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Comparing Reading Skills and Eye Movement Behavior of Low-Skilled Adult Readers and Typically Developing Child Readers

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COMPARING READING SKILLS AND EYE MOVEMENT BEHAVIOR OF LOW-SKILLED ADULT READERS AND TYPICALLY DEVELOPING CHILD READERS

By

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This dissertation is dedicated to my friends and family.

Thank you for loving and supporting me through the craziness.

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ABSTRACT

Adults enrolled in basic education exhibit poor academic performance, often reading at elementary and middle-school levels. The current study investigated the similarities and differences of reading skills and eye movement behavior between a sample of low-skilled adult readers and first grade students matched on word reading skill. T-tests for matched pairs found no significant differences on language comprehension, reading comprehension, or eye movement variables. Regression analyses revealed that language comprehension made greater contributions to reading comprehension for adults (verses children) in the simple view of reading model. Processing time (gaze duration) was found to account for unique variance in both passage reading comprehension and sentence comprehension efficiency after controlling for word reading and language skills for adults. For children, processing time was only a significant predictor for sentence comprehension efficiency.

Keywords: adult literacy, reading, eye movements, component skills, reading comprehension

CHAPTER ONE

INTRODUCTION

Reading skills develop as a function of several factors such as language skills, text exposure and high-quality instruction, to name a few. The widely accepted Simple View of Reading model purports that decoding skills and language comprehension skills together allow the reader to process and understand text (Gough & Tunmer, 1986). Dependency on decoding decreases as the reader develops automaticity and language comprehension becomes more strongly related to reading comprehension (Gough & Tunmer, 1986; Mellard & Fall, 2012). From a developmental prospective, children begin to become literate by first building the fundamental skills required for reading – phonological awareness, graphophonemic awareness and mastery of the alphabet, vocabulary growth, and oral language skills, (Ehri, 1987; Lonigan, Burgess, & Anthony, 2000; Muter, Hulme, Snowling, & Stevenson, 2004). Later, children and beginning readers are able to begin applying those fundamental skills in order to ascertain new information (Cain, Oakhill, & Bryant, 2004; Hoover & Gough, 1990).

This progression of skills works well for the majority of students. However, nearly one-third of adults in the United States cannot 'read to learn' and score at or below basic functional literacy levels (Sabatini, Sawaki, Shore, & Scarborough, 2010). Prior research has shown that many adults in basic education are only able to comprehend text at elementary school levels (Barnes, Kim, Tighe, & Vorstius, under review; Mellard & Fall, 2012; Tighe, Barnes, Connor, & Steadman, 2013). A large majority of the adults in basic education lack reading skills needed for academic success and career readiness (e.g., Kutner, et al., 2007).

Present Study

The purpose of this study was to compare low-skilled adult readers to typically-developing beginning readers on measures of component reading skills and eye movements in order to determine whether fundamental reading behaviors and skills are similar or different for the two groups of participants. Due to the limited amount of rigorous research with adults in basic education (Comings & Soricone, 2007), it is unknown if low-skilled adult readers exhibit similar reading processes as typically-developing beginning readers. This study contributed to the body of knowledge on adults with low literacy in two ways. First, the fundamental reading skills and patterns of low-skilled adult readers were compared to typically-developing beginning readers. This allowed for an evaluation of the ways in which these two populations of readers are similar in reading skills and eye movement behaviors. The comparison of regression models also allowed for the analysis of how word reading and language comprehension were related to reading comprehension across the two groups. Second, the current study investigated how eye movement behaviors may be related to word reading, language comprehension, passage reading comprehension, and sentence comprehension efficiency for both groups of readers.

Defining the Populations

Adult Basic Education (ABE) program participants are typically between the ages of 16 years and senior citizenship. These individuals are eligible to receive academic instruction via adult basic education programs if they are no longer enrolled in public education or a community college remedial program and have not received a high school diploma. ABE programs provide instruction to support the earning of a General Education Development (GED) certificate. Motivation for attendance varies, with some students enrolled to maintain driving privileges (high school dropouts under the age of 18 – this is a requirement in the state of Florida) and other students exhibiting high dedication to increasing their education (for a review of student motivations, see Greenberg et al., 2013; Mellard, Krieshok, Fall, & Woods, 2013). Adults in ABE programs characteristically exhibit low academic skills and functional literacy levels somewhere between lower elementary school to middle school. This is a heterogeneous population, with no overarching or defining characteristics beyond their common characteristic of lacking foundational academic skills at a level that would allow them to earn a General Education Development certificate (GED).

