scientific experiment conducted by Hermelin and O'Connor (1971a, 1971b). Considering only the hand and finger combinations utilized by Hermelin and O'Connor, this study did not find similar results. Instead, it showed that most participants performed better with either index finger than with either middle finger. Furthermore, no left hand advantage was found. Instead, there was an overall advantage for the right index finger and a dominant-hand advantage when reading with either one of the middle fingers.

When decoding braille symbols according to their dot-number configurations, it was determined that dominant reading finger and reading ability had a statistically significant impact on the hand and finger combinations that resulted in the greatest degree of fluency. Participants whose left index finger was the dominant reading finger tended to perform best on conditions involving the left index and middle fingers as well as just the left index finger. Likewise, participants whose right index finger was the dominant reading finger did best on conditions including the right index finger as well as the left and right index fingers. A relationship was also discovered that suggested a left hand advantage for proficient readers and a right hand advantage for struggling readers when decoding braille symbols in isolation.

Relationships were also found between the hand and finger combinations that produced the greatest amount of word-decoding fluency, participant traits, and instructional characteristics. Conditions utilizing both hands and either the index fingers alone or the index and middle fingers together resulted in the best fluency. Furthermore, participants who had no additional disabilities and whose primary language was English performed best on word identification. Having always attended a school for the blind, being instructed in both the core curriculum and a functional life skills curriculum as the result of having an additional disability, and preferring the tactual learning modality were related to better word fluency.

Finally, statistically significant interactions were also found for the hand and finger combinations that produced the best passage fluency, dominant reading finger(s), reading ability, participant attributes and instructional qualities. Participants whose dominant reading finger was the left index finger achieved the highest fluency on conditions involving both hands and either the index and middle fingers or just the index fingers. Those whose dominant reading finger was the right index finger also did better on conditions using the left and right index fingers. Moreover, participants without additional disabilities and whose primary language was English obtained the highest passage fluency scores. In addition, participants who had always attended schools for the blind and whose primary learning modality was tactual did better on passage reading.

# CHAPTER 5

# DISCUSSION

In this era of accountability, educators are required to use best practices supported by scientifically-based evidence as stipulated by the *No Child Left Behind Act* (NCLB). This requirement poses challenges for all educators, but especially those who teach children and youth with low-incidence disabilities such as visual impairment. In fact, a series of extensive reviews of literature related to the education of students who are blind or who have low vision consistently revealed a paucity of experimental or quasi-experimental research (Ferrell, Buettel, Sebald, & Pearson; 2006; Ferrell, Dozier, & Monson, 2011; Ferrell, Mason, Young, & Cooney, 2006; Kelly & Smith, 2011; Parker, Grimmett, & Summers, 2008; Parker & Pogrund, 2009; Wright, Harris, & Sticken, 2010). While such a lack of scientific inquiry is problematic in and of itself, it is extremely disconcerting when an insufficient research base is also riddled with contradictions.

Consequently, discovery of the only experimental research published in a peer-reviewed journal in the last 50 years pertaining to the hand and finger usage patterns of braille readers between the ages of three and 21 served as the impetus for this study because it contradicted what is believed to be best

practice. Given the fact that this research was conducted by cognitive psychologists who were not braille experts, it was tempting to summarily dismiss these controversial data in favor of historical conventions passed down from generation to generation by well-respected colleagues trained specifically in blindness and visual impairment.

As a field with more questions than answers, researchers often seek to be the one to pioneer a new instructional strategy, develop an innovative theory, or solve a great mystery, and the replication of previous research is often viewed as an insignificant contribution or a waste of limited resources. However, the possibility that the United States Department of Education could call into question instructional techniques used by braille teachers for over a century as the result of one scientific experiment that met NCLB's requirements for evidenced-based practice was troubling. In light of persistent concerns about braille users not attaining literacy skills at a rate commensurate with their sighted peers (Caton, Pester, & Goldblatt, 1979; Emerson, Holbrook, & D'Andrea, 2009; Fertsch, 1946, 1947; Knowlton & Wetzel, 1996; Lowenfeld, Abel, & Hatlen, 1969; National Center on Severe and Sensory Disabilities, 2006; Nolan & Kederis, 1969; Trent & Truan, 1997; Wetzel & Knowlton, 2000; Wormsley, 1996; Wright, Wormsley, & Kamei-Hannan, 2009), it was deemed prudent to devote the time and resources necessary to determine if the findings of Hermelin and O'Connor (1971a, 1971b) were an anomaly.

Thus, the remainder of this chapter discusses the theoretical implications and practical applications of the results and limitations of this constructive replication. The findings are first discussed in regards to the original research of Hermelin and O’Connor and then in relation to the specific research questions guiding this investigation. Finally, the chapter concludes with suggestions for future research and overarching conclusions.

## Hermelin and O’Connor Constructive Replication

Different fields often study the same issues from different angles. Although one might think the only professionals interested in braille would be those who work directly with individuals who are blind, cognitive psychologists and cognitive neuroscientists occasionally conduct research using braille as a stimulus. These studies oftentimes include sighted participants whose vision is occluded and sometimes involve participants who are blind. When people without vision are utilized, they usually serve as a comparison group since blindness is not the primary interest. In fact, the purpose of this line of scientific inquiry is to better understand typical brain processing during perceptual and cognitive tasks or to better understand brain plasticity as a result of a cerebral dysfunction.

Along these same lines, the research conducted by Hermelin and O’Connor (1971a, 1971b) was not aimed at improving braille mechanics. Their motive was to better understand which part of the brain is responsible for tactual reading since this task requires both language processing, which occurs primarily

in the left hemisphere, and spatial reasoning, which occurs primarily in the right hemisphere. Given the fact that each hemisphere controls the opposite side of the body, Hermelin and O'Connor speculated that determining which hand resulted in the fastest oral reading speeds would indicate the hemisphere of the brain that is dominant during braille reading. Therefore, it makes sense that Hermelin and O'Connor excluded two-handed reading techniques since the predominant cognitive theories of that time period focused on activation of one area of the brain depending on the activity.

The original finding of Hermelin and O'Connor (1971a, 1971b) demonstrated a left-hand advantage, thereby indicating that the right hemisphere of the brain is more likely to be dominant during the reading of unrelated, braille sentences. This would suggest that braille literacy is more of a spatial task than a language task, which supports the belief that braille reading is highly dependent on piecing together individual symbols to formulate words. Furthermore, this would also imply that the left hand is responsible for decoding braille shapes, which is supported by the previous research of Heller, Hocheisn, Gigerl, Zech, and Grasemann (as cited in Burklen, 1917/1932); Rudel, Denckla, and Hirsch (1977); and Rudel, Denckla, and Spalten (1974).

In keeping with the intent of the research conducted by Hermelin and O'Connor (1971a, 1971b), results from this constructive replication were initially analyzed using only the fluency data for single-finger conditions (LI, RI, LM, and RM) during passage reading. Unlike Hermelin and O'Connor who reported a left-

index-finger advantage for reading speed, this study found a medium, statistically significant effect ($\eta_G^2$ = .155, $p$ = .024) for the right index finger. The difference in these findings could be due to the fact that participants in this study read related sentences in a passage, whereas the participants in the original study read a series of unrelated sentences. Since there were more phonological and context clues available in the passages, it makes sense that the left hemisphere would be engaged more in the reading of related sentences than unrelated sentences.

Although this constructive replication did not support a global left-hand advantage, it did show such an advantage for those who were ambidextrous. This finding could be related to the fact that two of the three ambidextrous participants showed a slight preference for the left hand when completing the physical activities used to determine handedness. Furthermore, research on the human brain has shown that for almost 50% of left-handed people, language is processed in either the right hemisphere of the brain or on both sides of the brain (Beaumont, 2008; Taylor & Taylor, 1990). Therefore, it is not possible to make assumptions about hemispheric function for such a small group of ambidextrous participants.

Despite the fact that Hermelin and O'Connor reported a left-middle finger advantage in relation to the number of reading errors made, this study revealed mixed results. When comparing fluency scores (which accounted for both speed and accuracy) for the middle fingers, this same advantage was only found for

participants who were left handed. Likewise, participants who were right handed achieved greater fluency with the right middle finger than they did with the left middle finger. However, comparison of the mean number of passage miscues made during these conditions showed that participants made slightly fewer errors with the left middle finger ($\bar{x}$ = 5.94) than with the right middle finger ($\bar{x}$ = 6.14), the right index finger ($\bar{x}$ = 6.26), or the left index finger ($\bar{x}$ = 6.33). Further inspection of the number of miscues showed that participants made slightly fewer mistakes with the middle fingers ($\bar{x}$ = 6.04) than with the index fingers ($\bar{x}$ = 6.3) and with the left hand ($\bar{x}$ = 6.14) than with the right hand ($\bar{x}$ = 6.2). It is interesting that there was only a slight difference in the number of miscues made between the index and middle fingers when there was a large difference in fluency rates between the index fingers ($\bar{x}$ = 46.34) and the middle fingers ($\bar{x}$ = 26.92). This would most likely indicate that participants struggled to tactually discriminate braille with their middle fingers, but given enough time, they were able to read with accuracy that paralleled the index fingers. In fact, the left middle finger was the only one of these conditions during which participants did not make any omission errors.

It should be noted that three of the participants in the original study were unable to read sentences with their right hand alone, and one participant in the constructive replication was unable to read the passage assigned to the right middle finger. Thus, it is difficult to draw definitive conclusions about these particular data. Nevertheless, Hermelin and O'Connor attributed the left-hand

advantage when using only the middle finger to the fact that these fingers are not the primary reading finger, and when forced to be the primary reading finger, they may function in a decoding capacity. This same generalization cannot be made in this study since an ipsilateral (same-sided) tendency was observed. Perhaps the reason for this is that people typically have better manual dexterity with the dominant hand than the non-dominant hand. Since reading with one middle finger presumably requires more dexterity than using the more practiced index fingers, it would make sense for participants to perform better on this rare task using their dominant hand.

A direct comparison to the conditions employed by Hermelin and O’Connor (1971a, 1971b) did not corroborate their findings of a left-hand advantage. Overall, there was a right-hand advantage. Like Hermelin and O’Connor, this study concurred that the highest fluency scores were obtained using the index fingers, but there was no statistically significant, left-hand advantage found for the middle finger in regards to fluency. Although these findings differ from Hermelin and O’Connor, they validate conclusions from other research suggesting activation of the left-hemisphere of the brain when braille readers are able to use phonological and context clues to derive meaning (Maxfield; 1928; Millar, 1975; Wilkinson, 1982; Wilkinson & Carr, 1987).

As a result of the extensive modifications to the research of Hermelin and O’Connor (1971a, 1971b), caution must be taken when explaining differences in findings. Ultimately, the lack of a left-hand advantage in this study could be

related to the fact that Hermelin and O'Connor studied beginning braille readers while this research studied experienced braille readers. Lack of support for a left-hand advantage could also be the result of instituting different reading tasks than Hermelin and O'Connor. While this investigation found support for two-handed techniques, a left-hand advantage for beginning braille readers cannot be ruled out.

## Research Questions

While the research conducted by Hermelin and O'Connor (1971a, 1971b) makes sense when viewed through the lens of cognitive science, their findings do not translate well into educational practice. After scouring the literature within the fields of blindness and visual impairment, cognitive psychology, and cognitive neuroscience, it was decided that this constructive replication needed to be expanded in order to adequately address the complexities involved in the mechanics of efficient braille reading. In addition to the single-finger conditions explored by Hermelin and O'Connor, previous research suggested the need to examine multi-finger and bimanual conditions among struggling and proficient readers across a variety of reading tasks. It was also deemed important to further explore the role that the index and middle fingers played in braille reading, as well as the effect that basic participant attributes and characteristics of braille instruction had on braille fluency. Analysis of the statistical results and supplemental data occurs in the ensuing discussion as related to the theoretical and scientific foundations of braille mechanics with a focus on the practical

applications and implications of these findings. This chapter then concludes with a discussion of the limitations of this study and suggestions for future research pertaining to hand and finger usage patterns during braille reading.

**Q1: Hand/Finger Pattern(s) and Fluency**

The one clear trend in the literature review pointed to the efficacy of two-handed reading techniques (Burklen, 1917/1932; Lowenfeld, Abel, & Hatlen, 1969; Maxfield, 1925; Whitby as cited in Wormsley, 1979; Williams, 1971; Wright, Wormsley, & Kamai-Hannan, 2009). Since previous research only observed the natural patterns utilized by participants who were blind, this study went one step further and explored all plausible bimanual and multi-finger combinations using the index and/or middle fingers in order to answer the following research question.

> Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index + middle) resulted in the greatest degree of fluency?

Baseline data were collected in which participants were allowed to read using their preferred hand and finger usage patterns. Thirteen of the fifteen participants used two hands during the baseline assessment. Of these two-handed readers, two participants used only their index fingers and five used their index, middle, ring, and pinky fingers. The remaining six participants who read with two-hands employed finger combinations that were not parallel across both hands. These non-parallel finger patterns involved using fewer fingers on the non-dominant reading hand. The two participants who were one-handed readers

used at least three fingers. Given the fact that all of the participant scores were averaged for each condition, the baseline condition can essentially be thought of as a predominantly two-handed technique involving at least the index and middle fingers.

Previous research also suggested that the left hand is responsible for decoding individual characters while the right hand is responsible for phonological and contextual processing (Bradshaw, Nettleton, & Spehr, 1982; Millar, 1975, 1997). To assess this possibility, participants in this study were asked to complete three different reading tasks during each treatment condition. The first task on each test involved decoding seven braille symbols paired with a full cell of braille for orientation purposes. In order to force the brain to decode the symbols spatially, participants were instructed to announce the dot number configuration of these symbols. The second task involved reading 10 unrelated words in order to prompt phonological coding. Finally, participants read a select passage from an Informal Reading Inventory (IRI) consisting of 131 to 457 words, which allowed them to utilize all reading strategies, especially context clues. (Both the symbol and word sections were written linearly in paragraph style, like the passages, so as to eliminate variations in format as a confounding variable.) If the trend suggested by the literature review is true, one would expect that the left hand conditions would produce the highest fluency scores for symbol reading and that the right hand conditions would produce the highest fluency scores for passage reading followed by word reading.

The only instance in which treatment conditions were found to be statistically significant ($p < .005$) without the influence of another factor occurred while reading words. The hand and finger usage patterns that produced the greatest degree of fluency for word reading were the Baseline Condition, Condition LI-RI, and Condition LIM-RIM, and the effect size for these conditions was medium ($\eta_G^2 = .176$). These results provided additional support in the form of scientifically-based evidence for two-handed reading techniques when decoding unrelated words.

Given the fact that symbol reading is more of a novel task than reading words in isolation, one would expect symbol fluency scores to be the poorest. However, this was not always the case as word fluency scores dipped below their corresponding symbol fluency scores during five treatment conditions, and in fact word fluency scores for two conditions were the lowest scores obtained by participants during the entire experiment. These occurred during Conditions LM and RM. Refer to Figure 11 in order to compare the mean fluency scores for the baseline and experimental conditions on each of the three reading tasks.

While reading words in isolation, the participants often seemed to have difficulty tactually discriminating one or more braille symbols within a word, which sometimes made it impossible to accurately identify the word since there were no context clues available to help them formulate an educated guess. Hence, it makes sense that substitutions were the most common type of miscue made by participants while reading words. Repetitions were the second most

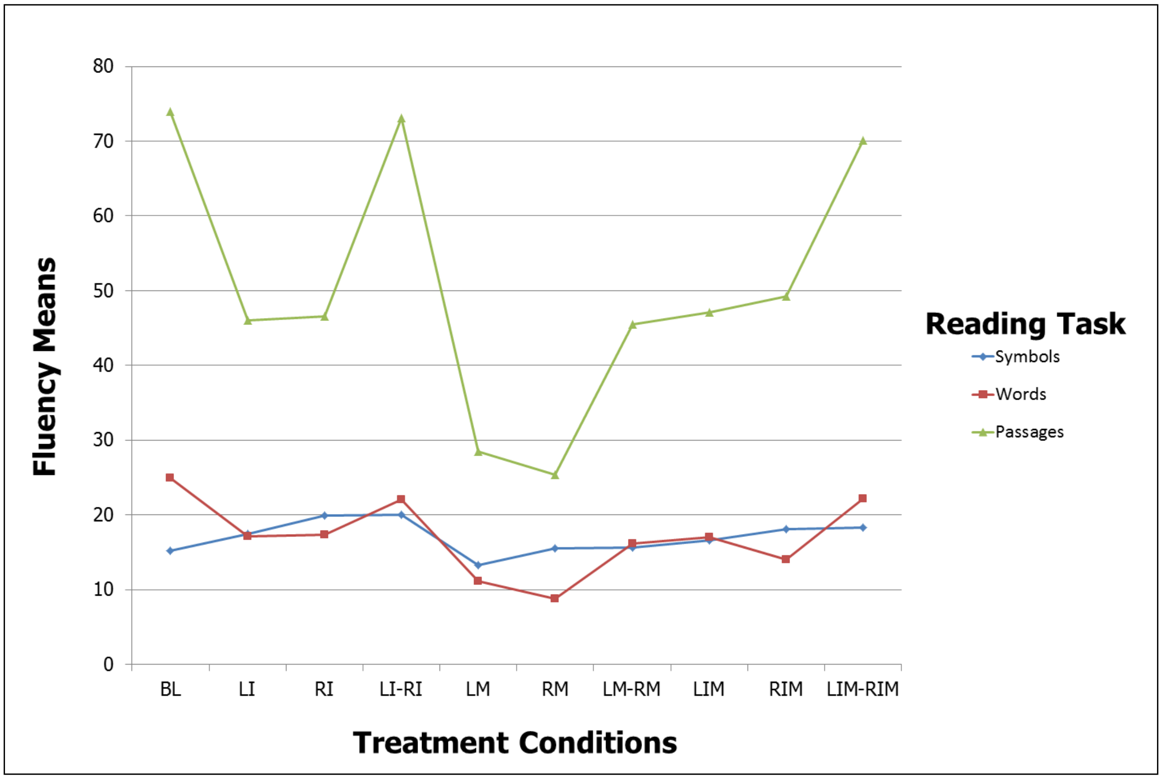



Figure 11

*Mean Fluency Scores for Conditions x Task*

common error, and these typically occurred while participants were rechecking words or transitioning between lines. Since the paragraph of unrelated words on each test consisted of only a couple of lines, the greater occurrence of repetitions during word reading than passage reading can be attributed to decoding difficulty. Furthermore, there were more hesitations during word reading than during any other reading task, which indicates that participants had a harder time accurately deciphering or pronouncing words in isolation. This is probably due to the need in this situation to first decode symbols individually and then blend them together instead of engaging in whole-word recognition. Figure

12 shows the average proportion of miscues made by all participants across the different treatment conditions and reading tasks.

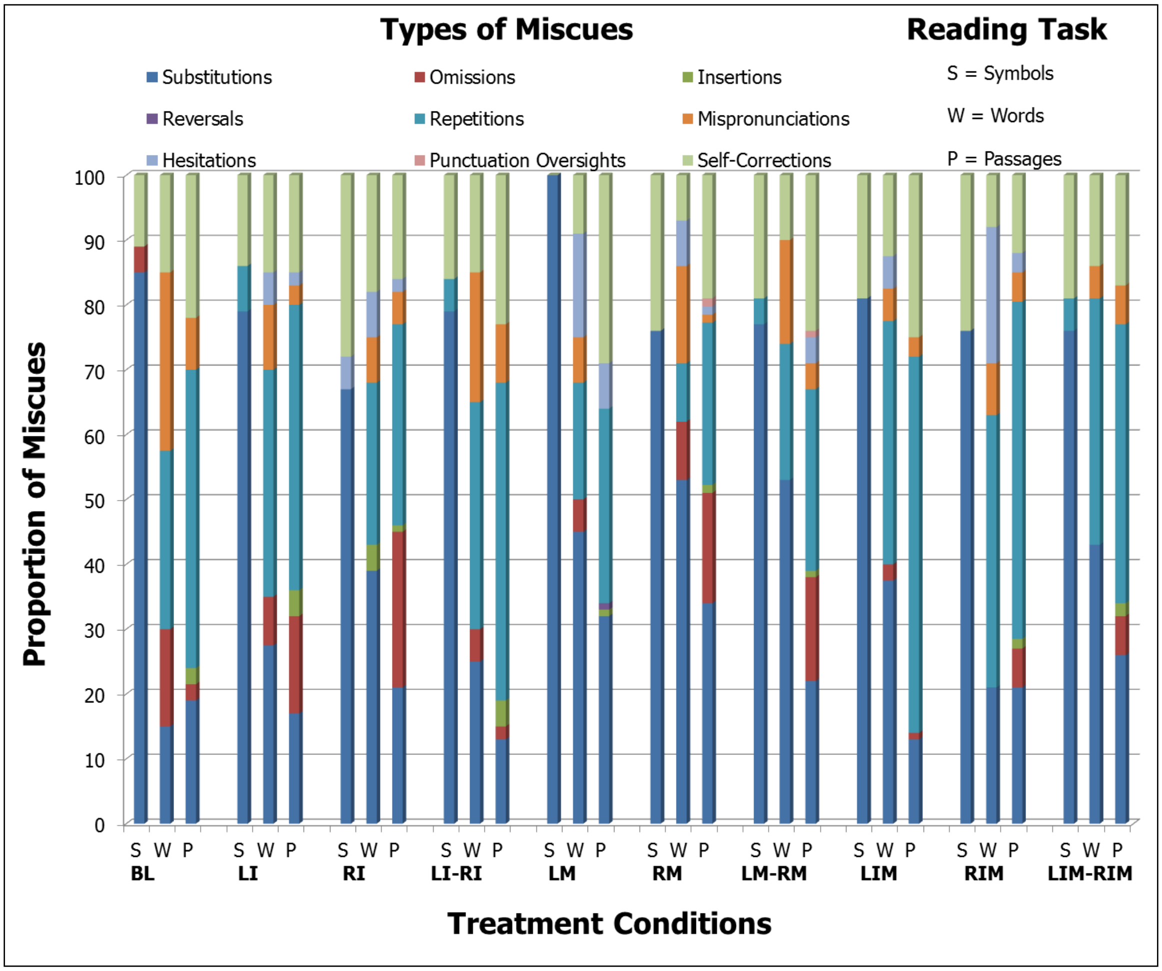



Figure 12

*Types of Miscues for Conditions x Task*

Overall, participants made a wider variety of mistakes when reading words than when reading symbols. While reading words in isolation was difficult, it appears that participants were able to use a variety of phonological strategies (such as sounding out words and using phonetic rules) to accurately decode words or to at least venture an educated guess. Since the data plot line for word

fluencies mirrored the data plot line for passage fluencies in terms of peaks and valleys (see Figure 11), this may support the notion that many of the same processes are involved in the reading of words and passages as compared to reading symbols.