Typically-developing readers in the present study are those who are still learning how to read (i.e., in the early years of elementary school) and are between the ages of 6 and 8 years. These children are learning to decode print while increasing oral language skills and text exposure, all while undergoing developmental and cognitive growth.

Reading Skills

Reading comprehension is believed to be the culminating product of several interrelated component reading skills (Cain, Oakhill, & Bryant, 2004; Carr, Brown, Vavrus, & Evans, 1990; Kim, Wagner, & Foster, 2011; Neuhaus, Foorman, Francis, & Carlson, 2001). However, the Simple View of Reading model has been supported for readers at all levels, including typically-developing children and adults with low literacy (Barnes et al., under review; Braze, 2007; Catts, Adlof, & Weismer, 2006; Joshi, Tao, Aaron, & Quiroz, 2012; Mellard & Fall, 2012; Sabatini et al., 2010). In the Simple View of Reading model, language comprehension and word reading skills are directly related to reading comprehension (Hoover, & Gough, 1990). However, word reading skill appears to be a higher-order process resulting from a combination of phonological ability, short-term memory, and letter knowledge (Oakhill & Cain, 2011). The ABE population exhibits a heterogeneous pattern of fundamental skill strengths and weaknesses, so weakness in decoding may be due to a number of combinations of fundamental skill deficits.

The ultimate goal of reading is comprehension. As individuals become skilled readers, they learn to construe meanings, make connections, and infer meaning beyond the cursory interpretation. With text experience and automaticity, the influence of word reading on reading comprehension decreases and other skills such as language comprehension and vocabulary become more important (Hoover & Gough, 1990; Mellard & Fall, 2012). This means that beginning readers rely heavily on decoding processes in order to decipher the written code and translate it into phonological representation. Decoding, one of two components in the Simple View of Reading (Hoover & Gough, 1990), is a foundational skill. Decoding is the process of making the connection between graphemes and the appropriate phonemes, then blending these sounds together to sound out the word. An overwhelming number of research studies support explicit, systematic phonics instruction to improve reading comprehension outcomes (Adams, 1990; National Institute of Child Health and Human Development, 2000; Torgerson, Brooks, & Hall, 2006). When decoding becomes an automatized process, reading comprehension improves because cognitive processes can be reallocated to understanding and making connections with the text (Perfetti, 1985, 2007; Perfetti, & Hogaboam, 1975).

Language comprehension, often referred to as listening comprehension, is the ability to understand spoken language. Language comprehension is highly predictive of reading comprehension, accounting for unique variance above and beyond decoding skill (e.g., Hoover & Gough, 1990). Therefore, the comprehension of language is a fundamental practice when the written text has been decoded. In the early grades, language comprehension is believed to support and correlate with reading comprehension (Chall, 1987), although not as strongly as decoding (Hoover & Gough, 1990). The relationship between language comprehension and reading comprehension continues to increase in later grades (Hoover & Gough, 1990). Early language comprehension does, however, impact later reading comprehension (NICHD Early Child Care Research Network, 2005). This means that as readers develop (and their reading processes mature), the relationship between language comprehension and reading comprehension should continue to grow stronger. Mellard and Fall (2012) extended these findings to include struggling adult readers in basic education programs. Using a cross-sectional research design with participants ranging in skill from beginning readers (similar to a 2nd grade level) to skilled readers (similar to 11th or 12th grade level) , Mellard and Fall (2012) modeled the increasing impact of oral language skills on reading comprehension.

Adults in ABE programs typically exhibit low academic and reading skills. Many of these adults are able to read, comprehend, and draw inferences from low-level texts only (Sabatini et al., 2010). Recent studies investigating component skills with adult struggling readers (Hall, Greenberg, & Laures-Gore, 2014; MacArthur, Konold, Glutting, & Alamprese, 2010; Taylor, Greenberg, Laures-Gore & Wise, 2012) revealed that adults in basic education settings exhibit lower than expected reading comprehension abilities, given their oral language comprehension. Sabatini et al. (2010) postulated that reading comprehension is suppressed by poor decoding skills, and that struggling adult readers simply substitute words from their oral vocabulary when challenged with reading an unfamiliar word. Substitutions result in comprehension breakdowns that can be observed downstream in the time course of comprehension (when integration of information takes place; e.g., Hyona et al., 2003).