Based on this supplemental information, it was not surprising that participants obtained higher word fluency scores on two-handed conditions than they did on similar one-handed conditions. Even though participants did better with the left and right middle fingers together than they did with either of the middle fingers alone, performance on Condition LM-RM was similar to one-handed conditions involving the index finger. Therefore, the middle fingers do not seem to play an essential role in word identification.

Although the data for all reading tasks hint at a two-handed advantage for conditions involving the index fingers of both hands, only a statistically significant difference for treatment conditions was found on word identification tasks. The most likely reason that word reading was the only task that produced significant findings may be related to the fact that word identification requires more tactual discrimination at the individual character level than passage reading and more language processing than the naming of symbols' dot configurations. This is aligned with current theory, which suggests that both hemispheres of the brain are actively involved in tactual reading (Millar, 1997, 2008).

Regardless of the role each hemisphere of the brain plays in braille reading, one would expect two-handed techniques to be best because it is easier

to maintain a straight line when there is a fixed, spatial reference-point that directs movement. Thus, one would expect to see an increase in the number of omissions for one-handed conditions, especially in relation to the word identification tasks. (This hypothesis does not apply to symbol reading because braille signs were all placed on one line. Furthermore, omissions are less likely to occur during passage reading because the participant is apt to correct omissions because of the resulting distortion in meaning.) The conditions in which there were no omissions made during word identification were as follows: RI, LM-RM, RIM, and LIM-RIM. While the Baseline Condition had the highest proportion of omissions for word reading, this is most likely the result of an order effect since the baseline assessment was always the first condition under which participants read. Thus, these data suggest that the right hand may play an important role in tracking, which is aligned with the conclusions drawn by both Hocheisn and Zech (as cited in Burklen 1917/1932).

Though braille users may sometimes be tempted to use one-hand to quickly scan lists of words, the results of this study indicate that two-handed reading is faster and more accurate. Therefore, TSVIs should encourage the use of at least both index fingers. When students resist this technique, it may be beneficial to collect and plot fluency data using different hand and finger combinations to demonstrate this advantage to the student.

**Q2: Handedness/Reading Finger Dominance and Fluency**

The literature also discussed the role that each hand plays as a factor that contributes to braille fluency. Some research indicated that the most fluent readers use each hand independently to simultaneously read different portions of text at the same time (Birms, 1976; Eatman, 1942; Fertsch, 1946, 1947; Gray & Todd, as cited by Wright, 2004; Lowenfeld, Abel, & Halten, 1969; Maxfield, 1925; Wormsley, 1979, 1981). Most of these conclusions were reached by observing or videotaping hand movements from above the reading surface, which showed the right hand reading the last part of a line of text while the left hand simultaneously read the beginning part of the next line of text. Given the fact that it is difficult to observe precise finger movements in relation to the individual braille characters when viewing from above the braille, researchers have devised systems for recording hand and finger movements from below a transparent surface (Breidegard, Jonsson, Fellenius, & Stromqvist, 2006; Davidson, Wiles-Kettenmann, Haber, & Appelle, 1980; Kilpatrick, 1985; Millar, 1988, 1997). This constructive replication utilized a reading stand similar to that devised by Millar in order to answer the following question.

Q2 Is there a relationship between handedness and/or dominant reading finger(s) and the hand and finger usage pattern that produced the greatest degree of fluency?

Videos capturing participants' finger movements in relation to individual braille symbols were analyzed to see which finger(s) displayed a reading patch; this is a fingertip that has been flattened and/or whitened because pressure has

been applied (Millar, 1988, 1997). Coding the reading patch proved to be problematic in part because of the quality of the video footage obtained in this constructive replication. However, the researcher and her assistant noticed that the reading patch was often displayed on fingers that were not actively involved in reading but instead were acting as placeholders or as leverage points to propel the hands across the line of text. Because the application of light pressure is an important aspect of proper braille mechanics (Castellano & Kosman, 1997; Harley, Truan, & Sanford, 1997; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997), the researcher questions Millar's premise that the reading finger(s) exert more pressure on the braille than the non-reading fingers. Thus, a modified coding system was devised to determine the dominant reading finger(s) by tallying the times each index and each middle finger was properly aligned with the row(s) of text being read and tallying the times each index and each middle finger were used to recheck that which had been read via retracing or scrubbing. Only the index and middle fingers were coded since there is agreement that these are the primary reading fingers (Castellano & Kosman, 1997; Harley, Truan, & Sanford, 1997; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). Hence, the finger(s) labeled dominant in this study functioned as both decoders and recheckers.

As for handedness, this study revealed no statistically significant findings, which is probably because the majority of participants in this study were right

handed. However, there were statistically significant effects for dominant reading finger and treatment conditions for both symbols ($p < .000$) and passages ($p < .003$ ). The effect size of this interaction during symbol reading was medium ($\eta_G^2 = .135$), and it was small ($\eta_G^2 = .095$) during passage reading. On both these reading tasks, participants achieved the highest fluency on conditions that included their dominant reading-finger, particularly when using two hands. In other words, participants whose dominant reading finger was the left index performed better on Conditions LIM and LI while reading symbols and the Baseline, Condition LIM-RIM, and Condition LI-RI while reading passages. Likewise, participants whose dominant reading finger was the right index performed better on Conditions RI and LI-RI while reading symbols and Conditions LI-RI and the Baseline while reading passages. Not surprisingly, participants obtained the lowest fluency scores when required to use the middle finger of their non-dominant hand.

A comparison of mean fluency rates based on dominant reading finger, as depicted in Figure 13, showed that participants whose left index finger was the dominant reading finger had slightly lower symbol fluency scores overall than those whose right index finger was the dominant reading finger. In contrast, participants whose left index finger was dominant obtained noticeably higher passage fluency scores overall than those whose right index finger was dominant. In addition, the symbol fluency data line follows the same relative pattern of peaks and valleys as the word fluency data line for those with a

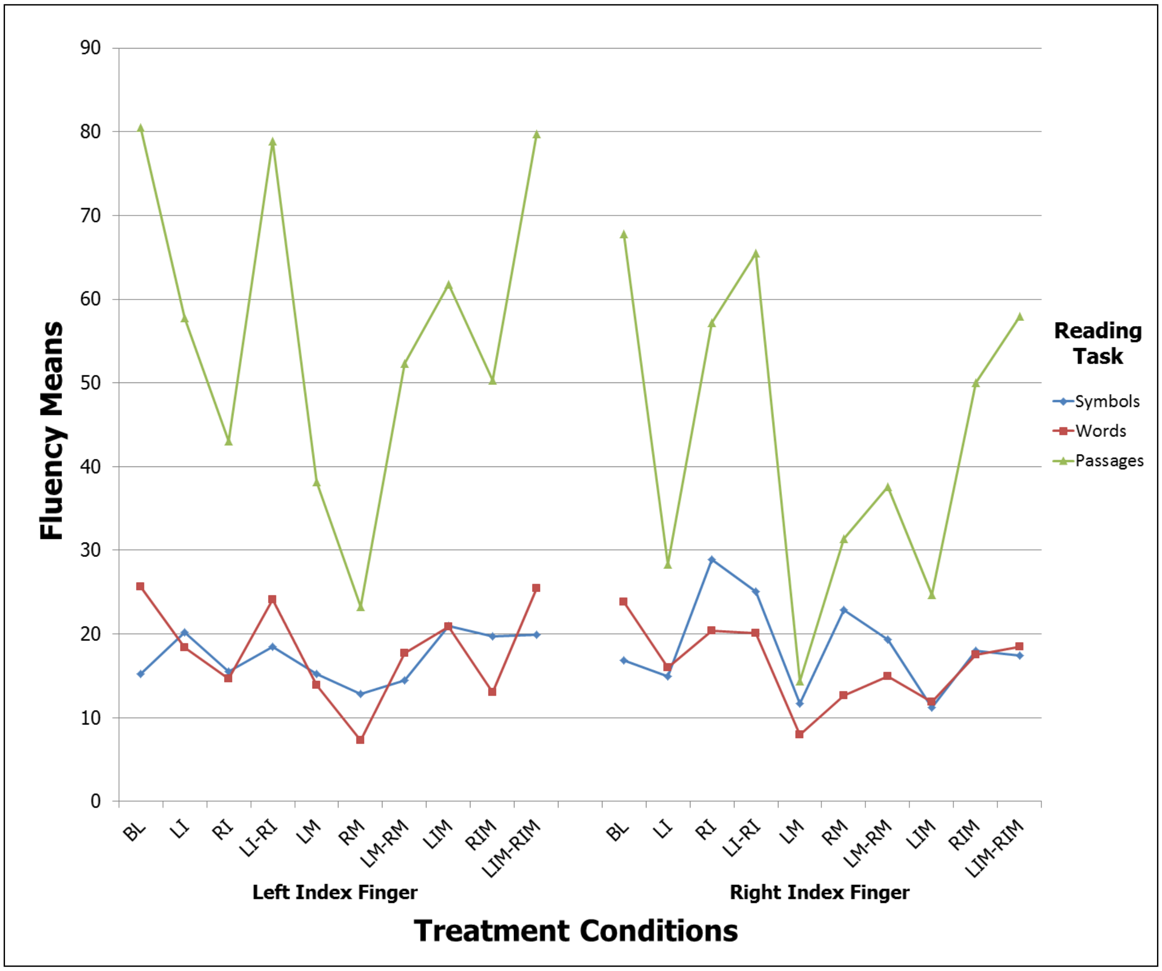



Figure 13

*Mean Fluency Scores for Reading Finger x Conditions and Task*

dominant left index reading finger. However, participants with a dominant right index finger received higher symbol fluency scores when using their left index finger instead of their right index finger and their left middle finger instead of their right middle finger. Since this occurred only during symbol reading, a highly spatial task, this may support the trend in the literature suggesting a left-hand advantage for spatial decoding tasks (Heller, Hocheisn, Gigerl, Zech, &

Grasemann as cited in Burklen, 1917/1932; Rudel, Denckla, & Hirsch, 1977; Rudel, Denckla, & Spalten, 1974).

Analysis of miscues based on dominant reading finger revealed a trend in which participants whose right index finger was the dominant reading finger were able to correct all their mistakes during symbol reading when using just the right index finger. This group also made a large proportion of self-corrections when reading words with just the right index finger and when reading passages with just the right middle finger. Since it was not possible to test for an interaction between handedness and dominant reading finger due to small sample size, this trend may be related to the fact that the majority of the participants were right handed. The proportion of various miscues made by participants based on their dominant reading finger is summarized in Table 14.

This study corroborated the trend in the literature suggesting that each hand plays different roles in braille reading when using two hands. While more detail is needed regarding the specific functions executed by each hand, these results indicated that the conditions resulting in the greatest degree of fluency included the dominant reading finger. During symbol reading, participants were able to achieve high levels of fluency using just their dominant reading finger, which is logical since they were only required to read one braille sign at a time. However, participants demonstrated better performance while reading passages with a minimum of two fingers. Given the increase in the length of the unit the reader is required to recognize during the reading of related words, it makes

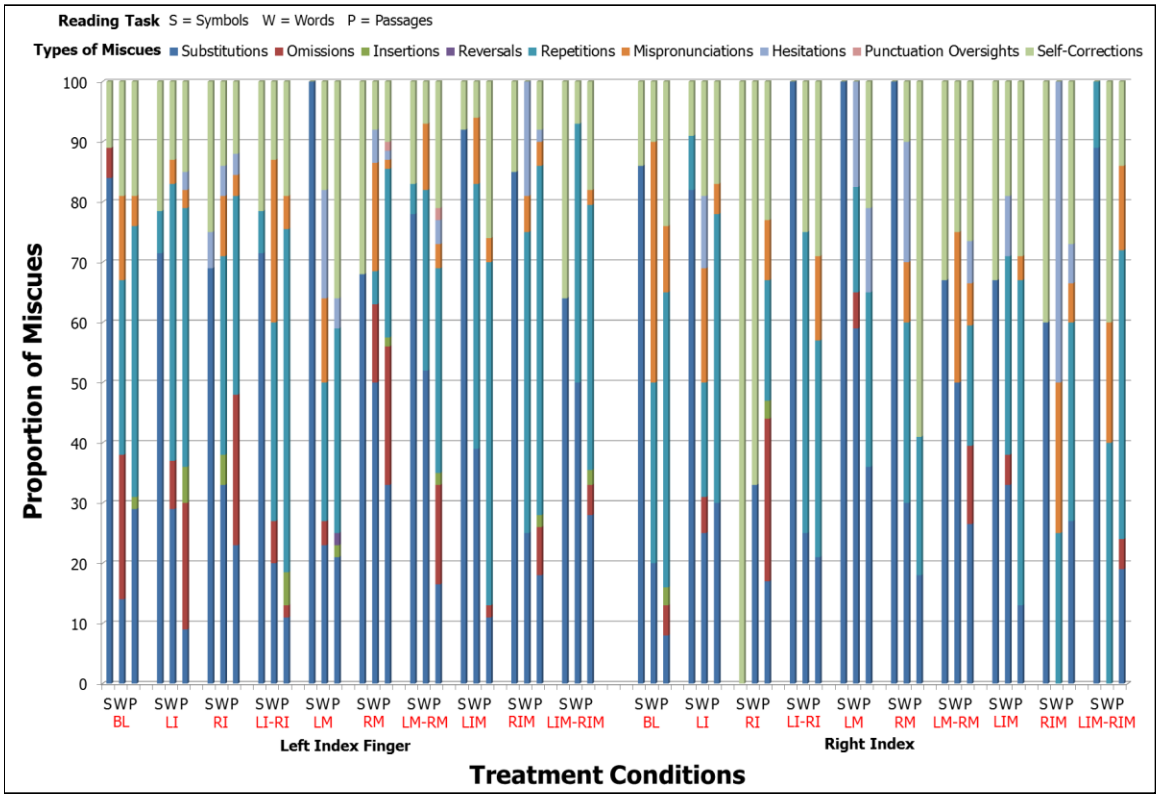



Figure 14

*Types of Miscues for Reading Finger x Conditions and Task*

sense that the use of multiple fingers would increase the size of the perceptual window thereby speeding up recognition (Nolan & Kederis, 1969).

Instead of merely monitoring the braille mechanics of students for use of two-handed techniques, it may be beneficial for TSVIs to determine which finger(s) is/are the dominant reader(s). This could potentially allow for a specific remediation plan for struggling readers or slow readers that would involve maximizing use of the dominant reading finger while strengthening the non-dominant reading finger. However, more research is needed on the role each finger plays before such systematic interventions can be developed and tested.

**Q3: Reading Ability and Fluency**

Another trend noted in the literature review was that good readers relied more on the right hand while poor readers relied more on the left hand (Fertsch, 1947; Holland & Eatman as cited in Wright, 2004; Millar, 1984). Researchers have attributed these findings to the tendency of beginning and struggling readers to engage more in letter-by-letter decoding while proficient readers utilize more phonological and context clues (Bradshaw, Nettleton, and Spehr, 1982; Millar, 1975, 1997). Hence, this study addressed this potentially confounding variable by pretesting participants to determine their instructional reading level. Participants were then tested at their highest independent reading level. Those whose instructional reading level was at or above their current grade level were classified as proficient readers, while those whose instructional reading level was below their current grade level were classified as struggling readers. Fluency scores were then analyzed accordingly in order to answer the following question:

> Q3 Is there a relationship between reading ability and the hand and finger usage pattern that produced the greatest degree of fluency?

Multiple interactions were found related to reading ability. The first statistically significant interaction revealed a small effect ($p$ <.048, $\eta_G^2$ =.039) for passage fluency on all treatment conditions based on reading ability. As demonstrated in Figure 15, proficient readers achieved higher passage fluency scores on all treatment conditions than struggling readers. While a similar trend is evident for symbols and words, there was much less of a difference in the

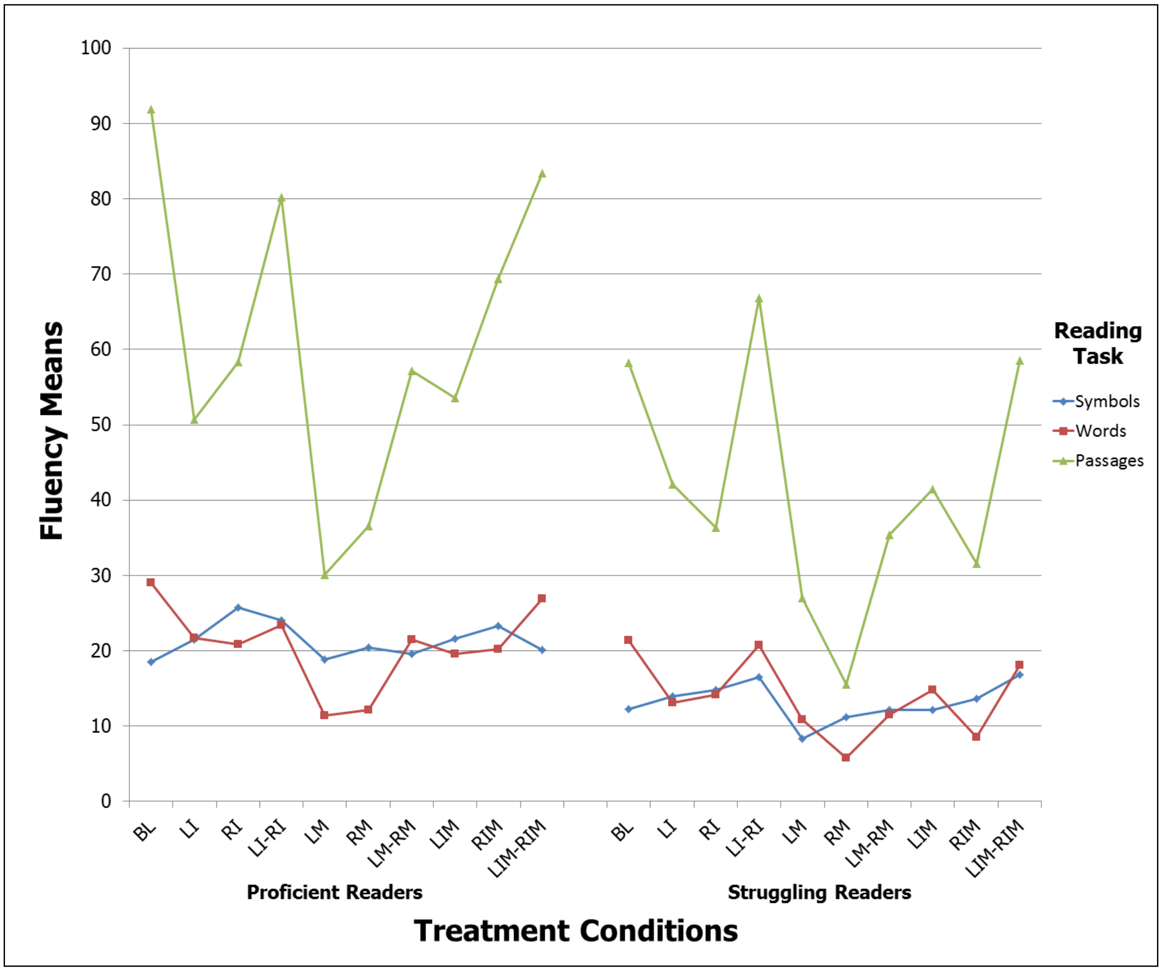



Figure 15

*Mean Fluency Scores for Reading Ability x Conditions and Task*

scores between proficient and struggling readers. This may indicate that proficient readers are better at using context clues than struggling readers and grapple with tasks where these types of clues are absent almost to the same extent as struggling readers. Figure 16 shows that proficient readers were also able to make more self-corrections than struggling readers as indicated by the green portions of each bar. Proficient readers also made more mispronunciations