The Eye-Mind Link

Considerable research has revealed an intimate connection between eye movement measures and cognitive processing (see Rayner, 1988). Eye movement researchers refer to this theory as the mind-eye link and propose that on-line analysis of eye movements reveals the underlying cognitive processes taking place. Thus, information gathered about global and local movement patterns of the eyes can serve as a proxy for the cognitive processing mechanisms in operation. Analysis of the global eye movement measures provides general information about how a reader approaches text and the level of automaticity that the individual brings to the task (Inhoff & Radach, 1998). Local eye movement patterns can be analyzed to determine within subject effects of word or text characteristics. The current study utilizes mainly global eye movement measures, the only exception being n+1 fixation duration. With global movements, the evaluation of both temporal and spatial eye movements is important, as they serve to contribute different information to the analysis (Inhoff & Radach, 1998). Temporal variables provide time course measures: durations of movements and fixations. Spatial variables provide distance and direction measures of movements between fixations.

Eye Movement Characteristics

As the eyes move through text, they do not do so smoothly. The eyes actually progress in a stop-and-go fashion, with visual information relayed to the brain only during the stops (fixations) that can occur as often as several times per second or as seldom as once per several seconds. While the eyes move from one fixation to the next (saccade), visual information is not relayed to the brain. This phenomenon has been exploited in research studies by covertly changing text in order to examine different preview effects.

Typical adult readers employ fixation durations (stops) lasting between 200 and 250ms, depending on the processing demands of the word. They also regress to earlier text approximately 10 to 15% of the time and exhibit saccade lengths of about 8 character spaces (Blythe & Joseph, 2011; Rayner, Chace, Slattery, & Ashby, 2006; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Beginning readers aged 6 to 8 years, on the other hand, exhibit longer fixation durations - lasting from 280 to as many as 432ms, mean saccade lengths ranging between 2.8 and 5.3 letters, and regress approximately 34 to 36% of the time (Huestegge, Radach, Corbic, & Huestegge, 2009; McConkie, Zola, Grimes, Kerr, Bryant, & Wolff, 1991; Rayner, 1986). Fixation duration is believed to be an immediate measure of word recognition, and paired with gaze duration may measure a participant's decoding ability (Hyona, Lorch, & Rinck, 2003). Gaze duration is also believed to capture lexical processing time (Hyona et al., 2003) while regressive saccades may capture a reader's attempt to repair comprehension breakdowns. In addition to the variables previously mentioned, eye movement variables of total viewing time and n+1 fixation duration are believed to capture delayed effects of lexical-semantic access and information integration (Hyona et al., 2003), meaning that slower processing of lower-frequency words can be observed downstream, when the eyes fixate the word following lower-frequency word.

Comparing the values established for each age group and level of comprehension to individual participant means in a given study allows researchers to establish course-grained measures of processing time, level of automaticity, and familiarity with the text. This analysis also provides information about how the reader (or group of participants, as in the current study) strategically approaches the text (Ashby, Rayner, & Clifton, 2005; Inhoff & Radach, 1998; Rayner et al., 2006).

Research Design and Research Questions

The current study consisted of two parts. First, a comparison study utilized tests of mean differences between matched pairs of low-skilled adult readers and typically-developing beginning readers to test for differences between the two groups' reading skills and key eye movement behaviors. Second, inferential statistics were used to explore models of reading behavior via two sets of multiple regression analyses. In order to evaluate whether the two groups of readers are different on language and reading comprehension, the two samples were matched on word reading skill, as assessed by the raw scores of the Woodcock Johnson III Letter Word Identification subtest. The first research question was: do low-skilled adult readers differ from typically-developing beginning readers in language comprehension, passage reading comprehension, or eye movement behavior? The second research question was: to what extent is language comprehension related to reading comprehension for these two groups of readers? The third research question was: do eye movement variables account for unique variance, above and beyond word reading skill and language comprehension, when added to the simple view of reading model for the two groups of readers?

Hypotheses and Implications

The first research question was asked to investigate group differences in eye movement measures and language and reading comprehension skills. First fixation duration and gaze duration are theorized to capture immediate word effects, while total viewing time and n+1 fixation duration are theorized to capture delayed effects of word knowledge (e.g., Hyona, et al., 2003). Therefore, the first hypothesis in the current study was that, due to being matched on word reading skill, the adult participants would not be significantly different from the child readers on measures of immediate word effects (first fixation duration and gaze duration).

However, a second hypothesis for the first research question was that the adults in the current study would be significantly higher than the children on the measures of language and reading comprehension, and significantly lower on total viewing time and n+1 fixation duration. The difference in language comprehension was expected because, due to more worldly experience, adult readers typically have a much larger oral vocabulary and richer semantic connections for words than children. Since language comprehension is correlated with reading comprehension (Hoover & Gough, 1990), the adults were hypothesized to perform higher on reading comprehension as well. The difference in eye movement variables such as total viewing time and n+1 fixation duration were predicted to result from higher comprehension levels.

The second research question addressed the relation of language comprehension to reading comprehension. Language comprehension becomes more strongly correlated with reading comprehension in the later years of education (Hoover & Gough, 1990); therefore, it was hypothesized that language comprehension would account for more variance in the second step of the adult model (compared to the child model) after controlling for word reading skill.

The third research question explored the relation between eye movement measures and reading comprehension when controlling for word reading and language comprehension skills. Current research in the field indicates a direct relation between eye movement variables and both immediate (fixation duration) and delayed (gaze duration and n+1 fixation duration) word knowledge (Hyona et al., 2003; Inhoff & Radach, 1998). Therefore, these eye movement measures may provide additional information about the cognitive processes of reading which may not be captured by component skill assessments (such as word reading and language comprehension assessments).

CHAPTER TWO

METHODS

Participants

Adult participants selected for this study were drawn from a larger study (Barnes, et al., under review) which utilized a nonrandom convenience sample from an adult basic education campus in northern Florida. This sampling method was chosen due to the relatively small population of adults with low literacy. The children in this study were drawn from a larger study across two school districts in northern Florida. The adult participants were matched on raw scores for the Woodcock-Johnson III Letter Word Identification subtest with typically developing first-grade students. Matching resulted in 25 matched pairs, with 6 matches made $\pm$ 1 raw score point, and the remaining 19 matches using identical raw scores.

Adults with Low Literacy

The adult participants in the current study included 25 adults (48% female, mean age 25 years) enrolled in a north Florida Adult Basic Education center during the spring semesters of academic years of 2012-2013 and 2013-2014, drawn from a larger study of struggling adult readers (Barnes, et al., under review). These participants were enrolled in literacy classes instructing all levels of primary and secondary literacy (i.e., beginning readers through middle-school level) and received a ten-dollar gift card for their participation. In order to exclude individuals with known cognitive deficits and to focus on low-skilled adult readers, individuals enrolled in classes geared toward instructing students with exceptionalities were not included in the sampling process of the original study and are not believed to have been represented in the current study. All but one participant were native English speakers. The one non-native English speaker communicated proficiently with research assistants and was described by the classroom teacher as being proficient in reading and speaking English at a level equivalent to peers, as she had lived in the United States and spoken English since childhood. This was likely not a representative sample of this population, as it was drawn from a single campus over a 12 month period.

Skill-Matched Beginning Readers

The typically-developing first-grade beginning reader participants who have been matched to the adults for the current study include 25 elementary children (48% female, mean age 7 years) drawn from a larger study aimed to assess reading skills and reading fluency development.

Materials and Measures

For the current study, the constructs of decoding, language comprehension and reading comprehension were measured using standardized subtests from the Woodcock-Johnson III Diagnostic Reading Battery (WJIII-DRB; Woodcock, Mather, & Schrank, 2004). Measures were dichotomously scored and reliability information is included in table 1. Due to large differences in age between the two groups of participants, raw scores were used in the tests of mean differences and regression analyses. EyeLink1000 (SR Research, 2013) hardware and software were used to collect temporal and spatial eye movement data at 500Hz, which provided temporal measures in 2-millisecond intervals (500 measures per second).