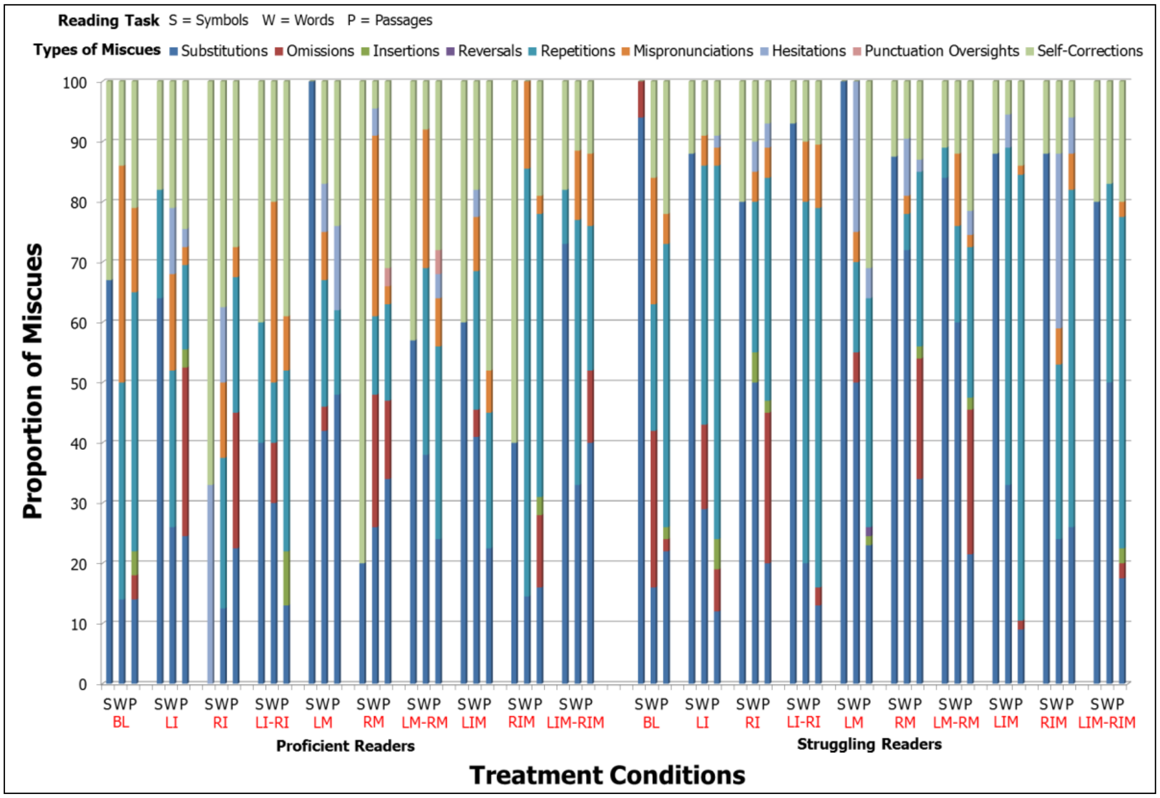



Figure 16

*Types of Miscues for Reading Ability x Conditions and Task*

than struggling readers, especially on the word identification tasks. Once again, this seems to support the importance of context clues for proficient reading.

In addition, statistically significant interactions between reading ability and dominant reading finger were discovered during both symbol ($p < .006$) and passage reading ($p < .011$). The effect size of the interaction during symbol reading was large ($\eta_G^2 = .282$), and it was medium ($\eta_G^2 = .230$) during passage reading. As alluded to earlier in the analysis of fluency based on dominant reading finger, participants whose left index finger was the dominant reading finger attained higher fluency scores than those whose right index finger was the

dominant reading finger. This finding is further explained by the interactions between reading ability and dominant reading finger in which a left-index-finger advantage for proficient readers and a right index finger advantage for struggling readers were revealed for both symbol and passage reading. This contradicted previous research indicating a right-hand advantage for experienced and proficient readers and a left-hand advantage for beginning and struggling readers (Bradshaw, Nettleton, & Spehr, 1982; Fertsch, 1947; Holland & Eatman as cited in Wright, 2004; Millar, 1975, 1984, 1997). Given the fact that tactual perception is just as important to braille reading as visual perception is to print reading, proficient readers may show a left-hand advantage because their tactual perception and/or spatial orientation may be more acute than struggling readers' tactual perception and/or spatial orientation. The fact that proficient readers were able to make more self-corrections on the symbol and reading tasks (tasks that required more acute spatial decoding and tactual perception) supports this assertion. However, more research is needed to determine if this is the case.

It is instinctual to remediate an academic weakness by training the struggling learner to acquire skills and techniques possessed by the master pupil. According to these findings that approach may not be prudent in the case of braille literacy. Given the fact that struggling readers actually performed better with their right index finger than their left index finger, it may not be as simple as retraining them to use their left index finger more. Since most of the

participants in this study were two-handed readers and the one-handed readers were equally divided between the proficient and struggling readers, it is highly unlikely that this particular finding is simply a case of the left index finger being less practiced. Therefore, it leads one to speculate about different tactual and language processing in the brain between these two groups. In order to get a better grasp on this, it may be necessary to conduct research using brain imaging technology.

**Q4: Participant Attributes, Instructional Characteristics, and Fluency**

In spite of sharing the common trait of visual impairment, this group is extremely heterogeneous. Such factors as age when sight was lost, amount of residual vision, and type of eye condition affect the perceptual abilities of students with visual impairments. Like society at large, this sect of the population also comes from a variety of cultural and linguistic backgrounds with an assortment of health issues that have the propensity to affect language and literacy levels. However, braille readers, who happen to have a variety of learning styles, are also educated in a variety of settings using a myriad of individualized teaching approaches that often result in personal modifications of recommended braille mechanics. All of these factors have the potential to impact braille fluency. Most researchers tend to address this heterogeneity by severely restricting sampling criteria. Oftentimes, this type of research produces results that TSVIs do not feel applies to their diverse caseloads. Consequently, this perpetuates a professional culture that tends to be dismissive of the importance

of research. In order to make this constructive replication relevant to the current student population, these potentially confounding variables were incorporated into the research design and specifically measured and analyzed in an attempt to answer the following question:

> Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, literacy modalities, educational setting, or instructional curriculum), participant characteristics (primary language, age vision lost, or presence of additional disabilities), and braille reading fluency?

The more variables included in a study, the larger the sample size needs to be (Gall, Gall, & Borg, 2007; Huck, 2011). Unfortunately, this is problematic in a field that serves students with low-incidence disabilities (Ferrell, 2007; Jackson, 2005; Luckner, 2005). In order to address these implications in this portion of the analysis, the dependent variable was simplified to include only baseline fluencies. Since participants tended to perform well during this condition (except for symbol reading), combined with the fact that they had not received any training in the experimental techniques, this was viewed as the most accurate measuring stick on which to compare the predictor variables.

Numerous participant attributes and instructional qualities were found to have a statistically significant impact on baseline fluency scores during word reading ($p < .001$) and passage reading ($p < .041$). The following predictor variables in order of importance had a large effect on word fluency ($f^2 = 6.94$): presence of additional disabilities, educational placement, primary language, primary literacy modality, and curriculum. Similar to word fluency, all the same

variables, excluding curriculum, had a large effect on passage fluency ($f^2$ = 1.56). However, the order of importance was slightly different and occurred as follows: primary literacy modality, primary language, presence of additional disabilities, and educational placement. The most likely explanation for lack of statistical significance for baseline symbol fluency and these predictor variables is that participants tended to perform poorest on the symbol portion of the baseline assessment because of an order effect and a novelty effect. If the baseline condition were randomly assigned, symbol fluency might have revealed significant results too. However, there is still a chance the aforementioned predictor variables would not have an impact on symbol fluency since it is a rarely used approach to reading braille.

**Presence of additional disabilities.** Of the three participants in this study who had additional disabilities, one was categorized as a proficient reader and the remaining two were classified as struggling readers. The proficient reader had cerebral palsy. One of the struggling readers had a learning disability while the other had a hormone deficiency as the result of septo-optic dysplasia. Even though no other disabilities were listed on the demographics questionnaire, septo-optic dysplasia also includes cognitive impairment and neurological dysfunction (Levack, 1994). Hence, it is highly probable that the struggling reader with septo-optic dysplasia also had an intellectual disability. While it is not surprising that the presence of additional disabilities had a negative impact on braille fluency during word and passage reading, the ability of these particular

students to participate in this study and for one to be a proficient braille reader should serve as an impetus for the provision of formalized braille instruction to students with visual impairments and other disabilities. As a matter of fact, there was one high school participant with a significant cognitive impairment who was able to read braille at a sixth grade level but who had to be excluded because of an inability to maintain the assigned hand and finger combinations.

**Primary language.** Since all the reading materials used in this experiment were written in English, there was an inherent bias in favor of native English speakers. Therefore, it makes sense that a relationship between word and passage fluency and English as the primary language was found. However, it should be noted that one of the second language learners was a proficient reader while the other was a struggling reader. The struggling reader was a recent immigrant who had only started receiving an education in the past three years. Within those three years, she had mastered American English Braille and had gone from being a non-reader to having an instructional reading level three years below grade level. Had the participant been in the United States longer, it is highly likely that this student would have been a proficient reader, which would have changed this particular finding. Thus, generalizations about second language learners should not be made from these results, especially since language proficiency scores were not reported.

**Primary literacy modality.** Motivation is a key ingredient in learning, and thus, it is natural that participants who preferred learning tactually

demonstrated higher word and passage fluency scores than participants who preferred learning auditorally. However, differences in learning modalities could potentially be the result of differences in cerebral processing. Given the fact that there were only two participants in this study who preferred the auditory modality, more research is needed to further explore this relevance of this finding.

**Educational placement.** Due to difficulty obtaining participants in the public schools, this study included only those who had always attended schools for the blind or who had attended a combination of public and residential schools. This study found that participants who had always attended residential schools obtained higher word and passage fluency scores. This could be related to the notion that former public school students come to a school for the blind because of difficulties encountered in their home schools. This finding could also be the tendency for students at schools for the blind to receive direct instruction in braille provided daily by a highly qualified braille teacher during critical emergent literacy stages. More research is needed involving braille readers who have always been in the public schools in order to evaluate and better understand this discovery.

**Curriculum.** An unexpected finding, which only occurred in relation to word fluency, indicated that participants who had received instruction in the general education curriculum as well as a functional academic/life skills curriculum obtained higher fluency scores than those participants who had only

been educated in the general education curriculum. This was particularly surprising, since only 14% (n = 1) of proficient readers had also received instruction in a specialized curriculum as compared to 63% (n = 5) of struggling readers. A plausible explanation for this relates to the fact that struggling readers often receive a great deal of instruction in sight-word and letter recognition techniques (Jackson, 2006). Thus, struggling readers may have been better equipped to decode words without the assistance of context clues than proficient readers.

All in all, this constructive replication provided scientifically-based evidence that confirmed what was believed to be best practice when teaching students with visual impairments how to use their hands and fingers to read braille. These included the use of two hands and two or more fingers. The conditions that consistently produced the lowest fluency scores were the use of either middle finger in isolation. This reinforced the theory that while it is beneficial to use multiple fingers, the index fingers tend to be the primary reading fingers. A summary of the statistically significant findings from this study are listed in Table 27 according to each research question.

While statistically significant results did not occur across all reading tasks, the raw data used as a supplement to this discussion demonstrated similar trends across many of the reading tasks and treatment conditions. These patterns warrant further investigation. Although this study supported what is believed to be best practice, it raised additional questions related to the role that

Table 27

*Statistically Significant Answers to Research Questions*

| | |
|---|---|
| Q1 | Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index + middle) resulted in the greatest degree of fluency? |
| A | Two-handed conditions involving the index fingers or the index and middle fingers resulted in the greatest degree of fluency when reading words in isolation. |
| Q2 | Is there a relationship between handedness and/or dominant reading finger(s) and the hand and finger usage pattern(s) that produced the greatest degree of fluency? |
| A | There was no relationship between handedness and the hand and finger usage pattern(s) that produced the greatest degree of fluency. However, two handed conditions involving the dominant reading finger produced the greatest degree of fluency when announcing the dot configurations of braille symbols and when reading passages. |
| Q3 | Is there a relationship between reading ability and the hand and finger usage pattern(s) that produced the greatest degree of fluency? |
| A | Proficient readers attained higher degrees of fluency on all treatment conditions (i.e., hand and finger usage patterns) than struggling readers when reading passages. Furthermore, a left index finger advantage was found for proficient readers and a right index finger advantage was discovered for struggling readers when reading symbols and passages. |
| Q4 | Is there a relationship between certain characteristics of braille instruction (years spent reading braille, literacy modalities, educational setting, or instructional curriculum), participant characteristics (primary language, age vision lost, or presence of additional disabilities), and braille reading fluency? |
| A | Participants without additional disabilities whose primary language was English, who preferred learning through the tactual modality, and who had always attended a residential school for the blind, attained higher baseline fluency scores during word and passage reading than their counterparts. Additionally, participants who had received instruction in a functional academics/life skills curriculum attained higher word fluency scores than participants educated in only the general education curriculum. |

each index finger plays during reading and how that affects reading proficiency as well as the role that educational placement and specialized curriculums play in facilitating braille fluency.

## Limitations

For the most part, the limitations of this research were the result of having a small sample size, which is a common issue affecting the research base in blindness and visual impairment (Ferrell, 2007). The literature review pinpointed holes in the existing research base on braille mechanics, which this study attempted to address. The first concern involved the predominance of research that relied heavily on correlation and observation. In light of the requirements of NCLB to use best practice supported by scientifically-based evidence, it was important to take this research to the next level by studying braille mechanics using experimental controls. Because this topic had been studied for over a century from a variety of different angles, there were a number of contradictory findings. Hence, it became necessary to expand the scope of the original study conducted by Hermelin and O'Connor (1971a, 1971b) in order to address these discrepancies. This involved increasing the number of experimental conditions to include all reasonable combinations utilizing the index and middle fingers to determine if two handed reading was better or if there was indeed a left hand advantage as postulated by Hermelin and O'Connor. Furthermore, it entailed videotaping hand movements from below a transparent surface in order to ascertain the role that each hand plays during braille reading

since this relates to the specific hemispheric functions of the brain, which is the theory behind the study that inspired this constructive replication. Finally, it was also essential to examine participant demographics given the heterogeneity of this population combined with the variety of educational settings and instructional techniques used to teach braille to students with visual impairments. Hence, a comprehensive experimental design was employed in an attempt to address all of these issues, and thus, care must be exercised when making comparisons to the research of Hermelin and O'Connor.

By including numerous variables in the research design, the ideal would have been to obtain a large sample. However, this was not possible given the limited resources and supports available to the researcher. According to the Federal Quota Census (American Printing House for the Blind, 2010), there were approximately 3,000 braille readers in the United States who qualified to participate in this study. Given the fact that the researcher tried to obtain participants in six different states, the estimated sampling pool was approximately 360 students. Several barriers were encountered while attempting to solicit participants from this pool. Initially, participants reading on grade level were sought, and numerous TSVIs indicated that these students did not exist. After accounting for the belief that half of this population has additional disabilities (Ferrell, 1998), 180 students were available for sampling, but it was difficult to get permission to solicit participants through the public schools without having to also obtain Internal Review Board approval from multiple

school districts. Due to the yearlong focus on preparing for and taking statewide assessments, students tended to be inaccessible during the school year. Furthermore, some TSVIs questioned the idea of basing decisions about braille mechanics on research instead of the student's personal preference or the professional's personal expertise. Finally, the researcher was denied permission to solicit participants and conduct research in conjunction with a national braille competition for the top braille readers. Thus, it became necessary to access students through schools for the blind. Out of the six surrounding states, four residential schools responded to the researcher's inquiry about sending information about the research to families of qualifying students. While attempts were made to include students in short-term placements, this proved too difficult to schedule. Moreover, many of the students who had won a regional braille competition did not return consent forms after multiple solicitation attempts were made. Like previous research, one of this study's major shortcomings is that it included only students attending schools for the blind.

In spite of multiple attempts to obtain a large sample, only 15 students were included in this study. Unfortunately, this resulted in unbalanced groups in relation to the following variables: handedness, dominant reading finger, primary language, and primary literacy modality. Thus, this data set is biased toward right handed, tactual learners with a dominant left-index reading finger who spoke English only and had no additional disabilities. Therefore, care needs to be taken when generalizing the results of this research. However, the researcher

implemented a counter-balanced design to make sure that the order of the treatment conditions was randomized since it was not possible to assign participants to a control group and a treatment group. While this minimizes an order effect, it does not totally eliminate the possibility that the order in which treatment conditions were administered affected fluency scores. All possible precautions were taken to avoid such an effect. Since the baseline condition was originally designed as a comparison to the treatment conditions instead of a treatment condition itself, there is an order effect because this was always the first testing session. Thus, any significant effects for baseline tasks may be due to the fact that participants were freshest at this point of the assessment, which would account for the trend of high scores on word and passage baselines. On the other hand, treatment conditions for which fluency scores were higher than the baseline condition could be the result of test familiarity.

The final limitation of this research involves the inability to determine the reliability and validity of the assessment instruments used in this particular study because of the small sample size. While there is some information about the reliability and validity of the informal reading inventories (IRIs) used to create the testing instruments, reliability and validity are not consistent across the various IRIs that were used to create the reading words and passage portions of the fluency assessments. Furthermore, the original IRIs were not normed on students who were braille readers. In addition, the symbol sections of the fluency assessments were unique, and thus, there was no information about the

reliability and validity of this portion of the assessments. Consequently, the fluency scores obtained from these instruments might not have yielded consistent results and might not have measured that which was intended. As a result, this may be the reason that significant results were not achieved for any given factor on each of the three different reading tasks.

## Implications for Practice and Future Research

Besides empirically confirming that two-handed braille reading techniques including the use of at least the index fingers results in the highest braille reading fluency, the outcomes of this study have important implications for future practice. Unfortunately, the reading rates of participants in this experiment fell below the norm, as passage fluency rates averaged 58.27 CWPM for struggling readers and 91.91 CWPM for proficient readers using their preferred hand and finger usage pattern. The oral-reading rates for this age group typically range from 123-151 words per minute (Hasbrouck & Tindal, 2006). Thus, improving the braille reading rate needs to become a priority of TSVIs, and results from this research provide possible avenues that need to be explored.

Braille instructors should directly teach and continually reinforce the use of two-handed reading techniques instead of allowing students to do whatever is most comfortable. Any athlete can attest to the importance of good form and the persistence that it takes to develop and maintain proper technique. Thus, beginning braille readers are not going to develop good technique without

constant practice and reinforcement. Itinerant teachers who cannot be there to monitor braille mechanics during reading activities need to develop action plans that can be implemented by paraprofessionals, general educators, parents, and the students themselves. TSVIs also need to monitor the technique used by experienced braille readers because technique can deteriorate over time. While IRIs and learning media assessments are a good measure of literacy skills and literacy modalities, a formal assessment needs to be developed to measure the efficacy of the braille mechanics used by the student. Conducting a mini experiment like this one, in which the TSVI plots fluency scores using the current technique and the ideal technique, can help provide students with the motivation to work toward the use of good braille mechanics.

Results revealed a link between braille fluency and the dominant reading finger. In the context of this study, dominant reading constituted the finger(s) that was/were most consistently aligned with the text being read and was/were used most to recheck the braille via scrubbing and retracing. More research is needed to understand the role of the dominant reading finger because all the research on this subject has produced different hypotheses. Furthermore, the premise on which the reading stand used in this study was developed was called into question during data coding. While the reading patch was occasionally evidenced, it seemed to be prevalent on the non-reading fingers. Therefore, there needs to be a systematic way to discern the function that each finger plays so that beginning braille readers, struggling braille readers, and slow braille

readers can train their fingers to work together effectively so as to achieve maximum reading fluency. In order for TSVIs to implement effective instructional and remediation strategies concerning the use of specific fingers, a reliable and valid system for evaluating finger dominance needs to be developed. Perhaps it would be beneficial to conduct mixed-methods research that also incorporates the use of think aloud strategies as a qualitative source of data in order to get direct feedback from braille readers about their finger usage on different tasks. This information could then pave the way for more experimental research pertaining to finger dominance.

Given the left-index finger advantage found for proficient readers and the right-index finger advantage found for struggling readers, more research needs to be done that compares and contrasts the braille reading techniques used by these groups. However, care must be taken not to assume that the same techniques that work for proficient readers will work for struggling readers. In fact, more research is needed pertaining to cerebral processing. Thus, future research may want to investigate the use of brain imaging technology, especially since current cognitive theories have demonstrated that various tasks do not activate just one side of the brain and that different parts of the brain can take on new tasks when the typical brain structure responsible for a given function has sustained damage (Gazzaniga, Ivry, & Mangun, 2008; Hannan, 2006; Sedato et al., 1996; Sedato & Hallet, 1999). This may prove to be particularly beneficial

in addressing the braille literacy needs of learners with significant cognitive impairments.

As part of the attempt to increase braille literacy skills of children and youth with visual impairments, research is needed about the quality and quantity of services provided in relation to braille. Most of the research on this topic has surveyed TSVIs and university faculty about perceived competence in and attitudes toward braille (Amato, 2000, 2002; Wittenstein, 1993, 1994). If it is true that half of the braille readers (which only comprise 10% of the entire population of students with visual impairments) are not proficient readers, and 34% of the entire population of students with visual impairments are non-readers (American Printing House for the Blind, 2010), then the field of blindness and visual impairment does have a literacy crisis on its hands. Since this study revealed that braille readers who had always attended residential schools for the blind had higher fluency rates, research comparing fluency rates across educational settings needs to be conducted, especially since this experiment did not include participants who had always attended public schools. Furthermore, it would be beneficial to compare braille fluency rates, especially in relation to reading miscues based on the curriculum used to teach children who are congenitally blind to read braille.

Like the 100 years of literature on braille mechanics that came before this study, this research has contributed meaningful data in terms of providing scientifically-based evidence for that which is thought to be best practice. This

type of evidence can be useful to researchers developing proposals seeking funding to help address questions raised by this study and others like it. Hopefully, these findings will also give practitioners the support they need to advocate for the services necessary to implement effective instructional practices that will reinforce good braille mechanics.

## Conclusion

Concerned about potential ramifications from the only piece of scientifically-based evidence pertaining to the braille mechanics of congenitally blind students with visual impairments published in the last fifty years, this study sought to constructively replicate the research of Hermelin and O'Connor (1971a, 1971b) to determine if their findings suggesting a speed advantage for the left index finger and an accuracy advantage for the left middle finger had any validity. This study did not produce similar results. Instead, it confirmed the efficacy of two-handed, braille-reading techniques that included the use of the index fingers. In addition, it was discovered that proficient readers performed better in conditions involving the left index finger while struggling readers performed better on conditions involving the right index finger. Finally, this research also demonstrated that the absence of additional disabilities, use of only English, preference for the tactual literacy modality, and having had an educational placement in only a residential school impacted braille fluency, but these findings may have been artifacts of this study's limitations.

As a result of sampling constraints, more research is needed to evaluate the reliability and validity of these findings, especially in terms of educational placement and primary language. Given the fact that there were no participants from the public schools or none who had started out at a school for the blind and transitioned to a public school, limited information is available regarding the efficacy of literacy skills attained at schools for the blind. Furthermore, it is not appropriate to draw conclusions about the impact of a second language on braille literacy since there were only two English language learners in this study. Additional research needs to account for varying levels of language proficiency—both spoken and written—as well as consideration of factors that have impacted the quality of these students' education.

Reading in and of itself is a complex process. Thus, the task of determining best practice for such a heterogeneous group of braille users can be daunting, especially when faced with limited resources. Nonetheless, braille literacy is a topic worthy of rigorous research because of its link to quality of life. Until braille readers have attained literacy levels commensurate with their peers, professionals must use research to inform practice and to improve outcomes.

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# APPENDIX A

## Internal Review Board Application and Approvals

University of Northern Colorado
INSTITUTIONAL REVIEW BOARD
Expedited Review 2010

**A. Purpose**

In spite of the lack of research supporting best practices, professionals in the field of blindness and visual impairment have promoted specific strategies for teaching braille. The recommended technique for reading braille involves using all fingers of both hands, except the thumbs, with emphasis on the index and middle fingers to lightly and smoothly scan halfway across a line of braille. At the midpoint, the left hand drops down to the next line of text while the right hand finishes the current line. After the current line of text is read, the left hand begins reading the next line while the right hand drops down diagonally to where the left hand is currently reading (Castellano & Kosman, 1997; Caton, Pester, & Goldblatt, 1979; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). However, just because this technique is supported by the experts and has been used over an extended period of time, it does not necessarily make it the most effective or efficient way of reading braille.

In fact, there is little research to adequately support this braille reading strategy as best practice. Furthermore, a small number of empirical studies have indicated that braille users read faster with their left hand and their index finger, which contradicts the current practice of reading more with the right hand than the left and using both the index and middle fingers (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982; Wilkinson & Carr, 1987). Although there are only these few articles contradicting the current hand and finger usage practices of braille readers, these are the only empirical studies examining such braille mechanics in recent times.

A plausible explanation for these findings relates to the hemisphere specific functions of the human brain. Typically, language and reading processes occur in the left hemisphere while visual-spatial or tactual-spatial tasks occur in the right hemisphere (Gazzaniga, Ivry, & Mangun, 2008). Given the fact that

each hemisphere of the brain controls the opposite side of the body, those braille readers predominantly engaging in phonological processes would read better with the right hand while those braille readers engaging in tactual-spatial processes would read better with the left hand (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982). Because braille is a tactual code comprised of various spatial configurations of one to six dots within a braille cell, this explanation for faster left-handed reading warrants further investigation.

Hence, the purpose of this study is to conduct a pseudo replication of Hermelin and O'Connor's (1971a, 1971b) research on hand and finger usage of braille readers in order to add to the scientifically-based research regarding braille mechanics. Specifically, hand and finger usage will be analyzed in terms of their effect on the following fluency indicators: oral reading speed and oral reading accuracy. Given the role of the brain in learning, it will also be important to analyze dominant hand preference as well as the age at which contracted braille is introduced, since there is often an indirect correspondence between letter-sound relationships (phonics) in contracted braille. Before making any monumental judgments regarding the efficacy of certain techniques, there needs to be multiple valid and reliable research studies in order to generalize the findings. This study is an attempt to get one step closer to establishing best practice in the area of increasing fluency through braille mechanics.

### *Research Questions*

The questions to be addressed in this study are as follows:

Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index-middle) results in the greatest degree of fluency?

Q2 Is there a relationship between handedness and hand usage patterns (left, right, or both) as indicated by the greatest degree of fluency?

Q3 Is there a relationship between reading level and the hand-usage pattern (left, right, or both) that produces the greatest degree of fluency?

Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, age at which braille was introduced, grade when contracted braille was introduced, literacy modalities, or educational setting) and braille reading fluency?

## B. METHOD

### *Participants*

Voluntary participants will be solicited by sending a written description of the study and participant requirements to the Superintendent of the Indiana School for the Blind and Visually Impaired, and he will be asked to send informational flyers to the families of all contracted braille users reading between grades four through nine who are congenitally blind or visually impaired (vision lost before the age of three) and are fluent English speakers. In order to entice volunteers, participants will be offered 25 dollars for completing the testing session. Interested students will be asked to have their parent directly contact the researcher by telephone or e-mail. These potential participants will then be sent the consent (parent permission) form in the mail with a self-addressed, stamped, return envelope. A demographic questionnaire will then be mailed to the faculty member at the Indiana School for the Blind who have access to the requested information. Upon receipt of the signed consent forms and completed demographic questionnaires, individual testing sessions will be arranged.

The desired sample size is a minimum of 15 participants (Cohen, 1988; Taylor, Katomeri, & Ussher, 2005). Ideally, these participants will be evenly distributed across reading levels so that there are five braille users reading between fourth and fifth grade, five braille users reading between sixth and seventh grade, and another five braille users reading between the eighth and

ninth grades. At a minimum, two participants are needed for each of these levels.

*Procedures*

Each participant will undergo two testing sessions, which are estimated to take 45 to 60 minutes each. Prior to testing, the student will be read the assent (student permission) form and will verbally indicate whether they wish to participate or not. Each verbal assent will be recorded on a tabletop digital recorder. Participants will then be asked to practice reading some preliminary words (a pre-assessment of graded-word lists). After the highest, instructional reading-level has been attained, the experimental treatment conditions will begin using randomly selected assessments from the appropriate grade level. The first condition involves having the student read 63 braille symbols, a grade-level list of 10 words, and a grade-level passage using their typical hand and finger patterns in order to establish a baseline.

Between each of the remaining testing conditions, participants will complete a series of simple, daily activities (such as, rolling a ball, opening a door, and grabbing an item) to determine hand-dominance. This should help break up the monotony of the testing sessions.

The remaining order of the nine treatment conditions will be implemented in a pre-determined random order. The treatment conditions are as follows: A) left index finger, B) right index finger, C) left index finger and right index finger, D) left middle finger, E) right middle finger, F) left middle finger and right middle finger, G) left index finger and left middle finger, H) right index finger and right middle finger, I) left index and middle fingers and right middle and index fingers. For each condition, participants will be asked to read seven randomly selected braille symbols, a grade-level list of 10 words, and a grade-level passage. In another attempt to minimize reading fatigue, participants will only have one minute to read the braille symbols, one minute to read the word lists, and two minutes to read the reading passages contained on each test (Mommers, 1980). Participants will be provided with both a verbal description of the hand and finger

technique to be used as well as a hand-under-hand demonstration. Each testing session will be videotaped so that data on braille reading fluency and hand dominance can be coded later.

All reading tasks will be done on a specially designed reading table designed to record hand and finger movements (see picture on the following page). The table has been constructed in a manner that allows only the participants' hands and voice to be recorded, thereby eliminating the possibility that participants can be identified visually. A digital table-top recorder will also be utilized to record the verbal assent to participate and the oral reading of the baseline and treatment conditions because the videotape does not always pick-up the reader's voice clearly.

*Inter-Observer Agreement*

Using the data from the pilot study, the lead researcher will train the assistant researcher by jointly coding the videotape data on the first participant. The researchers will then independently code the remaining data, and the coding will be reviewed to ensure that there is at least 80% inter-observer agreement. When there is more disagreement than this, the researchers will jointly review the tape and discuss the ratings until the acceptable level of agreement has been reached. In cases where at least 80% agreement, but not 100% agreement, has been attained, the scores of the two researchers will be averaged.

After this initial training session, the lead researcher will code all participant data while the assistant researcher will code one testing protocol for every participant. When agreement falls below 80%, the same procedures as

before will be implemented. If necessary, retraining on the pilot data will reoccur until satisfactory inter-observer reliability is regained.

*Data Analysis*

Each videotape will be analyzed independently by the researcher, and CWPM will be coded on individual score sheets. The assistant researcher will also independently code select video footage. Data will then be entered into a spreadsheet where preliminary analyses will be conducted. The following will be included in the initial analysis: descriptive statistics (mean, medium, mode, and standard deviation) to determine the distribution of scores and factor analysis to assess the reliability and validity of the assessment protocol.

The statistical analysis used to answer the first research question will be a one way, repeated measures, Analysis of Covariance (ANCOVA). This procedure discerns differences between one or more independent variables, a dependent variable, and one or more covariates (a measure that may differ between groups before the treatment) (Huck, 2004; Mertens & McLaughlin, 2004). The baseline measure serves as a covariate in this study. Basically, ANCOVA decrease error variance that may occur between the covariate and the dependent variable (Cone & Foster, 1993). In order to run an ANCOVA, a sample size of 10 to 20 participants is adequate since each subject undergoes each treatment (Cohen, 1988; Taylor, Katomeri, & Ussher, 2005).

A profile analysis will also be completed. This is a process in which individual scores are converted to standardized z scores. This allows for comparison among different participants on the dependent measure. At least two braille readers from each grade level are needed in order to compute a standardized score (Tabachnick, 2006).

The final research questions will be answered by computing descriptive statistics as well as conducting any possible t-tests. This statistic is typically used to assess differences in means between two groups (Huck, 2004). If the results of the ANCOVA are statistically significant, effect sizes will also be calculated in

order to determine the magnitude of the relationship between the variables (Gall, Gall, & Borg, 2003).

## C. RISKS, DISCOMFORTS, AND BENEFITS

I do not foresee any unusual risks involved in participating in this study beyond those typically associated with oral braille reading. The only reason that participants are being paid $25 is to entice voluntary participation. Since participants are informed ahead of time about the oral reading requirement, shy readers can decline to participate. Furthermore, the researcher will not make any corrections during the reading session.

### *Disposition of Data*

Confidentiality will be protected to the greatest extent possible by taking the following precautions: First, participants in this study will only be asked to provide their first name on the student demographic questionnaire. Participants will then be assigned a participant number, and this number will be used on the testing protocols and during data entry into SPSS. During videotaping, only the participants' hands will be recorded. After data analysis is complete, copies of the student questionnaire, testing protocols and videotapes will be stored in a locked file cabinet in the lead researcher's office. Electronic data will be stored on a password protected computer at the researcher's office. Data will be maintained for a period of five years, and then all physical and electronic copies of the data will be destroyed.

If participants and their parents agree, the lead researcher will keep a copy of the videotape for use in her university classes. This footage can be a valuable tool for prospective teachers of students with visual impairments because it demonstrates assessment processes they will need to utilize in order to assess literacy modalities and braille fluency. Essentially, this footage would only be utilized in braille and assessment courses.

## D. COSTS AND COMPENSATIONS

The researcher is offering to pay participants $25 as an incentive to volunteer to be part of this study. Given the fact that testing will not occur during the educational day, students will not miss any instructional time. In addition, participants do not incur any transportation costs since the researcher is coming to their school.

## E. GRANT INFORMATION

The researcher received a federally funded traineeship from the National Center on Low Incidence Disabilities, which included $1000 of dissertation support. This money is being utilized to pay participants, to build the reading stand, to buy videotapes and digital memory cards (for the digital tabletop recorder), and special paper on which to print the final copies of the dissertation.

## F. DOCUMENTATION

Please refer to the attached pages for consent forms, the student demographic questionnaire, hand dominance assessment, sample preliminary assessment, sample baseline protocol, and sample treatment protocols.

UNIVERSITY of
NORTHERN COLORADO

Informed Consent to Participate in Research
University of Northern Colorado
Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading

I am a doctoral candidate at the University of Northern Colorado and a Braille Literacy Project Leader at the American Printing House for the Blind. For my dissertation, I am researching braille reading fluency (speed and accuracy) in relation to braille reading mechanics (hand and finger usage). Interested participants should be children who have been blind since before the age of three and who are reading 4th through 9th grade-level, instructional materials in contracted braille. While reading 10 short lists and passages, the hand movements and oral recitation of the reading material will be recorded on video. Participants will also engage in a series of simple physical motions to determine hand-dominance (such as shaking hands).

Each testing session should take approximately 60 minutes, and there will be two testing sessions. In order to maximize confidentiality, you will only be asked to provide your child's first name to the researcher, and your child's face will not be recorded at any time. Furthermore, research data will be stored in a secure location that can only be accessed by the lead researcher. Data will be maintained for a period not exceeding five years, and then it will be destroyed. However, if you would like to give me permission to use the videotape in university courses for prospective teachers of students with visual impairments I teach, please initial the last page. I do not foresee any unusual risks to participants beyond those typically associated with oral braille reading.

CONTINUED ON BACK SIDE ☞

UNIVERSITY OF NORTHERN COLORADO
MCKEE HALL, CAMPUS BOX 141, GREELEY, CO 80630 • Office 970-351-2691 Fax 970-351-1061 www.edtech.unco.edu/coe/sped/sped.html

Please feel free to contact me via phone or e-mail if you have any questions or concerns about this research. If your child is interested in participating, and you would like for your child to participate in this research, read the passage below and sign this form. Finally, complete the *Student Information Questionnaire*. Please consult your child's teacher of students with visual impairments to obtain any necessary information. Return the completed consent form and questionnaire to me (the lead researcher) in the self-addressed, stamped envelope that has been provided. Upon receipt of these materials, I will contact your child to arrange for an individual testing session. Thank you for assisting me with my dissertation research.

Sincerely,

Lead Researcher
Loana Mason, M.A., COMS
Braille Literacy Project Leader
American Printing House for the Blind
1839 Frankfort Avenue
Louisville, KY 40206
502-899-2325 (work)
502-523-5907 (cell)
lmason@aph.org

Research Advisor
Kay Ferrell, Ph.D.
Professor
School of Special Education
Campus Box 141
University of Northern Colorado
Greeley, CO 80639
970-351-1653
kay.ferrell@unco.edu

Participation is voluntary, and you may decide to withdraw at any time. Your decision will be respected and will not interfere with any benefits you may be entitled to. If you would like to participate in this research, please complete the forms included in this mailing and return them to me at the address above. Be sure to provide a phone number so that your child may be contacted to set up a testing session. Please retain a copy of this form for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the IRB Chairperson of the Office of Sponsored Programs, Kepner Hall, Suite #25, University of Northern Colorado, Greeley, CO 80630; 970-351-2161.

CONTINUED ON NEXT PAGE ☞

______ Initial — Yes, I give Loana Mason permission to use the video from this testing session in her university classes for prospective teachers of students with visual impairments.

_________________________________ _________________________

Parent/Guardian Signature — Date

Contact Phone Number: ________________ Best Time to Call: _______________

Assent to Participate in Research

University of Northern Colorado

Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading

Dear Braille Reader,

My name is Loana Mason, and I create braille materials for the American Printing House for the Blind. I am doing research on braille reading, and I would like to videotape the hand movements of contracted braille users reading aloud a number of different braille words and stories. If you would like, you can earn $25 for reading braille to me for about two hours.

If you want to help me, I will ask you to read 10 different sets of braille symbols, words, and stories. You will be asked to read as fast and as correctly as possible using different hand and finger combinations. While you are reading aloud, I will videotape your hand movements and record your voice. I will also ask you to do a series of physical tasks. This is not a test, and you will not be graded on your performance. While I will calculate how many words per minute you are able to read correctly, nobody but me and my assistants will know what your score is. We will do this reading outside of school so that you do not have to miss any classes.

I will also ask your parents and teacher of students with visual impairments to fill out a questionnaire. Basically, the questions I ask describe you, your visual impairment, and your literacy skills. If you would like to see the questionnaire, please let me know and I can send you a braille copy.

Reading braille to me will probably not help or hurt you. Your parents have said that it

is okay for you to read for me, but you do not have to. If you say "yes" and then change your mind, you can stop at anytime. Please let me know if you have any questions. When asked if you would like to help me with my research on braille reading, say "yes," or "no." If you have any concerns about your selection or treatment as a research participant, please contact the IRB Chairperson of the Office of Sponsored Programs, Kepner Hall, Suite #25, University of Northern Colorado, Greeley, CO 80630; 970-351-2161.

If you agree, I would also like to use the videotape of your hands during braille reading to teach future teachers of students with visual impairments. They will not be able to see your face and will only know your first name. You can still read for my research project and not allow me to use this videotape in college classes I teach. If it is okay for me to use the videotape please say "yes" when asked.

Do you want to be part of this study?
Can I use the videotape of your hand movements in college classes I teach?

**ATTENTION**
**PARTICIPANTS NEEDED**
**for a Braille Study**

Do you know which hand
is the best hand for reading braille?

Do you know which finger
is the best finger for reading braille?

This research is seeking to explore the hand and finger combination that results in the fastest and most accurate reading of braille. If you would like to know the answer to these questions, please participate in this research. All participants will be paid $25 to read braille for an hour at a time during two different testing sessions.

You would be a great participant if you…

- Read contracted braille
- Lost your vision before the age of 3
- Read books written for 4th graders or above
- Are in grades kindergarten through 12

If you are interested, please have your parents contact

Loana Mason
Braille Literacy Project Leader
American Printing House for the Blind
502-899-2325
lmason@aph.org

IRB Changes in Protocol 2010

Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading

Lead Investigator: Loana Mason, Doctoral Candidate

Proposed changes are due to difficulty obtaining the minimum number of participants required for my research. Thus, I need to broaden the number of schools for the blind from whom I solicit participants and on whose campuses I conduct the study. I am talking with schools near me and so far have obtained written permission to conduct my research at the Kentucky School for the Blind and the Tennessee School for the Blind. I am attaching these letters for your review. I am in the process of trying to obtain formal permission from the Missouri School for the Blind and the Ohio School for the Blind and will provide supporting documentation upon receipt.

**Indiana School for the Blind and Visually Impaired**
**7725 North College Avenue**
**Indianapolis, Indiana 46240-2504**

***Superintendent's Office***
***James R. Durst***
jdurst@isbvik12.org

*(317) 253-1481*
*(317) 251-6511 Fax*

May 6, 2010

To Whom It May Concern:

As the superintendent of the Indiana School for the Blind and Visually Impaired, I am pleased to have the opportunity for our school to work with Loana Mason in the collection of data for her dissertation. I grant Loana permission to test congenitally blind, contracted braille users reading text between the 4th and 9th grade levels attending ISBVI who wish to participate in the following study: An Experimental Replication of Hand and Finger Usage in Braille Reading.

In order to not have a negative impact on the school schedule or student outcomes, it will be necessary for Loana to complete testing outside of the school day. It will also be necessary for her to provide a cover letter and a permission form that can be sent to parents of students desiring to participate in the study.

Based on the fact that the end of the current school year is drawing to a close, it would be ideal for the data collection to take place at the start of the 2010-2011 school year.