Reading and Language Measures

Word reading. The Letter Word Identification (LWID) subtest of the WJIII-DRB was used as a measure of word reading accuracy. The assessment consists of lists of words for the participant to read, beginning with single letters and progressing to increasingly complex and less-frequent polysyllabic words. The LWID subtest has a median reliability of .91 for children aged 5 to 19 years and a median reliability of .94 for adults (Schrank, Mather, & Woodcock, 2004). Cronbach's alpha for the current sample was: adults .88, children .88.

Reading comprehension. Two measures were used to assess reading comprehension. Passage reading comprehension was assessed using the Passage Comprehension subtest of the WJIII-DRB. This subtest assesses reading comprehension by requiring participants to complete a cloze activity. This task requires the use of vocabulary and comprehension skills to fill in the missing word in each progressively more complex passage. The Passage Comprehension (PC) subtest has a median reliability of .83 for children aged 5 to 19 years and a median reliability of .88 for adults (Schrank et al., 2004). Cronbach's alpha for the current sample was: adults .75, children .68. All of the Woodcock-Johnson III subtests are standardized and norm-referenced, and provide a raw score that can be used in conjunction with the participant's age to attain derived standard scores [*M*=100(*SD*=15)] as well as age and grade equivalencies. Sentence comprehension efficiency was assessed using the Test of Silent Reading Efficiency and Comprehension (TOSREC ; Wagner et al, 2010). This assessment presents a series of sentences (i.e. 'A cow is an animal.') and participants read each sentence then indicate whether the sentence was true or false. The TOSREC is typically a group-administered, paper-based assessment. However, for the purposes of the studies that the current study draws upon, this task was adapted to digital administration using the EyeLink1000 system (SR Research, 2013).

Language comprehension. The Oral Comprehension subtest of the WJIII-DRB was used as a measure of oral language comprehension. This assessment is an oral version of a cloze activity where the participant uses syntactic and semantic clues to provide a missing word in a short passage. The Oral Comprehension (OC) subtest has a median reliability of .80 for children aged

5- 19 years and a median reliability of .89 for adults (Schrank, et al., 2004). Cronbach's alpha for the current sample was: adults .60, children .82.

Eye-Tracking

Eye movement variables in the current study were comprised of both temporal and spatial variables. Temporal eye tracking variables included fixation duration, gaze duration, total viewing time, and n+1 fixation duration. Each fixation was measured independently. The current standard in eye tracking research publications is to use the fixation durations without including saccade times (e.g., Ashby, Yang, Evans, & Rayner, 2012; Vorstius, Radach, Mayer, & Lonigan, 2013, Barnes, et al., under review). Therefore, in the current study, saccade times were not included in temporal variables. **Fixation duration** measured mean processing time for words that are only fixated once (Rayner, 1988). In the current study, this was the duration of the first fixation on each word. **Gaze duration** measured mean word processing time when the word is fixated more than once (Rayner, 1988). This was the sum of all fixation durations on the word prior to the movement of the eyes to another word. **Total viewing time** included the first gaze duration as well as all re-readings of a word. This was the total amount of time the reader looks at any letter in (or part of) the word. **N+1 fixation duration** measured processing time for low-frequency words and represented the first fixation duration for word n+1 (the next word) for a subset of the words in the experiment. In order to analyze effects of semantic processing, the words included in the n+1 fixation duration were those with a standard frequency index rating (Zeno, Ivens, Millard, & Duvvuri, 1995) less than 30 per million words of text (and which do not appear as the final word in the sentence; n = 13 words). This number was chosen because the lowest frequency index rating of all words in the oral sentence reading task was 1, the frequency ratings quickly increased, and this subset of 13 words represented 12 percent of the words presented in the task. These are the words of which comprehension of meaning was necessary for comprehension of the sentences.

Spatial eye tracking variables included initial landing position, saccade amplitude, skipping rate, and proportion of regressive saccades. **Initial landing position** measured the position of the letter (within the word) where the eyes land when they first look to a word. **Saccade amplitude** measured the distance (in letter spaces) the eyes move between fixations on progressive (forward-moving) saccades. **Skipping rate** measured the percentage of words that were not fixated either in first pass or via regressions. **Proportion of regressive saccades** measured the percentage of saccades that end on text or space occurring earlier than the start of the saccade (i.e., regressing to earlier text).