Again, we look forward to working with Loana and trust the information she collects will have a positive impact on students who are blind or have low vision.

Sincerely,

James R. Durst
Superintendent

JRD:klk

KENTUCKY SCHOOL for the BLIND
1867 Frankfort Avenue, Louisville, KY 40206-3153
502-897-1583, Business Fax: 502-897-2994
Classroom Fax: 502-897-2850
Health Center Fax: 502-897-1282
www.ksb.k12.ky.us
Serving Students Since 1842

Loana Mason
Braille Literacy Project Leader
American Printing House for the Blind
1839 Frankfort Avenue
Louisville, KY 40206

February 8, 2011

Dear Ms. Mason,

In our email correspondences, you have indicated that you are interested in testing congenitally blind, contracted Braille users between the grades of Kindergarten through 12th grade who read text written at a 4th through 9th grade level, and who have functional use of both hands and the ability to ready orally. This is a letter confirming that you have permission to utilize students attending the Kentucky School for the Blind who meet these criteria, provided that the appropriate consent from each of the parents is given. Since we are unable to give you the names and addresses of these students, you will need to supply KSB with any consent forms and we will send them home for parent consent.

Sincerely,

John Roberts
Director of Instruction
Kentucky School for the Blind

**Patricia L Yocum**
Superintendent

Established 1851
NCA Accredited

# Missouri School for the Blind

February 22, 2011

To Whom It May Concern:

This letter is to verify that Loana Mason had permission to test contracted braille users reading between 4th and 9th grade levels at the Missouri School for the Blind during the Spring 2011 semester. She provided our braille instructor, Mrs. Patti Schonlau, with consent forms that were signed by the parents or guardians of students wishing to volunteer for her study, *An Experimental Replication of Hand and Finger Usage Patterns in Braille Reading*. Before testing each student who returned a signed consent form, Loana secured the verbal assent of each student, and she paid each student $25 for voluntarily participating in her research.

Sincerely,

Joyce Waddell

Joyce Waddell
Assistant Superintendent
Missouri School for the Blind

02/17/2011 11:07 615-231-7329 TN SCHOOL FOR BLIND PAGE 02/02

STATE OF TENNESSEE
**Tennessee School for the Blind**
And
**Educational Resource Center for the Visually Impaired**
115 Stewarts Ferry Pike – Nashville, Tennessee 37214
Phones: 615-231-7323 – Fax: 615-871-9312

To:
University of Northern Colorado's Institutional Review Board
Jim A. Oldham, Superintendent for the Tennessee School for the Blind

I herby grant Loana Mason permission to conduct her research study with students attending the Tennessee School for the Blind (TSB). I am aware that she will be using human participants, i.e. TSB students, in her braille study. I am aware that she may need data from student records to complete this research.

I trust that the results of this research study will be a valuable contribution to TSB, and to the field of education for students who are blind or visually impaired. I am in support of her efforts and can be called upon to provide any assistance.

Best of luck with your research efforts.

Sincerely,

Jim A. Oldham
Superintendent for the Tennessee School for the Blind

STUDENT'S COPY

UNIVERSITY of NORTHERN COLORADO
Institutional Review Board (IRB)

March 25, 2010

TO: Carol Roehrs
School of Nursing

FROM: Gary Heise, Co-Chair GDH
UNC Institutional Review Board

RE: Expedited Review of Proposal, *An Experimental Replication of Hand and Finger Usage in Braille Reading,* submitted by Loana Mason (Research Advisor: Kay Ferrell)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Gary Heise, School of Sport and Exercise Science, Campus Box 39, (x1738). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as is. Carol Roehrs 3-31-10
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: 4-23-2010 to 4-23-2011.

Gary D. Heise 23 Apr 2010
Gary Heise, Co-Chair Date

Comments: permission letter/email to IRB (me)

University of Northern Colorado
INSTITUTIONAL REVIEW BOARD
Expedited Review 2007

**STATEMENT OF PROBLEM/RESEARCH QUESTION**

In spite of the lack of research supporting best practices, professionals in the field of blindness and visual impairment have promoted specific strategies for teaching braille. The recommended technique for reading braille involves using all fingers of both hands, except the thumbs, with emphasis on the index and middle fingers to lightly and smoothly scan halfway across a line of braille. At the midpoint, the left hand drops down to the next line of text while the right hand finishes the current line. After the current line of text is read, the left hand begins reading the next line while the right hand drops down diagonally to where the left hand is currently reading (Castellano & Kosman, 1997; Caton, Pester, & Goldblatt, 1979; Koenig & Holbrook, 2000; Mangold, 1994; Swenson, 1999; Wormsley & D'Andrea, 1997). However, just because this technique is supported by the experts and has been used over an extended period of time, it does not necessarily make it the most effective or efficient way of reading braille.

In fact, there is little research to adequately support this braille reading strategy as best practice. Furthermore, a small number of empirical studies have indicated that braille users read faster with their left hand and their index finger, which contradicts the current practice of reading more with the right hand than the left and using both the index and middle fingers (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982; Wilkinson & Carr, 1987). Although there are only these few articles contradicting the current hand and finger usage practices of braille readers, these are the only empirical studies examining such braille mechanics in recent times.

A plausible explanation for these findings relates to the hemisphere specific functions of the human brain. Typically, language and reading processes occur in the left hemisphere while visual-spatial or tactual-spatial tasks occur in the right hemisphere (Gazzaniga, Ivry, & Mangun, 2008). Given the fact that

each hemisphere of the brain controls the opposite side of the body, those braille readers predominantly engaging in phonological processes would read better with the right hand while those braille readers engaging in tactual-spatial processes would read better with the left hand (Hermelin & O'Connor, 1971a, 1971b; Wilkinson, 1979, 1982). Because braille is a tactual code comprised of various spatial configurations of one to six dots within a braille cell, this explanation for faster left-handed reading warrants further investigation.

Hence, the purpose of this study is to conduct a pseudo replication of Hermelin and O'Connor's (1971a, 1971b) research on hand and finger usage of braille readers in order to add to the scientifically-based research regarding braille mechanics. Specifically, hand and finger usage will be analyzed in terms of their affect on the following fluency indicators: oral reading speed and oral reading accuracy. Given the role of the brain in learning, it will also be important to analyze dominant hand preference as well as the age at which contracted braille is introduced, since there is often an indirect correspondence between letter-sound relationships (phonics) in contracted braille. Before making any monumental judgments regarding the efficacy of certain techniques, there needs to be multiple valid and reliable research studies in order to generalize the findings. This study is an attempt to get one step closer to establishing best practice in the area of increasing fluency through braille mechanics.

### *Research Questions*

The questions to be addressed in this study are as follows:

Q1 Which pattern of hand usage (left, right, or both) and finger usage (index, middle, or index-middle) results in the greatest degree of fluency?

Q2 Is there a relationship between handedness and hand usage patterns (left, right, or both) as indicated by the greatest degree of fluency?

Q3 Is there a relationship between reading level and the hand-usage pattern (left, right, or both) that produces the greatest degree of fluency?

Q4 Is there a relationship between certain characteristics of braille instruction (years spent reading braille, age at which braille was introduced, grade when contracted braille was introduced, literacy modalities, or educational setting) and braille reading fluency?

**METHOD**

*Participants*

Voluntary participants will be solicited by sending a written description of the study and participant requirements to the regional consultants on visual impairment and the principal of the Illinois School for the Visually Impaired (ISVI). The ISVI principal and vision consultants will be asked to distribute the information on this study to the TvIs. All TVIs will be asked to send a copy of the flyer home to the families of all contracted braille readers on their respective caseloads reading between grades four through nine who are congenitally blind or visually impaired (vision lost before the age of three) and are fluent English speakers. In order to entice volunteers, participants will be offered 25 dollars for completing the testing session. Interested students will be asked to have their parent directly contact the researcher by telephone or e-mail. These potential participants will then be sent consent (parent permission) and assent (student permission) forms in the mail with a self-addressed, stamped, return envelope. A demographic questionnaire to be completed by the student's TVI will also be included in this mailing. A copy of the student questionnaire is included in this application. Upon receipt of the signed consent/assent forms and completed demographic questionnaires, individual testing sessions will be arranged.

The desired sample size is a minimum of 15 participants (Cohen, 1988; Taylor, Katomeri, & Ussher, 2005). Ideally, these participants will be evenly distributed across reading levels so that there are five braille users reading

between fourth and fifth grade, five braille users reading between sixth and seventh grade, and another five braille users reading between the eighth and ninth grades. At a minimum, two participants are needed for each of these levels.

*Procedures*

During the individual testing sessions, which are estimated to take 60 to 90 minutes, participants will first be asked to complete a baseline assessment consisting of activities to determine hand dominance, all 63 braille symbols, a grade-level list of words, and a grade-level passage using their typical hand and finger patterns. This portion of the baseline assessment will actually be conducted during a scheduled break halfway throughout the experiment in order to prevent reading fatigue. Thus, the break will occur after the completion of the baseline condition and the first four treatment conditions.

The remaining order of the nine treatment conditions will be implemented in a pre-determined random order. The treatment conditions are as follows: A) left index finger, B) right index finger, C) left index finger and right index finger, D) left middle finger, E) right middle finger, F) left middle finger and right middle finger, G) left index finger and left middle finger, H) right index finger and right middle finger, I) left index and middle fingers and right middle and index fingers. For each condition, participants will be asked to read seven randomly selected braille symbols, a grade-level list of 10 words, and a grade-level passage. In another attempt to minimize reading fatigue, participants will only have one minute to read the braille symbols, one minute to read the word lists, and two minutes to read the reading passages contained on each test (Mommers, 1980). Participants will be provided with both a verbal description of the hand and finger technique to be used as well as a hand-under-hand demonstration. Each testing session will be videotaped so that data on braille reading fluency and hand dominance can be coded later.

### *Pilot Study*

In order to refine the procedures to be used in this experiment, a pilot study will be conducted. Given the small number of braille users reading between the first and ninth grades, it is not advisable to tap into the limited sample pool that exists. Thus, adults with visual impairments who read contracted braille will be used to pilot the procedures to be followed in the data collection process. Since the intent is merely to refine the testing protocol, the desired sample size is between three to five participants. Unfortunately, it is not feasible to gain enough participants in the pilot study to conduct reliability and validity on the testing instrument because it is recommended that there be three to six times as many participants as there are variables (Cattell, 1978). Using this formula, a minimum of nine to 18 participants would be needed in order to assess the reliability and validity of the testing instrument. Given the low-incidence nature of congenital blindness, it will be too difficult to obtain nine to 18 participants for a pilot study and another 10 to 20 participants for the actual experiment. Thus, validity and reliability will be analyzed on the experimental data, and if necessary, will be discussed as a limitation of the study.

Voluntary participants will be solicited through disability support services at Illinois State University and Illinois Wesleyan University. If necessary, acquaintances of the researcher will also be asked to partake in the pilot study. Participants will be paid 25 dollars once the testing has been completed. After conducting the pilot, procedures will be modified as necessary.

### *Inter-Observer Agreement*

Using the data from the pilot study, the lead researcher will train the assistant researcher by jointly coding the videotape data on the first participant. The researchers will then independently code the remaining data, and the coding will be reviewed to ensure that there is at least 80% inter-observer agreement. When there is more disagreement than this, the researchers will jointly review the tape and discuss the ratings until the acceptable level of agreement has been

reached. In cases where at least 80% agreement, but not 100% agreement, has been attained, the scores of the two researchers will be averaged.

After this initial training session, the lead researcher will code all participant data while the assistant researcher will code one testing protocol for every participant. When agreement falls below 80%, the same procedures as before will be implemented. If necessary, retraining on the pilot data will reoccur until satisfactory inter-observer reliability is regained.

*Data Analysis*

Each videotape will be analyzed independently by the researcher, and CWPM will be coded on individual score sheets. The assistant researcher will also independently code select video footage. Data will then be entered into a spreadsheet where preliminary analyses will be conducted. The following will be included in the initial analysis: descriptive statistics (mean, medium, mode, and standard deviation) to determine the distribution of scores and factor analysis to assess the reliability and validity of the assessment protocol.

The statistical analysis used to answer the first research question will be a one way, repeated measures, Analysis of Covariance (ANCOVA). This procedure discerns differences between one or more independent variables, a dependent variable, and one or more covariates (a measure that may differ between groups before the treatment) (Huck, 2004; Mertens & McLaughlin, 2004). The baseline measure serves as a covariate in this study. Basically, ANCOVA decrease error variance that may occur between the covariate and the dependent variable (Cone & Foster, 1993). In order to run an ANCOVA, a sample size of 10 to 20 participants is adequate since each subject undergoes each treatment (Cohen, 1988; Taylor, Katomeri, & Ussher, 2005).

A profile analysis will also be completed. This is a process in which individual scores are converted to standardized z scores. This allows for comparison among different participants on the dependent measure. At least two braille readers from each grade level are needed in order to compute a standardized score (Tabachnick, 2006).

The final research questions will be answered by computing descriptive statistics as well as conducting any possible t-tests. This statistic is typically used to assess differences in means between two groups (Huck, 2004). If the results of the ANCOVA are statistically significant, effect sizes will also be calculated in order to determine the magnitude of the relationship between the variables (Gall, Gall, & Borg, 2003).

## RISKS/BENEFITS AND COST/COMPENSATION TO PARTICIPANTS

I do not foresee any unusual risks involved in participating in this study beyond those typically associated with oral braille reading. The only reason that participants are being paid $25 is to entice voluntary participation. Since participants are informed ahead of time about the oral reading requirement, shy readers can decline to participate. Furthermore, the researcher will not make any corrections during the reading session.

### *Disposition of Data*

Confidentiality will be protected to the greatest extent possible by taking the following precautions: First, participants in this study will only be asked to provide their first name on the student demographic questionnaire. Participants will then be assigned a participant number, and this number will be used on the testing protocols and during data entry into SPSS. During videotaping, only the participants' hands will be recorded. After data analysis is complete, copies of the student questionnaire, testing protocols and videotapes will be stored in a locked file cabinet in the lead researcher's home. Electronic data will be stored on a password protected computer. Data will be maintained for a period of five years, and then all physical and electronic copies of the data will be destroyed.

If participants and their parents agree, the lead researcher will keep a copy of the videotape for use in her university classes. This footage can be a valuable tool for prospective teachers of students with visual impairments because it demonstrates assessment processes they will need to utilize in order

to assess literacy modalities and braille fluency. Essentially, this footage would only be utilized in the braille course and the assessment course.

**DOCUMENTATION**

Please refer to the attached pages for consent forms, the student demographic questionnaire, hand dominance assessments, and sample miscue analysis testing protocols.

## RESPONSE TO 2ND REVIEWER

1. Your consent form refers to access to the data by "assistant researchers," whereas your assent form refers to a single "research assistant." Shouldn't your assent form also refer to your research assistants (in the plural)? Could you please correct this in final copy? I have corrected this in the consent/assent forms and have re-submitted them for your review.

2. This is not an IRB question, but I wondered whether all teachers would understand the terms you use for students' academic programs (see the Student Information Questionnaire). And is this list mutually exclusive, or might teachers choose more than one? Teachers of the visually impaired (TVI) should be familiar with all of the terminology contained in the *Student Questionnaire*. I have added my contact information on this form, in case the TVI has any questions. Where there could be multiple answers, I requested that each applicable option be checked and the dominant option also be asterisked.

3. Per UNC IRB procedures, researchers are to submit letters (or emails) of permission from institutions that are sites of data collection ("Present information regarding permission from site of data collection, if external to UNC. This must include letters of permission signed by appropriate officials of cooperating institutions such as daycare centers, schools, hospitals, clinics and other universities."). Please obtain an email confirmation from an appropriate official at each of the institutions from which you are recruiting participants and forward the emails to me (these seem to include the Illinois School for the Visually Impaired, Illinois State Univ., and Wesleyan Univ.). I will print them out then and append them to your UNC IRB application. As indicated by Dr. Ferrell's response, this poses an undue hardship since I my participant pool includes all students with visual impairments reading contracted braille on grade level who are in grades 4-9. Once I have my list of participants, I will arrange testing sites based on geographic proximity. Before conducting any testing, I will have to secure permission, but it does not make sense to pre-arrange these sites since I may not have any participants in that area. However, I can submit these e-mails once I have determined the testing sites after my participants have volunteered.

4. Please provide the specific secure location where consent forms will be stored. Usually this is the research advisor's UNC office (since consent forms are federally audited documents that need to remain accessible to the UNC IRB). However, if you would like to store these consent forms in your office at Illinois State University, please confirm that the consent forms will be available to UNC IRB if needed (and I will then verify with Dr. Lahman that this arrangement would be acceptable when she returns from her conference—if I hear otherwise from Dr. Lahman, I will let you know.). Your own ISU IRB may require you to maintain the consent forms on your campus, and we at UNC IRB need to accommodate this requirement if it exists. Consent forms will be maintained in a locked file cabinet in the researcher's office at Illinois State University. I will also send photocopies of the signed consent forms to my research, Dr. Ferrell, and she will keep them in a locked file cabinet in her office.

5. Can you provide us with a copy of your IRB approval from ISU so that we can append it to your UNC IRB application? I have photocopied the e-mail from the ISU IRB board giving me permission to undertake this study, and have attached it as a file.

6. Please confirm the locations where you will do the actual testing are as listed in the ISU IRB application, section 1.e. I don't see the same information in the UNC IRB application (unless I missed this information). Until I get my voluntary participants, I will not know where the actual testing will occur. However, the possible sites are as follows: 1) The Chicago Lighthouse for the Blind (for students in the northern part of the state), Illinois State University (for students in the central part of the state), and Illinois School for the Visually Impaired (for students in the southern part of the state).

7. I don't have a request here, but I want to suggest that some of the younger children may require a break during the testing. Midway through the testing session, the students will complete a series of physical tasks to help determine hand dominance. This will give them a break from reading. At this time, I will also give the student a rest, restroom, and drink break.

ILLINOIS STATE
UNIVERSITY

*Department of Special Education*

Campus Box 5910
Normal, IL 61790-5910
Telephone: (309) 438-5419
Facsimile: (309) 438-8699

Informed Consent to Participate in Research

Illinois State University

Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading

I am a doctoral candidate at the University of Northern Colorado and an assistant professor at Illinois State University. For my dissertation, I am researching braille reading fluency (speed and accuracy) in relation to braille reading mechanics (hand and finger usage). Interested participants should be children who are blind and visually impaired reading 4th through 9th grade-level, instructional materials in contracted braille. While reading 10 short lists and passages, the hand movements and oral recitation of the reading material will be recorded on video. Participants will also engage in a series of simple physical motions to determine hand-dominance (such as shaking hands).

The testing session should take approximately 60-90 minutes. In order to maximize confidentiality, you will only be asked to provide your child's first name to the researcher, and your child's face will not be recorded at any time. Furthermore, research data will be stored in a secure location that can only be accessed by the lead and assistant researchers. Data will be maintained for a period not exceeding five years, and then it will be destroyed. However, if you would like to give this professor permission to use the videotape in university courses for prospective teachers of students with visual impairments, please initial the last page. I do not foresee any unusual risks to participants beyond those typically associated with oral braille reading.

Please feel free to contact me via phone or e-mail if you have any questions or concerns about this research. If your child is interested in participating, and you would like for your child to participate in this research, read the passage below and sign this form. Finally, complete the *Student Information Questionnaire*. Please consult your

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child's teacher of students with visual impairments to obtain any necessary information. Return the completed consent form and questionnaire to me (the lead researcher) in the self-addressed, stamped envelope that has been provided. Upon receipt of these materials, I will be contacting you to arrange for an individual testing session. Thank you for assisting me with my dissertation research.

Sincerely,

| Lead Researcher | Research Advisor |
|---|---|
| Loana Mason, M.A., COMS | Kay Ferrell, Ph.D. |
| Assistant Professor | Professor |
| Department of Special Education | School of Special Education |
| Campus Box 5910 | Campus Box 141 |
| Illinois State University | University of Northern Colorado |
| Normal, IL 61790-5910 | Greeley, CO 80639 |
| 309-438-5829 | 970-351-1653 |
| lmason@ilstu.edu | kay.ferrell@unco.edu |

Participation is voluntary, and you may decide to withdraw at any time. Your decision will be respected and will not interfere with any benefits you may be entitled to. If you would like to participate in this research, please complete the forms included in this mailing and return them to me at the address above. Be sure to provide a phone number so that you may be contacted to set up a testing session. Please retain a copy of this form for future reference. If you have any concerns about your selection or treatment as a research participant, please contact the IRB Chairperson of the Sponsored Programs Office, Campus Box 3040, Illinois State University, Normal, IL 61790-3040; 309-438-8451.

_________ Yes, I give Loana Mason permission to use the video from this testing session in her university classes for prospective teachers of students with visual impairments.
Initial

______________________________________ ______________________

Parent/Guardian Signature Date

Contact Phone Number: ____________________ Best Time to Call: __________________

ILLINOIS STATE
UNIVERSITY

Department of Special Education

Campus Box 5910
Normal, IL 61790-5910
Telephone: (309) 438-5419
Facsimile: (309) 438-8699

Assent to Participate in Research

Illinois State University

Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading

Dear Braille Reader,

My name is Loana Mason, and I am a teacher at Illinois State University. I am doing research on braille reading, and I would like to videotape the hand movements of contracted braille users reading aloud a number of different braille words and stories. If you would like, you can earn $25 for reading braille to me for about an hour or an hour and a half.