Eye Tracking Material

An electronic version of the TOSREC (Wagner, et al., 2010) for first grade readers was used for both sets of participants. Participants were asked to read each sentence and submit their answers via a button response box. A total of seven sample sentences were administered before the actual assessment, and participants were provided opportunities to ask questions about the procedure. In any instance where the participant was unsure of the procedure, the directions and practice exercises were discussed until a clear understanding was established. Eye movement patterns were recorded during this task, and the participants in each study completed as many sentences as possible in a time window of four minutes of text exposure. This means that time was counted from the beginning (sentence presentation) to the end (button press by participant) of each trial and tallied until the participant reached the four-minute threshold.

Apparatus

All sentence text was presented on a 21-inch Viewsonic monitor with a gray background, at a resolution of 1024 x 768 (32 bits per pixel) with a refresh rate of 75Hz. Text was presented in Courier New 15 point type so that each character fills the same amount of horizontal space. There was 78cm of viewing distance between the monitor and the participants' eyes, with one character of text filling .5 degrees of visual angle. Viewing and data collection were binocular using an EyeLink1000 eye tracking system (SR Research, 2013) and a sampling rate of 500Hz. Participants in each study were asked to keep their heads positioned on a chin rest and their forehead against a bar to minimize head movements. Before the start of each experiment, the tracker's accuracy was checked and calibrated. An additional opportunity to recalibrate was provided after every fifth sentence. Measurement accuracy was maintained via repeated calibration and validation as needed (McConkie, 1981). After each sentence, the participants pressed either a green button to indicate the sentence was correct, or a red button to indicate the sentence was incorrect.

Procedure

For both groups of participants, the eye movement data collection began with a three-point calibration of the eye-tracking system. The operator initiated a sequential presentation of three fixation points, spread across the screen in a line pattern to cover the areas where the text appeared. The calibration step was considered successful when all points were fixated to within .5 degree of visual angle of the marked points. Participants responded to sentences until they reached the four-minute threshold. The WJIII component skill achievement assessment battery was also administered in a one-on-one setting with each participant. All data were collected by trained graduate research assistants who were familiar with the equipment, the tests, and standardized testing procedures.

Analytic Method

Fixation and saccade data points were collected using EyeLink1000 software (SR Research, 2013). After collection, the data were visually inspected using EyeMap software (Tang, Reilly, & Vorstius, 2012) to detect any problems with the data. All data files were used in the current analysis. Pairs of fixations were aggregated to fixation-based and word-based matrices and imported into SPSS (IBM Corp., 2012). The data were checked for extreme scores and some data points were excluded from the analysis.

The theoretical basis for excluding fixations and gazes below or above a certain threshold is such that words fixated for a very short time are not cognitively processed while words fixated for an extremely long time are statistical outliers. There appears to be no specific standard in the field - neither in the literature as a whole, or nor even by the same researchers across studies. For example, Ashby, Rayner, and Clifton (2005) cut off fixations shorter than 120ms, citing that readers are not cognitively capable of processing a word in less than 120ms while Ashby, Yang and Rayner (2012) included fixations between 80 and 800ms in their analysis. Recent research (Vorstius et al., 2013; Barnes, et al., under review) indicates that excluding fixations below 70ms provides a reasonable cutoff that does not exclude a large portion of data. Additionally, fixation durations above 1200ms will be excluded, as will be gaze durations above 2400ms, and total viewing durations above 4800ms. This approach allows for multiple maximum fixations of each word and multiple looks to a word, given the maximum fixation duration of 1200ms. This process resulted in the exclusion of 3.9% of the data, leaving 96.1% of the data in the analysis set.

Adult participants were matched to a sample of beginning readers based on word reading skill (as assessed by raw scores from the WJIII-DRB Letter Word Identification). This matching process resulted in high-skilled beginning readers relative to other first grade students being matched with lower-skilled adult readers. Similar to the current study, Sabatini and colleagues (2010) found non-normal distributions of component reading skills in their sample of 515 participants. Non-parametric tests were conducted to account for the non-normality of the data distribution of two variables, as well as the dependency created by matching participants. Specifically, the Wilcoxon signed-ranks tests of mean differences for matched pairs were performed to test for group differences in the two eye movement variables with non-normal distributions and paired-samples t-tests were used to test for group differences for the remaining variables.

Power Analyses

A sensitivity power analysis for a Wilcoxon signed-ranks t-test (for matched pairs) was performed by GPower 3.1 (Faul, Erdfelder, Buchner, & Lang, 2009). This analysis revealed that for tests of mean differences with two groups (25 participants in each group), power of .80 and alpha of .007 (.05/7 separate t-tests: Oral Comprehension, Passage Comprehension, TOSREC, first fixation duration, gaze duration, total viewing time, and n+1 fixation duration), a moderate effect size of .48 was needed to detect mean differences between the two groups. Sensitivity power analyses for F-tests revealed that with power of .80 and alpha of .05, a multiple linear regression model with 2 (and 4) predictor variables (Simple View of Reading & Simple View plus Eye Movements Models) required an effect size of .44 (and .63) to reach statistical significance for each group.

CHAPTER THREE

RESULTS

Descriptive Statistics & Bivariate Correlations

Table 1 summarizes the level of skill exhibited on reading and language measures as well as eye movement measures by both the sample of adults in basic education classes and the typically-developing child readers. Where available, standard scores are reported (TOSREC first grade assessment is not normed with adults and standard scores are therefore unavailable).

For the adults, standard scores for the current sample were as follows: *M* = 70 (*SD* = 13.5) in Letter Word Identification; *M* = 71 (*SD* = 11.0) in Passage Comprehension; and *M* = 87 (*SD* = 7.5) in Oral Comprehension. Performance on the Letter Word Identification for this group fell more than one standard deviation below the adult normative group. Passage Comprehension was also nearly one SD lower than the adult normative mean with a corresponding age equivalency of about 7 years, 3 months. Although Oral Comprehension scores within one standard deviation of the normative mean, a raw mean score of 20 (20^{th} percentile) was still relatively low. For the eye movement variables, the sample of adults exhibited the following characteristics: *M* = 296 (*SD* = 44.3) in fixation duration; *M* = 409 (*SD* = 78.4) in gaze duration; *M* = 650 (*SD* = 175.9) in total viewing time; *M* = 297 (*SD* = 78.6) in n+1 fixation duration; *M* = 1.5 (*SD* = 0.19) in initial landing position; *M* = 1.7 (*SD* = 0.42) in saccade amplitude; *M* = 0.21 (*SD* = 0.09) in skipping rate; and *M* = 0.35 (*SD* = 0.10) in proportion of regressive saccades. Fixation duration of 296 was higher than typical adults' average of 200-250ms, saccade amplitude of 1.7 was much shorter than typical adults' saccade amplitude of around 8 character spaces, and proportion of regressive saccades of 35% was higher than typical adult readers of 10-

15 percent (typical adult variables from: Blythe & Joseph, 2011; Rayner, Chace, Slattery, & Ashby, 2006; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989).

For the children, standard scores for the current sample were as follows: *M* = 125 (*SD* = 14) in Letter Word Identification; *M* = 112 (*SD* = 11.6) in Passage Comprehension; and *M* = 119 (*SD* = 17) in Oral Comprehension. Additionally, standard scores for the children's TOSREC were *M* = 123 (*SD* = 32). Performance on the Letter Word Identification for this group fell more than one standard deviation above the child normative group. Passage Comprehension was within one standard deviation, but high around the 80th percentile with a corresponding age equivalency of 8 years, 1 month. Oral Comprehension and TOSREC scores fell more than one standard deviation above the child normative group. For the eye movement variables, the sample of children exhibited the following characteristics: *M* = 293 (*SD* = 46.3) in fixation duration; *M* = 414 (*SD* = 72.6) in gaze duration; *M* = 647 (*SD* = 117.4) in total viewing time; *M* = 287 (*SD* = 71.7) in n+1 fixation duration; *M* = 1.5 (*SD* = 0.24) in initial landing position; *M* = 1.7 (*SD* = 0.36) in saccade amplitude; *M* = 0.23 (*SD* = 0.12) in skipping rate; and *M* = 0.31 (*SD* = 0.09) in proportion of regressive saccades. Fixation duration of 293 was typical for 6-8 year old readers, saccade amplitude of 1.7 was slightly shorter than expected for 6-8 year old readers' saccade amplitude of around 2.8-5.3 character spaces, and proportion of regressive saccades of 31% was slightly lower than typical 6-8 year old readers' regressions of 34-36 percent (typical child variables from: Huestegge, Radach, Corbic, & Huestegge, 2009; McConkie, Zola, Grimes, Kerr, Bryant, & Wolff, 1991; Rayner, 1986).