If you want to help me, I will ask you to read 10 different sets of braille symbols, words, and stories. You will be asked to read as fast and as correctly as possible using different hand and finger combinations. While you are reading aloud, I will videotape your hand movements and record your voice. During your break, I will also ask you to do a series of physical tasks. This is not a test, and you will not be graded on your performance. While I will calculate how many words per minute you are able to read correctly, nobody but me and my assistants will know what your score is. We will do this reading outside of school so that you do not have to miss any classes.

I will also ask your parents and teacher of students with visual impairments to fill out a questionnaire. Basically, the questions I ask describe you, your visual impairment, and your literacy skills. If you would like to see the questionnaire, please let me know and I can send you a braille copy.

Reading braille to me will probably not help or hurt you. Your parents have said that it

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is okay for you to read for me, but you do not have to. If you say "yes" and then change your mind, you can stop at anytime. Please let me know if you have any questions. When asked if you would like to help me with my research on braille reading, say "yes," or "no." If you have any concerns about your selection or treatment as a research participant, please contact the IRB Chairperson of the Sponsored Programs Office, Campus Box 3040, Illinois State University, Normal, IL 61790-3040; 309-438-8451.

If you agree, I would also like to use the videotape of your hands during braille reading to teach future teachers of students with visual impairments. They will not be able to see your face and will only know your first name. You can still read for my research project and not allow me to use this videotape in my college classes. If it is okay for me to use the videotape please say "yes" when asked.

Do you want to be part of this study?
Can I use the videotape of your hand movements in my university classes?

ILLINOIS STATE
UNIVERSITY

*Department of Special Education*

Campus Box 5910
Normal, IL 61790-5910
Telephone: (309) 438-5419
Facsimile: (309) 438-8699

Consent to Participate in Research

Illinois State University

Project Title: An Experimental Replication of Hand and Finger Usage in Braille Reading: A Pilot Study

Dear Braille Reader,

My name is Loana Mason, and I am a teacher at Illinois State University. I am doing research on braille reading, and I would like to videotape the hand movements of contracted braille users reading aloud a number of different braille words and stories. If you would like, you can earn $25 for reading braille to me for about an hour or an hour and a half.

If you want to help me, I will ask you to read 10 different sets of braille symbols, words, and stories. You will be asked to read as fast and as correctly as possible using different hand and finger combinations. While you are reading aloud, I will videotape your hand movements and record your voice. During your break, I will also ask you to do a series of physical tasks. This is not a test, and you will not be graded on your performance. While I will calculate how many words per minute you are able to read correctly, nobody but me and my assistant will know what your score is. We will do this reading outside of school so that you do not have to miss any classes.

I will also ask you to fill out a questionnaire. Basically, the questions I ask describe you, your visual impairment, and your literacy skills.

Reading braille to me will probably not help or hurt you. If you say choose to participate and then change your mind, you can stop at anytime. Please let me know if you have

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any questions. When asked if you would like to participate in this research, say either "yes," or "no." If you have any concerns about your selection or treatment as a research participant, please contact the IRB Chairperson of the Sponsored Programs Office, Campus Box 3040, Illinois State University, Normal, IL 61790-3040; 309-438-8451.

If you agree, I would also like to use the videotape of your hands during braille reading to teach future teachers of students with visual impairments. They will not be able to see your face and will only know your first name. You can still read for my research project and not allow me to use this videotape in my college classes. If it is okay for me to use the videotape, please say "yes" when asked that question.

Sincerely,

Lead Researcher
Loana Mason, M.A., COMS
Assistant Professor
Department of Special Education
Campus Box 5910
Illinois State University
Normal, IL 61790-5910
309-438-5829
lmason@ilstu.edu

Research Advisor
Kay Ferrell, Ph.D.
Professor
School of Special Education
Campus Box 141
University of Northern Colorado
Greeley, CO 80639
970-351-1653
kay.ferrell@unco.edu

Do you want to be part of this study?
Can I use the videotape of your hand movements in my university classes?

# ATTENTION

## PARTICIPANTS NEEDED
**for a Braille Study**

Do you know which hand
is the best hand for reading braille?

Do you know which finger
is the best finger for reading braille?

This research is seeking to explore the hand and finger combination that results in the fastest and most accurate reading of braille. If you and your child would like to know the answer to these questions, please participate in this research. All participants will be paid $25 to read braille for 60-90 minutes.

You would be a great participant if you…

- Read contracted braille
- Lost your vision before the age of 3
- Are in grades 4-9 and are reading on grade level

If you are interested, please contact

Loana Mason, M.A., COMS
309-438-5829
lmason@ilstu.edu

# ATTENTION

## PARTICIPANTS NEEDED
**for a Braille Study**

Do you know which hand
is the best hand for reading braille?

Do you know which finger
is the best finger for reading braille?

This research is seeking to explore the hand and finger combination that results in the fastest and most accurate reading of braille. If you would like to know the answer to these questions, please participate in this research. All participants will be paid $25 to read braille for 60-90 minutes.

You would be a great participant if you…

- Read contracted braille
- Are an adult

If you are interested, please contact

Loana Mason, M.A., COMS
Assistant Professor @ Illinois State University
309-438-5829
lmason@ilstu.edu

STUDENT'S COPY

February 15, 2007

TO: Mark Riddle
School of Social Sciences

FROM: Maria Lahman, Co-Chair
UNC Institutional Review Board

RE: Expedited Review of Proposal, *An Experimental Replication of Hand and Finger Usage in Braille Reading: A Pilot Study,* submitted by Loana Mason (Research Advisor: Kay Ferrell)

First Consultant: The above proposal is being submitted to you for an expedited review. Please review the proposal in light of the Committee's charge and direct requests for changes directly to the researcher or researcher's advisor. If you have any unresolved concerns, please contact Maria Lahman, ASRM, Campus Box 124, (x1603). When you are ready to recommend approval, sign this form and return to me.

I recommend approval as is. [signature] 2 April '07
Signature of First Consultant Date

The above referenced prospectus has been reviewed for compliance with HHS guidelines for ethical principles in human subjects research. The decision of the Institutional Review Board is that the project is approved as proposed for a period of one year: May 4, 2007 to May 4, 2008

[signature]
Maria Lahman, Co-Chair Date

Comments: Please see e-mail correspondence and revisions. Researcher will send written notices of permission for data collection sites.

UNIVERSITY of
NORTHERN COLORADO

February 19, 2007

Loana Mason
SED 5910

Thank you for submitting the research protocol titled An Experimental Replication of Hand and Finger Usage in Braille Reading for review by the Illinois State University Institutional Review Board (IRB). The IRB has Approved this research protocol following an Expedited Review procedure. You may begin this research.

This protocol has been given the IRB number 2007-0034. This number should be used in all correspondence with the IRB. You may proceed with this study from 2/19/2007 to 2/19/2008. You must notify the IRB before 2/1/2008 if you will need a continuation beyond that ending date.

This approval is valid only for the research activities, timeline, and subjects described in the above named protocol. IRB policy requires that any changes to this protocol be reported to, and approved by, the IRB before being implemented. You are also required to inform the IRB immediately of any problems encountered that could adversely affect the health or welfare of the subjects in this study. Please contact Joseph Casto, PhD, Assistant Director of Research, at 438-2520 or myself in the event of an emergency. All correspondence should be sent to:

Institutional Review Board
Campus Box 3330
Professional Development Building
Telephone: 438-2529

It is your responsibility to notify all co-investigators ( ), including students, of the classification of this protocol as soon as possible.

Thank you for your assistance, and the best of success with your research.

Beverly Smith, Chairperson
Institutional Review Board
Telephone: 438-7645

cc: Jeff Bakken, IRB Department Rep., SED

# APPENDIX B

## Student Information Questionnaire

Student Information Questionnaire

Parents: Please have your child's teacher of students with visual impairments fill out the following information regarding your child who is blind or visually impaired. If you have any questions about the use of this information in the research study described in this packet, please contact the lead researcher, Loana Mason, Illinois State University, Normal, IL 61790.

## **Demographic Information**

Student's Fist Name: ________________ Age: _______ Grade: _____

Gender (circle one): Female or Male Ethnicity: __________________________

Primary/Secondary Language: ____________________/______________________

## **Medical Information**

Visual Diagnosis: ____________________ Age at Onset: ________________

Visual Acuities: Left Eye ________ Right Eye _______ Visual Fields: ______

Additional Disabilities: __________________________________________________

## **Literacy Information**

Primary Literacy Modality: ______ Secondary Literacy Modality: __________

Years of Reading Braille: _______ Grade Contracted Braille Introduced: ___

Age Braille Introduced: _________ Instructional Reading Level (Grade): ___

**CONTINUED ON NEXT PAGE**

## Educational Information

Current Educational Placement (circle one): Public School or Specialized School

Years in Current Educational Placement: ______

Academic Program: ______ General Education Curriculum

______ Accelerated Curriculum

______ Functional Academics Curriculum

______ Life Skills Curriculum

☺ **THANKS** ☺

# APPENDIX C

## Hand and Finger Dominance Assessments

# Hand Dominance Baseline Test
(Adapted from Hermelin and O'Connor 1971a)

This test is part of the baseline assessment and is conducted during the break halfway through the experiment. Ask the participant to complete the following activities, and then mark the hand with which the participant completed the task. Determine hand dominance by tabulating the check marks in each column. If there is less than a two point difference between the columns, label the participant as ambidextrous; otherwise, label hand dominance in accordance with the column that has the highest score.

| | | Left | Right |
|---|---|---|---|
| 1. | Use the toothbrush on the tray and pretend to brush your teeth. | | |
| 2. | Using one hand, pick up the coin on the tray. | | |
| 3. | Use the crayon to draw a picture. | | |
| 4. | Open the door. | | |
| 5. | Pick up the ball on the tray and throw it to me. | | |
| 6. | Use the cup on the tray and pretend to take a drink. | | |
| 7. | Touch your nose. | | |
| 8. | Point at me. | | |
| 9. | Use the spoon on the tray and pretend to eat. | | |
| 10. | Raise your hand as if you had a question. | | |

Hand Dominance:

Hand Use During Braille Reading

Complete this form whenever a participant is required to read braille using multiple hands/fingers. Review each video recording, pause the tape every five seconds, and mark the fingers that are aligned with the braille on the current line being read. Mark multiple boxes if appropriate. Then watch the video again and mark any fingers that engage in scrubbing or retracing of each braille unit (symbol or word) for each subsection of the test. Tally the totals for each column, and indicate which finger(s) were dominant during each test.

Student: Treatment Condition: Form:

Braille Symbols

| 5 Second Time Intervals | Left Index Finger | Left Middle Finger | Right Index Finger | Right Middle Finger |
|---|---|---|---|---|
| .05 | | | | |
| .10 | | | | |
| .15 | | | | |
| .20 | | | | |
| .25 | | | | |
| .30 | | | | |
| .35 | | | | |
| .40 | | | | |
| .45 | | | | |
| .50 | | | | |
| .55 | | | | |
| .60 | | | | |
| | | | | |
| Scrubbings or Retracings | | | | |
| Totals: | ________ | ________ | ________ | ________ |

Word List

| 5 Second Time Intervals | Left Index Finger | Left Middle Finger | Right Index Finger | Right Middle Finger |
|---|---|---|---|---|
| .05 | | | | |
| .10 | | | | |
| .15 | | | | |
| .20 | | | | |
| .25 | | | | |
| .30 | | | | |
| .35 | | | | |
| .40 | | | | |

| | | | | |
|---|---|---|---|---|
| .45 | | | | |
| .50 | | | | |
| .55 | | | | |
| .60 | | | | |
| | | | | |
| Scrubbings or Retracings | | | | |

Totals: ____________ ____________ ____________ ____________

Reading Passage

| 5 Second Time Intervals | Left Index Finger | Left Middle Finger | Right Index Finger | Right Middle Finger |
|---|---|---|---|---|
| .05 | | | | |
| .10 | | | | |
| .15 | | | | |
| .20 | | | | |
| .25 | | | | |
| .30 | | | | |
| .35 | | | | |
| .40 | | | | |
| .45 | | | | |
| .50 | | | | |
| .55 | | | | |
| .60 | | | | |
| .65 | | | | |
| .70 | | | | |
| .75 | | | | |
| .80 | | | | |
| .85 | | | | |
| .90 | | | | |
| .95 | | | | |
| .100 | | | | |
| .105 | | | | |
| .110 | | | | |
| .115 | | | | |
| .120 | | | | |
| | | | | |
| Scrubbings or Retracings | | | | |

Totals: ____________ ____________ ____________ ____________

Hand/finger dominance for braille symbols: ________________________________

Hand/finger dominance for the word list: __________________________________

Hand/finger dominance for the reading passage: ___________________________

# APPENDIX D

## Testing Directions Script

Testing Directions Script

**Introduction to Session 1**

“Thank you for being in my study. Before we begin, I need to give you information about my research and record your verbal agreement to participate. Then, I will have you practice reading some word lists aloud. Next you will be asked to read aloud 10 different sets of characters, words, and stories using assigned hand and finger combinations. After each story you read, you will be asked to complete a simple, physical activity. We will complete the first 5 sets of readings and activities today, and we will do the remaining half the next time we meet, which will be _________________. It should take about 45 minutes for us to do all of this, and we can take a break at the end of any reading passage if needed.

“Please read the permission form. When you are done I need you to say, ‘Yes, I want to be part of this study,’ or ‘No, I do not want to be part of this study.’ I also need you to say, ‘Yes, you can use the videotape in college classes you teach,’ or ‘No, you cannot use the videotape in the college classes you teach.’

“Do you have any questions before we begin?”

***Physical activities are taken from the Hand-Dominance Baseline Test and will be completed in order after each treatment condition, starting with the Baseline Assessment.**

**Introduction to Session 2**

“I am so glad that you came back to finish the rest of the reading activities. Before you leave today, I have $25 to give you as a thank you for helping me. You’ve only got 5 more reading tests using different hand and finger combinations and five more simple physical activities to do. Do you still want to continue to be in my study?” (If student declines to participate in the remainder of the study, thank him/her and give them $12.50.)

Great! Then let’s get started. The procedures are the same as last time, and it should only take about 45 minutes to complete everything. Once again, you will read 5 different sets of braille symbols, words, and stories while I continue to tape your voice and hand movements. Remember that the goal is to read as quickly and correctly as possible. If you make a mistake, you are allowed to correct yourself. However, I am not allowed to help; so, if you are not sure how to say a word, just give it your best try. Do you have any questions? If you need a break after any reading passage, just let me know.”

***Physical activities are taken from the Hand-Dominance Baseline Test and will be completed in order after each treatment condition, starting with the Baseline Assessment.**

**Pre-Assessment**

"I'm going to give you a list of 20 words to practice reading aloud to me. If you are unsure of a word, give it your best try. If it is too hard, you can skip it. After you have had enough practice, I will ask you to read some braille symbols, words, and stories to me."

**Baseline Assessment**

Braille Symbols

"When I say, go, read each character after the full cell of braille as quickly and as correctly as you can. Instead of telling me its name, I want you to tell me its dot numbers" (Have the student practice using an enlarged cell with numbers). "If you make a mistake, you may correct yourself. If you are uncertain of a word, give it your best try because I cannot help you. When you read the word stop in all capitals, take your hands off the page and put them in your lap. You may now find the word start in all capitals, but do not move your fingers until I say, go. Are you ready? Go!"

Braille Words

"When I say go, read aloud the paragraph of words as quickly and as correctly as you can. These words are unrelated, and thus, they do not have any combined meaning. If you make a mistake, you may correct yourself. If you are uncertain of a word, give it your best try because I cannot help you. When you read the word stop in all capitals, take your hands off the page and put them in your lap. You may now find the separation line, and then find the word start in all capitals. Do not move your fingers until I say, go. Are you ready? Go!"

Braille Story

"When I say go, read the story aloud as quickly and as correctly as you can. If you make a mistake, you may correct yourself. If you are uncertain of a word, give it your best try because I cannot help you. When you read the word stop in all capitals, take your hands off the page and put them in your lap. You may now find the word start in all capitals, but do not move your fingers until I say, go. Are you ready? Go!"

**Treatment Condition A: Left Index Finger**

"The directions for this test are the same as the first test, except you can only read using your left index finger. While reading, keep your right hand in your lap. You may either make a fist with all your fingers, except your left index," (demonstrate for participant) "or you may raise all your fingers in the air, except your left index" (demonstrate for participant)." Whichever method you choose, your left index finger, must be the only finger that touches any braille. Do you understand?" (Check reader's hand position.)

Braille Symbols

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

Braille Words

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

Braille Story

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition B: Right Index Finger**

"The directions for this test are the same as the first test, except you can only read using your right index finger. While reading, keep your left hand in your lap. You may either make a fist with all your fingers, except your right index," (demonstrate for participant) "or you may raise all your fingers in the air, except your right index" (demonstrate for participant)." Whichever method you choose, your right index finger, must be the only finger that touches any braille. Do you understand?" (Check reader's hand position.)

<u>Braille Symbols</u>

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Words</u>

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Story</u>

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition C: Left and Right Index Fingers**

"The directions for this test are the same as the first test, except you can only read using your left and right index fingers. While reading, you may either make a fist with all your fingers, except your index fingers," (demonstrate for participant) "or you may raise all your fingers in the air, except your index fingers" (demonstrate for participant)." Whichever method you choose, both your left and right index fingers, must touch the braille at all times. Do you understand?" (Check reader's hand position.)

<u>Braille Symbols</u>

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your index fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Words</u>

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hands until I say, go. Remember that only your index fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Story</u>

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your index fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition D: Left Middle Finger**

“The directions for this test are the same as the first test, except you can only read using your left middle finger. While reading, keep your right hand in your lap. You may either make a fist with all your fingers, except your left middle,” (demonstrate for participant) “or you may raise all your fingers in the air, except your left middle” (demonstrate for participant).” Whichever method you choose, your left middle finger, must be the only finger that touches any braille. Do you understand?” (Check reader’s hand position.)

<u>Braille Symbols</u>

“When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

<u>Braille Words</u>

“When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your left middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

<u>Braille Story</u>

“When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

**Treatment Condition E: Right Middle Finger**

“The directions for this test are the same as the first test, except you can only read using your right middle finger. While reading, keep your left hand in your lap. You may either make a fist with all your fingers, except your right middle,” (demonstrate for participant) “or you may raise all your fingers in the air, except your right middle” (demonstrate for participant).” Whichever method you choose, your right middle finger, must be the only finger that touches any braille. Do you understand?” (Check reader’s hand position.)

Braille Symbols

“When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

Braille Words

“When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your right middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

Braille Story

“When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right middle finger should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!”

**Treatment Condition F: Left and Right Middle Fingers**

"The directions for this test are the same as the first test, except you can only read using your left and right middle fingers. While reading, you may either make a fist with all your fingers, except your middle fingers," (demonstrate for participant) "or you may raise all your fingers in the air, except your middle fingers" (demonstrate for participant)." Whichever method you choose, both your left and right middle fingers, must touch the braille at all times. Do you understand?" (Check reader's hand position.)

<u>Braille Symbols</u>

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Words</u>

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hands until I say, go. Remember that only your middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Story</u>

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition G: Left Index and Left Middle Fingers**

"The directions for this test are the same as the first test, except you can only read using your index and middle fingers on your left hand. While reading, keep your right hand in your lap. You may either make a fist with all your fingers, except your left index and middle," (demonstrate for participant) "or you may raise all your fingers in the air, except your left index and middle" (demonstrate for participant)." Whichever method you choose, your left index and middle fingers, must touch the braille at all times. Do you understand?" (Check reader's hand position.)

<u>Braille Symbols</u>

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Words</u>

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Story</u>

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your left index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition H: Right Index and Right Middle Fingers**

"The directions for this test are the same as the first test, except you can only read using your index and middle fingers on your right hand. While reading, keep your left hand in your lap. You may either make a fist with all your fingers, except your right index and middle," (demonstrate for participant) "or you may raise all your fingers in the air, except your right index and middle" (demonstrate for participant)." Whichever method you choose, your right index and middle fingers, must be touch the braille at all times. Do you understand?" (Check reader's hand position.)

Braille Symbols

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

Braille Words

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

Braille Story

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hand until I say, go. Remember that only your right index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

**Treatment Condition I: Left Index and Middle Fingers Plus Right Index and Middle Fingers**

"The directions for this test are the same as the first test, except you must read using the following four fingers: your left index and middle fingers plus your right index and middle fingers. While reading, you may either make a fist with all your fingers, except your index and middle fingers," (demonstrate for participant) "or you may raise all your fingers in the air, except your index and middle fingers" (demonstrate for participant)." Whichever method you choose, your left index and middle fingers plus your right index and middle fingers, must touch the braille at all times. Do you understand?" (Check reader's hand position.)

<u>Braille Symbols</u>

"When I say, go, tell me the dot numbers of the character after each full cell of braille as quickly and correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Words</u>

"When I say, go, read aloud the paragraph of words as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the separation line and then the word start in all capitals, but do not move your hands until I say, go. Remember that only your index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

<u>Braille Story</u>

"When I say go, read the story aloud as quickly and as correctly as you can until you read the word stop in all capitals. You may now find the word start in all capitals, but do not move your hands until I say, go. Remember that only your index and middle fingers should be touching any braille and that you need to put your hands in your lap after you have finished. Are you ready? Go!"

# APPENDIX E

# Content of the Assessment Protocols

Content of the Assessment Protocols

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 4 | Baseline Test 1 (4b1) | 6, 8, 39, 29, 54, 23, 55, 20, 61, 38, 47, 2, 34, 13, 31, 60, 35, 21, 30, 58, 10, 48, 52, 43, 18, 53, 24, 41, 45, 63, 1, 9, 46, 26, 42, 16, 32, 11, 50, 33, 15, 7, 40, 22, 57, 28, 37, 17, 36, 5, 51, 25, 19, 49, 14, 3, 12, 27, 44, 56, 62, 59, & 4 | tennis, swarm, friendship, nonsense, windshield, gulf, ocean, crickets, cookbook, & impact | Analytical Reading Inventory: Form B (159 words) |
| 4 | Baseline Test 2 (4b2) | 7, 24, 52, 48, 47, 21, 32, 57, 39, 35, 18, 11, 10, 59, 26, 49, 9, 2, 50, 36, 4, 46, 22, 62, 45, 37, 17, 20, 60, 51, 31, 61, 16, 5, 38, 42, 15, 19, 40, 30, 8, 53, 58, 1, 55, 3, 41, 63, 44, 23, 28, 33, 54, 34, 43, 12, 14, 13, 27, 25, 6, 29, & 56 | polite, chill, covered, jealous, signal, interrupted, tray, anxious, saddle, & goodness | Bader Reading & Language Inventory: Form 4C/A (178 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 4 | Baseline Test 3 (4b3) | 16, 39, 40, 55, 45, 15, 60, 25, 11, 17, 19, 54, 36, 4, 59, 61, 31, 46, 5, 22, 3, 37, 12, 33, 57, 14, 29, 38, 10, 20, 47, 27, 44, 34, 48, 51, 58, 35, 32, 2, 42, 7, 30, 1, 18, 8, 41, 53, 6, 43, 62, 63, 52, 23, 56, 49, 26, 21, 9, 24, 28, 50, & 13 | ability, downhill, accident, electric, property, internal, cemetery, jungle, balance, & fortunate | Roe/Burns Informal Reading Inventory: Form A (272 words) |
| 4 | Test 1 (4a1) | 13, 58, 63, 32, 44, 61, & 16 | distance, salary, memorize, target, nature, serious, holiday, jelly, greet, & illustrated | Roe/Burns Informal Reading Inventory: Form C (150 words) |
| 4 | Test 2 (4a2) | 50, 11, 31, 21, 9, 6, & 5 | ancient, thought, given, wreck, adventurer, sport, voyage, medicine, sight, & certainly | Basic Reading Inventory: Form LN (251 words) |
| 4 | Test 3 (4a3) | 42, 1, 34, 35, 15, 56, & 41 | noon, disturb, relax, stove, solid, dolphin, shiver, remote, holly, & silent | Reading Inventory for the Classroom: Form B (294 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 4 | Test 4 (4a4) | 37, 52, 10, 39, 55, 59, & 18 | award, slope, exercise, sample, pump, yesterday, excellent, oyster, portion, & wrong | Stieglitz Informal Reading Inventory: Form B (168 words) |
| 4 | Test 5 (4a5) | 45, 12, 2, 33, 22, 4, & 19 | landscape, entered, gaze, exhibit, decided, nineteen, compound, dull, weep, & served | Critical Reading Inventory: Form BS (215 words) |
| 4 | Test 6 (4a6) | 8, 28, 30, 26, 23, 46, & 60 | present, rifle, lantern, fame, wrecked, people, desert, scamper, guarded, & bike | Reading Inventory for the Classroom: Form D (244 words) |
| 4 | Test 7 (4a7) | 20, 36, 53, 51, 62, 49, & 27 | operator, language, weather, amazed, sausage, adaptation, morning, expert, lung, & sleeve | Stieglitz Informal Reading Inventory: Form C (153 words) |
| 4 | Test 8 (4a8) | 25, 40, 3, 54, 38, 47, & 48 | zebra, relief, statue, precious, lettuce, increase, compass, starve, assembly, & subject | Roe/Burns Informal Reading Inventory: Form D (142 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 4 | Test 9 (4a9) | 43, 7, 14, 24, 57, 29, & 17 | disturbance, amount, savage, offend, alphabet, tiresome, official, grape, settlers, & sunlight | Bader Reading & Language Inventory: Form 4C (172 words) |
| 5 | Baseline Test 1 (5b1) | 59, 4, 48, 32, 7, 33, 43, 55, 38, 29, 41, 2, 3, 39, 17, 24, 51, 30, 36, 18, 34, 44, 8, 52, 16, 63, 1, 37, 49, 6, 35, 21, 46, 58, 11, 20, 19, 9, 28, 14, 5, 31, 22, 26, 45, 10, 57, 62, 47, 23, 42, 56, 27, 53, 25, 54, 50, 60, 15, 40, 13, 61, & 12 | impulse, registration, terrify, brag, ransom, shrill, behaved, haunt, attention, & oars | Basic Reading Inventory: Form LE (250 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 5 | Baseline Test 2 (5b2) | 62, 39, 3, 44, 36, 56, 31, 38, 52, 37, 43, 61, 5, 63, 9, 35, 27, 20, 46, 22, 6, 34, 21, 50, 23, 48, 28, 55, 33, 42, 54, 49, 11, 29, 47, 14, 10, 1, 2, 40, 4, 25, 41, 58, 51, 15, 18, 32, 59, 53, 26, 8, 57, 45, 30, 12, 13, 7, 16, 17, 24, 60, & 19 | symbol, scar, considered, discussed, biography, platform, attract, manager, dentist, & wrestle | Classroom Reading Inventory: Form B Post (147 words) |
| 5 | Baseline Test 3 (5b3) | 56, 47, 15, 37, 53, 22, 9, 19, 42, 16, 34, 26, 45, 30, 36, 46, 39, 18, 7, 10, 54, 27, 32, 8, 41, 49, 35, 3, 11, 50, 59, 14, 13, 38, 5, 62, 33, 31, 55, 25, 43, 40, 17, 58, 2, 63, 4, 6, 1, 29, 48, 28, 60, 23, 57, 52, 12, 51, 21, 24, 61, 20, & 44 | radar, furnish, gallant, obstacles, abandon, rehearse, impress, public, shrewd, & sandal | Analytical Reading Inventory: Form B (181 words) |
| 5 | Test 1 (5a1) | 1, 41, 51, 56, 35, 52, & 40 | goblin, treatment, dismiss, yarn, instinct, baggage, poisonous, halt, turban, & rude | Ekwall/Shanker Reading Inventory: Form D (149 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 5 | Test 2 (5a2) | 19, 59, 55, 31, 7, 29, & 4 | emerald, entrance, gym, zigzag, dreary, hitched, coconut, conquer, ditch, & worthless | Bader Reading & Language Inventory: Form 5C (192 words) |
| 5 | Test 3 (5a3) | 26, 33, 42, 38, 36, 60, & 54 | plantation, telegram, funeral, zone, lacked, tales, grease, journal, astonish, & argument | Bader Reading & Language Inventory: Form 5C/A (150 words) |
| 5 | Test 4 (5a4) | 57, 2, 12, 13, 30, 49, & 20 | drowsy, deprived, series, magical, weird, disappointed, pledge, bore, double, & squash | Classroom Reading Inventory: Form B Pre (145 words) |
| 5 | Test 5 (5a5) | 28, 8, 48, 6, 27, 39, & 16 | sleet, oxygen, attach, giant, hymn, commander, attend, error, acquainted, & bandit | Roe/Burns Informal Reading Inventory: Form C (132 words) |
| 5 | Test 6 (5a6) | 61, 25, 9, 17, 58, 47, & 37 | foam, social, detour, fumble, splendid, international, muscle, raid, shack, & scanty | Basic Reading Inventory: Form LN (250 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 5 | Test 7 (5a7) | 3, 62, 10, 23, 11, 63, & 21 | tend, terrific, grim, legal, establish, loaf, relative, intermediate, ignore, & massive | Roe/Burns Informal Reading Inventory: Form D (131 words) |
| 5 | Test 8 (5a8) | 22, 18, 24, 46, 5, 32, & 34 | depressed, bakery, starvation, assignment, cabinet, satisfactory, crude, wrist, movement, & remarkable | Analytical Reading Inventory: Form S (200 words) |
| 5 | Test 9 (5a9) | 45, 50, 15, 53, 14, 44, & 43 | Investigate, base, grief, mumps, indication, guarantee, mutual, scissors, pouch, & manufacture | Ekwall/Shanker Reading Inventory: Form B (151 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 6 | Baseline Test 1 (6b1) | 50, 6, 56, 60, 30, 20, 41, 7, 34, 33, 37, 27, 24, 1, 62, 17, 55, 39, 36, 47, 54, 40, 25, 18, 48, 26, 5, 31, 49, 51, 38, 19, 35, 58, 22, 44, 11, 59, 29, 10, 42, 46, 61, 9, 32, 4, 53, 14, 12, 28, 8, 2, 16, 3, 45, 57, 63, 52, 43, 15, 21, 23, & 13 | width, resemble, athletic, cheap, despite, legendary, omelet, pulley, wreath, & narrator | Classroom Reading Inventory: Form B Pre (205 words) |
| 6 | Baseline Test 2 (6b2) | 25, 33, 52, 58, 21, 11, 48, 13, 43, 10, 45, 28, 18, 23, 38, 12, 5, 35, 4, 53, 22, 32, 50, 1, 36, 14, 29, 24, 49, 9, 41, 40, 6, 17, 2, 47, 7, 30, 19, 16, 34, 8, 44, 59, 37, 55, 46, 15, 51, 20, 60, 57, 63, 62, 26, 39, 54, 27, 3, 56, 31, 61, & 42 | ruffle, classified, experience, license, activity, appropriate, irrigated, jagged, economics, & headlight | Stieglitz Informal Reading Inventory: Form A (203 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 6 | Baseline Test 3 (6b3) | 55, 30, 16, 7, 29, 11, 60, 38, 53, 1, 5, 27, 15, 35, 42, 63, 51, 25, 3, 59, 48, 41, 9, 61, 49, 39, 28, 12, 52, 18, 33, 2, 57, 37, 56, 24, 23, 50, 54, 10, 17, 14, 36, 62, 47, 58, 13, 4, 6, 46, 21, 40, 19, 32, 8, 22, 45, 34, 44, 31, 26, 20, & 43 | scarcely, farthest, yield, furiously, fund, extinct, reluctant, graduation, applause, & representative | Analytical Reading Inventory: Form C (192 words) |
| 6 | Test 1 (6a1) | 24, 6, 44, 9, 8, 18, & 1 | applaud, puny, medical, prominently, thrived, gallery, bail, association, dandelion, & bridge | Stieglitz Informal Reading Inventory: Form D (232 words) |
| 6 | Test 2 (6a2) | 5, 30, 27, 34, 32, 39, & 4 | greatness, absurd, materials, successful, odor, crutch, somewhat, variety, championships, & counterclockwise | Roe/Burns Informal Reading Inventory: Form A (158 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 6 | Test 3 (6a3) | 53, 10, 56, 46, 35, 11, & 47 | microphone, armor, midstream, calm, guppy, miniature, phase, enthusiastic, frustrate, & opportunity | Ekwall/Shanker Reading Inventory: Form C (147 words) |
| 6 | Test 4 (6a4) | 54, 29, 41, 50, 43, 20, & 22 | evident, minor, fingerprint, fable, congratulation, acquire, mockingbird, wanderer, mob, & doughnut | Stieglitz Informal Reading Inventory: Form B (218 words) |
| 6 | Test 5 (6a5) | 37, 40, 55, 28, 15, 58, & 60 | ordeal, pounce, pressure, routine, substitute, examination, pliers, youngster, aggressive, & reliable | Stieglitz Informal Reading Inventory: Form C (227 words) |
| 6 | Test 6 (6a6) | 2, 25, 52, 23, 38, 13, & 36 | clutching, particle, assemble, temperature, sympathy, possessions, slavery, rehearsal, solar & falter | Basic Reading Inventory: Form LN (250 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 6 | Test 7 (6a7) | 63, 45, 21, 31, 57, 42, & 48 | predictable, fifteenth, beggar, emerge, comment, dazzle, tornado, biscuit, politician, & jumbo | Ekwall/Shanker Reading Inventory: Form B (175 words) |
| 6 | Test 8 (6a8) | 51, 26, 12, 14, 61, 19, & 49 | decay, insistent, communicate, consideration, unexpected, daily, billows, shipment, precise, & intense | Analytical Reading Inventory: Form S (219 words) |
| 6 | Test 9 (6a9) | 59, 7, 17, 16, 3, 62, & 33 | lens, forbid, affairs, unconscious, vow, collision, pyramids, silken, hostile, & failure | Ekwall/Shanker Reading Inventory: Form A (154 words) |
| 7 | Baseline Test 1 (7b1) | 46, 44, 20, 49, 45, 11, 16, 53, 21, 61, 18, 56, 39, 63, 36, 58, 60, 9, 43, 48, 50, 22, 57, 17, 26, 5, 27, 59, 34, 6, 41, 62, 14, 54, 10, 15, 51, 7, 55, 37, 2, 33, 25, 35, 38, 47, 28, 19, 30, 24, 31, 4, 40, 8, 3, 52, 29, 23, 32, 1, 42, 13, & 12 | stability, identical, blight, sophisticated, proven, puncture, typhoon, divert, resemblance, & blockade | Stieglitz Informal Reading Inventory: Form C (236 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 7 | Baseline Test 2 (7b2) | 1, 32, 61, 21, 39, 25, 49, 42, 44, 29, 18, 4, 55, 5, 48, 27, 63, 37, 51, 23, 33, 41, 24, 58, 3, 36, 40, 11, 13, 30, 2, 53, 20, 8, 6, 46, 19, 15, 16, 57, 54, 10, 22, 26, 28, 35, 52, 17, 38, 34, 60, 12, 9, 43, 45, 7, 56, 50, 62, 14, 47, 59, & 31 | feminine, flatter, tranquil, forge, imperative, kerchief, dominion, dormitory, bombard, & evaluate | Ekwall/Shanker Reading Inventory: Form B (162 words) |
| 7 | Baseline Test 3 (7b3) | 29, 14, 28, 17, 45, 50, 43, 6, 53, 21, 49, 24, 59, 60, 41, 32, 9, 55, 35, 33, 37, 23, 51, 2, 47, 3, 31, 12, 18, 42, 27, 48, 54, 11, 40, 58, 10, 16, 15, 20, 25, 4, 7, 13, 44, 57, 19, 30, 8, 39, 38, 56, 61, 34, 5, 52, 63, 22, 36, 46, 26, 62, & 1 | bankruptcy, disadvantage, zoologist, dwell, mayonnaise, motivate, domain, luggage, pollute, & justifiable | Bader Reading & Language Inventory: Form 7C/A (220 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 7 | Test 1 (7a1) | 33, 13, 29, 45, 28, 1, & 19 | execute, pompous, condescend, founder, questionable, administration, amber, monarch, unstable, & tampered | Roe/Burns Informal Reading Inventory: Form D (188 words) |
| 7 | Test 2 (7a2) | 47, 60, 50, 39, 12, 49, & 54 | ornamental, exited, lacquer, motives, fraud, inconvenience, remainder, dense, illegal & childish | Analytical Reading Inventory: Form B (236 words) |
| 7 | Test 3 (7a3) | 16, 52, 53, 21, 2, 58, & 4 | glorify, expressway, confidential, eliminated, slogan, impounded, ravenous, sanitation, translation, & dispatch | Ekwall/Shanker Reading Inventory: Form C (141 words) |
| 7 | Test 4 (7a4) | 59, 20, 51, 46, 14, 36, & 55 | repetition, designer, glamorous, obscure, sentimental, jazz, algebra, impetuous, enumerate, & hibernation | Ekwall/Shanker Reading Inventory: Form A (146 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 7 | Test 5 (7a5) | 34, 44, 38, 3, 7, 42, & 32 | novel, status, enlarge, saliva, conflict, fantastic, contemplate, gardener, pamphlet, & crisis | Stieglitz Informal Reading Inventory: Form A (207 words) |
| 7 | Test 6 (7a6) | 5, 6, 35, 40, 43, 22, & 57 | industrious, vocabulary, daunted, omitted, hemisphere, interpretation, cantaloupe, inhale, luxurious, & hypnotize | Classroom Reading Inventory: Form B Pre (161 words) |
| 7 | Test 7 (7a7) | 9, 15, 62, 11, 23, 27, & 61 | publication, peninsula, unsuspecting, depot enchant, inventory, focus, tuberculosis, incredible, & frequency | Stieglitz Informal Reading Inventory: Form B (204 words) |
| 7 | Test 8 (7a8) | 17, 56, 8, 48, 26, 25, & 30 | include, derby, distress, obtainable, harmony, sundry, domestic, ridicule, capillary, & segment | Classroom Reading Inventory: Form A Pre (206 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 7 | Test 9 (7a9) | 41, 37, 18, 31, 63, 24, & 10 | quench, knapsack, regardless, turnpike, chauffeur, subtle, vivid, nimble, gangster, & unfair | Roe/Burns Informal Reading Inventory: Form A (164 words) |
| 8 | Baseline Test 1 (8b1) | 46, 31, 42, 11, 21, 51, 63, 3, 13, 5, 7, 45, 25, 30, 48, 23, 14, 18, 43, 35, 47, 52, 57, 33, 15, 38, 8, 50, 61, 28, 37, 24, 29, 59, 26, 58, 44, 12, 16, 54, 34, 19, 40, 62, 53, 55, 41, 1, 60, 56, 39, 36, 20, 9, 49, 6, 2, 17, 4, 22, 32, 27, & 10 | toxic, convey, furnishing, incredulous, migrate, sanctuary, stamina, wealthiest, discourse, & celebrity | Basic Reading Inventory: Form LE (250 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 8 | Baseline Test 2 (8b2) | 47, 56, 27, 4, 22, 44, 63, 15, 26, 20, 3, 41, 30, 33, 16, 52, 36, 62, 53, 32, 11, 6, 42, 13, 43, 39, 8, 54, 49, 2, 31, 19, 51, 59, 12, 23, 9, 10, 28, 18, 17, 46, 55, 61, 38, 25, 58, 45, 1, 50, 48, 37, 34, 29, 7, 14, 21, 24, 40, 5, 57, 60, & 35 | neurotic, ruthless, hierarchy, binocular, phenomenal, gradient, intact, dungeon, divorce, & inevitable | Classroom Reading Inventory: Form A Pre (171 words) |
| 8 | Baseline Test 3 (8b3) | 43, 40, 15, 52, 33, 11, 35, 1, 50, 5, 63, 28, 37, 44, 26, 49, 16, 13, 4, 24, 3, 55, 10, 27, 59, 53, 51, 61, 9, 19, 48, 31, 38, 36, 42, 20, 21, 17, 18, 34, 58, 12, 41, 30, 62, 25, 6, 60, 46, 22, 8, 23, 32, 39, 7, 29, 54, 57, 47, 2, 14, 56, & 45 | testimonial, rehabilitation, synthetic, impressive, legislation, duly, acrid, duration, recruit, & fling | Roe/Burns Informal Reading Inventory: Form B (159 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 8 | Test 1 (8a1) | 5, 11, 61, 55, 60, 52, & 13 | candid, ventilate, ferocity, voluntarily, immaculate, federation, belligerent, miscellaneous, quartet, & pneumonia | Roe/Burns Informal Reading Inventory: Form C (183 words) |
| 8 | Test 2 (8a2) | 32, 40, 34, 36, 47, 39, & 57 | placid, intricate, infuriate, nocturnal, impurity, indignant, assumption, imperfect, serial, & horrid | Ekwall/Shanker Reading Inventory: Form C (163 words) |
| 8 | Test 3 (8a3) | 17, 54, 29, 33, 56, 27, & 21 | greedy, modifications, function, beverage, mortgage, vastly, vacancy, maximum, carburetor, & oblong | Ekwall/Shanker Reading Inventory: Form B (144 words) |
| 8 | Test 4 (8a4) | 24, 22, 1, 2, 15, 35, & 62 | tangible, reluctantly, scallop, comedian, improvised, energetic, evade, detection, profound, & patriotic | Roe/Burns Informal Reading Inventory: Form D (188 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 8 | Test 5 (8a5) | 6, 63, 8, 45, 59, 28, & 18 | seriousness, implication, bleak, monotonous, horsepower, limitation, unaccustomed, serenity, notorious, & lubricant | Ekwall/Shanker Reading Inventory: Form A (163 words) |
| 8 | Test 6 (8a6) | 20, 58, 25, 48, 31, 44, & 42 | optimism, delusion, urgency, gorge, encircle, garlic, embassy, maneuver, sauntered, & convincingly | Bader Reading & Language Inventory: Form 8C (182 words) |
| 8 | Test 7 (8a7) | 41, 46, 12, 7, 38, 16, & 50 | bankrupt, motive, variation, exception, frustration, utilization, mutton, shiftless, knowledgeable, & xylophone | Roe/Burns Informal Reading Inventory: Form A (196 words) |
| 8 | Test 8 (8a8) | 43, 53, 51, 14, 30, 10, & 37 | transformation, skyscraper, investment, kidnapper, poise, negative, detain, capacious, perishable, & habitual | Classroom Reading Inventory: Form B Pre (169 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 8 | Test 9 (8a9) | 26, 49, 19, 4, 9, 23, & 3 | authorized, qualification, quote, upholster, embodiment, joyously, fortify, arrogant, linoleum, & liberal | Ekwall/Shanker Reading Inventory: Form D (162 words) |
| 9 | Baseline Test 1 (9b1) | 41, 44, 28, 59, 36, 16, 38, 33, 23, 46, 19, 4, 45, 10, 21, 40, 56, 51, 17, 31, 55, 57, 11, 24, 62, 48, 15, 14, 13, 43, 8, 37, 63, 20, 53, 26, 49, 12, 5, 27, 9, 30, 6, 22, 3, 25, 18, 2, 52, 50, 61, 47, 42, 29, 58, 35, 1, 32, 60, 34, 7, 54, & 39 | furtive, inventive, corsage, overwhelm, apprehend, consecutive, mesmerize, insidious, quarantine, & kinship | Basic Reading Inventory: Form LN (251 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 9 | Baseline Test 2 (9b2) | 44, 40, 32, 43, 36, 39, 56, 61, 26, 5, 9, 18, 38, 13, 34, 58, 54, 30, 11, 57, 19, 60, 21, 35, 8, 16, 1, 28, 52, 15, 51, 14, 47, 50, 24, 63, 2, 17, 45, 23, 25, 62, 10, 42, 31, 20, 41, 29, 48, 33, 55, 37, 7, 12, 27, 4, 59, 53, 6, 3, 49, 22, & 46 | overwhelm, mesmerize, corsage, kinship, inventive, apprehend, insidious, quarantine, furtive, & consecutive | Ekwall/Shanker Reading Inventory: Form C (202 words) |
| 9 | Baseline Test 3 (9b3) | 52, 29, 31, 13, 24, 38, 4, 16, 60, 22, 44, 58, 3, 23, 39, 30, 21, 25, 59, 54, 7, 47, 37, 5, 1, 15, 12, 57, 53, 14, 56, 19, 43, 35, 51, 49, 18, 45, 46, 9, 63, 32, 61, 42, 41, 27, 34, 8, 48, 20, 26, 2, 28, 62, 11, 6, 50, 55, 36, 17, 33, 10, & 40 | quarantine, corsage, overwhelm, mesmerize, consecutive, insidious, kinship, furtive, inventive, & apprehend | Roe/Burns Informal Reading Inventory: Form D (184 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 9 | Test 1 (9a1) | 60, 61, 62, 53, 14, 7, & 18 | horde, utilize, burnished, biceps, texture, redeem, crochet, detrimental, expire, & relevant | Roe/Burns Informal Reading Inventory: Form A (142 words) |
| 9 | Test 2 (9a2) | 59, 30, 5, 20, 54, 17, & 63 | embezzle, compress, conservative, disband, barracks, discern, gruesome, scrutinize, ecstatic, & coronation | Reading Inventory for the Classroom: Form D (457 words) |
| 9 | Test 3 (9a3) | 22, 43, 52, 47, 6, 50, & 29 | transition, autobiography, disrupt, ethnic, amputate, sarcasm, nationality, wince, crave, & idolize | Ekwall/Shanker Reading Inventory: Form A (187 words) |
| 9 | Test 4 (9a4) | 39, 55, 36, 46, 42, 44, & 56 | warp, velocity, siesta, alien, lethal, jaunty, conscientious, detach, heathen, & famished | Roe/Burns Informal Reading Inventory: Form B (193 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 9 | Test 5 (9a5) | 31, 27, 34, 21, 57, 4, & 25 | detract, hypocrisy, disapprove, equivalent, ingenious, insignificant, complex, earthy, luminous, & animation | Ekwall/Shanker Reading Inventory: Form D (198 words) |
| 9 | Test 6 (9a6) | 51, 37, 23, 15, 33, 26, & 2 | ecstasy, chronic, deceased, binoculars, contestant, mechanism, vestibule, vaudeville, debatable, & audible | Basic Reading Inventory: Form LE (250 words) |
| 9 | Test 7 (9a7) | 10, 48, 13, 24, 41, 3, & 8 | trajectory, bewitch, bleach, robust, controversy, momentous, certify, isolation, bayonet & random | Roe/Burns Informal Reading Inventory: Form C (173 words) |
| 9 | Test 8 (9a8) | 45, 12, 16, 58, 32, 19, & 49 | monogram, data, predecessor, misconduct, vacate, exaggerate, contraction, empathy, slur, & disqualify | Stieglitz Informal Reading Inventory: Form B (252 words) |

| Grade Level | Assessment Form | Braille Symbols (see 7 Line Braille Chart) | Word Lists | Reading Passages |
|---|---|---|---|---|
| 9 | Test 9 (9a9) | 28, 40, 35, 9, 1, 38, & 11 | perennial, insomnia, ethereal, apprentice, comparable, disastrous, strategy, momentary, abolition, & conservation | Ekwall/Shanker Reading Inventory: Form B (174 words) |

# Random Order of Braille Symbols

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| ⠁ | ⠃ | ⠉ | ⠙ | ⠑ | ⠋ | ⠛ | ⠓ | ⠊ | ⠚ |
| 54 | 63 | 15 | 32 | 37 | 34 | 52 | 59 | 29 | 38 |
| ⠅ | ⠇ | ⠍ | ⠝ | ⠕ | ⠏ | ⠟ | ⠗ | ⠎ | ⠞ |
| 36 | 43 | 57 | 23 | 2 | 9 | 28 | 1 | 47 | 4 |
| ⠥ | ⠧ | ⠭ | ⠽ | ⠵ | ⠯ | ⠿ | ⠷ | ⠮ | ⠾ |
| 30 | 20 | 26 | 14 | 53 | 44 | 51 | 17 | 22 | 7 |
| ⠡ | ⠣ | ⠩ | ⠹ | ⠱ | ⠫ | ⠻ | ⠳ | ⠪ | ⠺ |
| 5 | 45 | 16 | 8 | 12 | 10 | 21 | 40 | 62 | 48 |
| ⠂ | ⠆ | ⠒ | ⠲ | ⠢ | ⠖ | ⠶ | ⠦ | ⠔ | ⠴ |
| 49 | 25 | 19 | 55 | 42 | 27 | 56 | 35 | 50 | 58 |

| | | | | | |
|---|---|---|---|---|---|
| ⠌ | ⠬ | ⠼ | ⠜ | ⠄ | ⠤ |
| 60 | 39 | 11 | 41 | 6 | 18 |

| | | | | | | |
|---|---|---|---|---|---|---|
| ⠈ | ⠘ | ⠸ | ⠐ | ⠨ | ⠰ | ⠠ |
| 24 | 46 | 33 | 3 | 31 | 13 | 61 |

# APPENDIX F

## Miscue Analysis Coding Forms

Miscue Coding Symbols
(Adapted from Flynt and Cooter, 2004; Koenig & Holbrook, 1995)

| Miscue | Definition | Coding |
|---|---|---|
| Substitutions | Saying a different word or part of a word than appears in the original text. | Write word said above the word that appears in the original text. |
| Omissions | Leaving out a word or phrase that appears in the original text. | Draw a line through the word or phrase in the original text that has been skipped. |
| Insertions | Adding a word or phrase that does not appear in the original text. | Insert a ^ in the original text and write in the additional word(s) said. |
| Reversals | Changing the order of one or more words in a phrase or a sentence. | Circle the two words or phrases being reversed and connect the circles with a ←→. |
| Repetitions | Saying a word or phrase more than once. | Underline the word or phrase and place a *rr* below it. |
| Mispronunciations | Incorrectly pronouncing all the phonemes (smallest units of sound) in a word (National Reading Panel, 2000; Rasinski, Blachowicz, & Lems, 2006) and are affected by dialects (Johns, 2005; Leslie & Caldwell, 2006; Stieglitz, 2002) | Underline the word and place an *mp* below it. |
| Hesitations | Pauses in reading at the end of a word or line of text that last for more than 5 seconds | Place a – where the pause occurs. |
| Punctuation Oversights | Failing to pause for punctuation | X through the punctuation mark. |
| Self-Corrections | Fixing a mistake without any prompts | Code the initial miscue and then X through the correction. |

# Miscue Analysis Coding Sheet
(Adapted from Flynt and Cooter, 2004; Koenig & Holbrook, 1995)

Student: Treatment Condition: Form:

**Directions:** Watch the video recording of the student reading the following materials. Record any errors the student makes on the passages below by using the coding symbols described on the attached handout. After the passages have been coded, place tally marks in each appropriate column for all errors made within a given row of text.

| | Miscue Tally | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Significant Miscues | | | | Insignificant Miscues | | | | |
| | Substitutions | Omissions | Insertions | Reversals | Repetitions | Mispronunciations | Hesitations | Punctuation Oversights | Self-Corrections |
| *Insert Braille Symbols (Double Spaced)* | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| *Insert Word List (Double Spaced)* | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

| | Miscue Tally | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Significant Miscues | | | | Insignificant Miscues | | | | |
| | Substitutions | Omissions | Insertions | Reversals | Repetitions | Mispronunciations | Hesitations | Punctuation Oversights | Self-Corrections |
| *Insert Reading Passage (Double Spaced)* | | | | | | | | | |

**Summary of Data**

| Braille Symbols | Word List | Reading Passage |
|---|---|---|
| Time (in seconds): | Time (in seconds): | Time (in seconds): |
| SPM: | WPM: | WPM: |
| Total Miscues: | Total Miscues: | Total Miscues: |
| Significant Miscues: | Significant Miscues: | Significant Miscues: |
| CSPM: | CWPM: | CWPM: |

# APPENDIX G

## Pretests

Pre-Assessment Coding Sheet (4th Grade) for ___________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. player | ________________ | ________________ |
| 2. amused | ________________ | ________________ |
| 3. flock | ________________ | ________________ |
| 4. boom | ________________ | ________________ |
| 5. moccasin | ________________ | ________________ |
| 6. whiskers | ________________ | ________________ |
| 7. uproar | ________________ | ________________ |
| 8. regulation | ________________ | ________________ |
| 9. preview | ________________ | ________________ |
| 10. eighty | ________________ | ________________ |
| 11. fifteen | ________________ | ________________ |
| 12. innocent | ________________ | ________________ |
| 13. engine | ________________ | ________________ |
| 14. foundation | ________________ | ________________ |
| 15. excellent | ________________ | ________________ |
| 16. shouldn't | ________________ | ________________ |
| 17. castle | ________________ | ________________ |
| 18. weary | ________________ | ________________ |
| 19. aware | ________________ | ________________ |
| 20. program | ________________ | ________________ |

Pre-Assessment Coding Sheet (5th Grade) for ___________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. estimation | ________________ | ________________ |
| 2. thicket | ________________ | ________________ |
| 3. officially | ________________ | ________________ |
| 4. escaped | ________________ | ________________ |
| 5. vision | ________________ | ________________ |
| 6. marvelous | ________________ | ________________ |
| 7. seasonal | ________________ | ________________ |
| 8. halt | ________________ | ________________ |
| 9. moan | ________________ | ________________ |
| 10. nugget | ________________ | ________________ |
| 11. poaching | ________________ | ________________ |
| 12. ankle | ________________ | ________________ |
| 13. summit | ________________ | ________________ |
| 14. prehistoric | ________________ | ________________ |
| 15. hazel | ________________ | ________________ |
| 16. emergency | ________________ | ________________ |
| 17. helmet | ________________ | ________________ |
| 18. blush | ________________ | ________________ |
| 19. typical | ________________ | ________________ |
| 20. blood | ________________ | ________________ |

Pre-Assessment Coding Sheet (6th Grade) for ___________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. partial | ________________ | ________________ |
| 2. pulp | ________________ | ________________ |
| 3. hesitate | ________________ | ________________ |
| 4. apparatus | ________________ | ________________ |
| 5. survival | ________________ | ________________ |
| 6. extensive | ________________ | ________________ |
| 7. igloo | ________________ | ________________ |
| 8. moisture | ________________ | ________________ |
| 9. navigator | ________________ | ________________ |
| 10. nurture | ________________ | ________________ |
| 11. ladle | ________________ | ________________ |
| 12. grizzly | ________________ | ________________ |
| 13. dispose | ________________ | ________________ |
| 14. instruction | ________________ | ________________ |
| 15. distrust | ________________ | ________________ |
| 16. broadcast | ________________ | ________________ |
| 17. yacht | ________________ | ________________ |
| 18. cushion | ________________ | ________________ |
| 19. punish | ________________ | ________________ |
| 20. complicated | ________________ | ________________ |

Pre-Assessment Coding Sheet (7th Grade) for ___________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. enact | ________________ | ________________ |
| 2. indifferent | ________________ | ________________ |
| 3. ambitious | ________________ | ________________ |
| 4. popper | ________________ | ________________ |
| 5. rayon | ________________ | ________________ |
| 6. terrain | ________________ | ________________ |
| 7. glisten | ________________ | ________________ |
| 8. wrest | ________________ | ________________ |
| 9. stockade | ________________ | ________________ |
| 10. glossy | ________________ | ________________ |
| 11. versatile | ________________ | ________________ |
| 12. economical | ________________ | ________________ |
| 13. warrant | ________________ | ________________ |
| 14. omen | ________________ | ________________ |
| 15. quaint | ________________ | ________________ |
| 16. apprehension | ________________ | ________________ |
| 17. forge | ________________ | ________________ |
| 18. nominate | ________________ | ________________ |
| 19. irregular | ________________ | ________________ |
| 20. observation | ________________ | ________________ |

Pre-Assessment Coding Sheet (8th Grade) for ____________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. mortgage | ________________ | ________________ |
| 2. exhilarating | ________________ | ________________ |
| 3. identification | ________________ | ________________ |
| 4. leaflet | ________________ | ________________ |
| 5. intolerant | ________________ | ________________ |
| 6. novelty | ________________ | ________________ |
| 7. brigade | ________________ | ________________ |
| 8. valve | ________________ | ________________ |
| 9. enumeration | ________________ | ________________ |
| 10. prestige | ________________ | ________________ |
| 11. perpendicular | ________________ | ________________ |
| 12. intrigue | ________________ | ________________ |
| 13. contrive | ________________ | ________________ |
| 14. antiseptic | ________________ | ________________ |
| 15. pretext | ________________ | ________________ |
| 16. faculty | ________________ | ________________ |
| 17. fortify | ________________ | ________________ |
| 18. calculate | ________________ | ________________ |
| 19. nomination | ________________ | ________________ |
| 20. manifest | ________________ | ________________ |

Pre-Assessment Coding Sheet (9th Grade) for ___________________

| | | |
|---|---|---|
| Independent Level = 19-20 correct | Sight Words Correct | |
| Instructional Level = 14-18 correct | Analysis Words Correct | |
| Frustration Level = 0-13 correct | Total Words Correct | |

| | Sight | Analysis |
|---|---|---|
| 1. mandates | ________________ | ________________ |
| 2. nucleic | ________________ | ________________ |
| 3. parasite | ________________ | ________________ |
| 4. succinct | ________________ | ________________ |
| 5. editorialize | ________________ | ________________ |
| 6. enzyme | ________________ | ________________ |
| 7. alliance | ________________ | ________________ |
| 8. convoy | ________________ | ________________ |
| 9. escalation | ________________ | ________________ |
| 10. retrovirus | ________________ | ________________ |
| 11. metaphysical | ________________ | ________________ |
| 12. extenuating | ________________ | ________________ |
| 13. protestations | ________________ | ________________ |
| 14. nurture | ________________ | ________________ |
| 15. iniquity | ________________ | ________________ |
| 16. idealism | ________________ | ________________ |
| 17. infectious | ________________ | ________________ |
| 18. famine | ________________ | ________________ |
| 19. ritual | ________________ | ________________ |
| 20. poignant | ________________ | ________________ |

# APPENDIX H

## ANOVA Summaries for Handedness by Reading Task

In the handedness ANOVAs, there were significant effects for reading ability on both symbols ($F(1, 10) = 8.977$, $p = .013$) and words ($F(1, 10) = 6.976$, $p = .025$). The least squares means revealed a large gap on symbol fluency between struggling readers (LSM = 12.437) versus proficient readers (LSM = 24.180), which also held true for word fluency for struggling readers (LSM = 12.883) and proficient readers (LSM = 24.750). In addition, a main effect for treatment conditions was found for words and passages. The highest word fluencies were for the following conditions: C (LSM = 26.002), Baseline (LSM = 25.619), and I (LSM=23.388). Word fluencies were poorest for Conditions E (LSM = 8.203) and D (LSM = 12.123). As for passage fluencies, scores were highest on the Baseline Condition (LSM = 80.654), Condition I (LSM = 73.949), and Condition C (LSM = 72.190) and lowest on Condition E (LSM = 23.235) and Condition D (LSM = 33.412). This coincides with the ANOVA findings presented for research question one. Results from these ANOVAs are summarized in the Tables 28-30 that follow.

Table 28

*Handedness ANOVA Summary for Symbol Fluency*

| Source | SS | df | MS | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| Treatment Conditions | 424.376 | 3.029 | 140.085 | 1.319 | .286 | .117 |
| Treatment Conditions x Handedness | 636.255 | 6.059 | 105.013 | .989 | .451 | .165 |
| Treatment Conditions x Reading Ability | 215.069 | 3.029 | 70.994 | .668 | .579 | .063 |
| Treatment Conditions x Handedness x Reading Ability | 356.873 | 3.029 | 117.802 | 1.109 | .361 | .100 |
| Error | 3217.955 | 30.294 | 106.223 | | | |
| Between-Subjects Factors | | | | | | |
| Handedness | 267.537 | 2 | 133.769 | .304 | .744 | .057 |
| * Reading Ability | 3947.096 | 1 | 3947.096 | 8.977 | .013 | .473 |
| Handedness x Reading Ability | 1725.912 | 1 | 1725.912 | 3.926 | .076 | .282 |
| Error | 4396.663 | 10 | 439.666 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

Table 29

*Handedness ANOVA Summary for Word Fluency*

| | Source | SS | df | MS | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | | |
| * | Treatment Conditions | 2224.961 | 2.917 | 762.887 | 5.804 | .003 | .367 |
| | Treatment Conditions x Handedness | 875.756 | 5.833 | 150.138 | 1.142 | .363 | .186 |
| | Treatment Conditions x Reading Ability | 242.982 | 2.917 | 83.313 | .634 | .595 | .060 |
| | Treatment Conditions x Handedness x Reading Ability | 341.412 | 2.917 | 117.062 | .891 | .455 | .082 |
| | Error | 3833.581 | 29.165 | 131.445 | | | |
| Between-Subjects Factors | | | | | | | |
| | Handedness | 610.691 | 2 | 305.346 | .878 | .445 | .149 |
| * | Reading Ability | 2424.993 | 1 | 2424.993 | 6.976 | .025 | .411 |
| | Handedness x Reading Ability | 873.751 | 1 | 873.751 | 2.513 | .144 | .201 |
| | Error | 3476.348 | 10 | 347.635 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.

Table 30

*Handedness ANOVA Summary for Passage Fluency*

| Source | SS | df | MS | F | p | $\eta^2$ |
|---|---|---|---|---|---|---|
| Within-Subjects Factor | | | | | | |
| * Treatment Conditions | 21022.929 | 3.822 | 5499.942 | 13.071 | .000 | .567 |
| Treatment Conditions x Handedness | 6342.542 | 7.645 | 829.656 | 1.972 | .080 | .283 |
| Treatment Conditions x Reading Ability | 3575.378 | 3.822 | 935.378 | 2.223 | .087 | .182 |
| Treatment Conditions x Handedness x Reading Ability | 1460.828 | 3.822 | 382.177 | .908 | .455 | .082 |
| Error | 16083.766 | 38.224 | 420.778 | | | |
| Between-Subjects Factors | | | | | | |
| Handedness | 5463.569 | 2 | 2731.785 | .704 | .517 | .123 |
| Reading Ability | 18211.546 | 1 | 18211.546 | 4.695 | .055 | .319 |
| Handedness x Reading Ability | 3914.292 | 1 | 3914.292 | 1.009 | .339 | .092 |
| Error | 38790.407 | 10 | 3879.041 | | | |

* Note: Factors that are statistically significant are marked with an asterisk. Since main effects are ignored when there is an interaction effect, significant main effects are only marked with an asterisk in the absence of interaction effects.