Table 2 and Table 3 display correlations for each group. Many significant relations were found within and between eye movement measures and component skill assessments. For the adults, Passage Comprehension was positively correlated with both Letter Word Identification (*r*

= .46, $p = .02$) and Oral Comprehension ($r = .65$, $p < .001$); however, Letter Word Identification and Oral Comprehension were not correlated with each other ($r = .14$, $p = .51$). The TOSREC measure was correlated with all component skill assessments (rs = .43 to .59, ps < .03) and negatively correlated with temporal eye movement measures (rs = -.47 to -.91, ps < .02). Temporal measures of global eye movements (fixation duration, gaze duration, total viewing time, and n+1 fixation duration) were negatively correlated with Letter Word Identification (rs = -.50 to -.55, ps < .02) and Passage Comprehension (rs = -.59 to -.66, ps $\leq$ .002). The only spatial measure of eye movements correlated with the component skill assessments was skipping rate, which was moderately correlated with Letter Word Identification ($r = .50$, $p = .01$) and the standard score for Passage Comprehension ($r = .41$, $p = .04$).

For the children, Passage Comprehension was positively correlated with both Letter Word Identification ($r = .71$, $p < .001$) and Oral Comprehension ($r = .81$, $p < .001$), and Letter Word Identification and Oral Comprehension were moderately correlated with each other (r = .51, $p = .01$). The TOSREC measure was correlated with Letter Word Identification ($r = .45$, p = .02) and Passage Comprehension ($r = .42$, $p = .04$) and the standard score for Oral Comprehension ($r = .40$, $p = .05$), but not the raw score ($r = .34$, $p = .10$). The TOSREC measure was also negatively correlated with two of the temporal eye movement measures: gaze duration ($r = -.66$, $p < .001$) and total viewing time ($r = -.72$, $p < .001$). Gaze duration appeared to be the only temporal eye movement variable related to Passage Comprehension ($r = -.43$, $p = .03$) and Oral Comprehension ($r = -.43$, $p = .03$). Of the spatial eye movement variables, saccade amplitude was correlated with Oral Comprehension ($r = .42$, $p = .04$) and Passage Comprehension ($r = .51$, $p = .01$), and skipping rate was correlated with Letter Word Identification ($r = .41$, $p = .04$) and Passage Comprehension ($r = .42$, $p = .04$).

Observations of Tables 2 and 3 reveal interesting trends of correlations. For the children, correlations of larger magnitude were observed between component skills and for the relation of component skills to passage reading comprehension (as compared to adults). The children also exhibited a fewer number of statistically significant correlations between eye movement variables and component skills. The adults, on the other hand, not only exhibited a higher number of statistically significant correlations between eye movement variables and component skills, but also exhibited correlations of stronger magnitude for component skills and the sentence comprehension efficiency measure. The differing trends of correlations between component skill assessments and eye movement measures and may reveal group-specific variations in cognitive processing not captured by component skill assessments.

Research Question 1

In order to address the first research question, 'Do low-skilled adult readers differ from typically-developing beginning readers in language comprehension, passage reading comprehension, or eye movement behavior?' tests of mean differences were performed comparing the adults and children. While all variables showed skewness values with an absolute value less than 1.3, two variables exhibited high kurtosis values in the children's data (2.3 for fixation duration and 2.8 for n+1 fixation duration; see Table 1). Therefore, Wilcoxon signed-ranks t-tests were performed for these two comparisons and paired-samples t-tests were performed for the remaining comparisons. The Wilcoxon Signed-ranks tests indicated no group effects for either fixation duration ($Z = -.44$, $p = .66$) or n+1 fixation duration ($Z = -.74$, $p = .46$). Paired-samples t-tests indicated no group effects on raw scores for Oral Comprehension [$t(24) = 1.75$, $p = .09$], Passage Comprehension [$t(24) = 0.74$, $p = .46$], TOSREC [$t(24) = 0.57$, $p = .57$], gaze duration [$t(24) = -.027$, $p = .79$], or total viewing time [$t(24) = -.068$, $p = .95$]. See Tables 4 and 5 for these comparisons.

Research Question 2

In order to address the second research question, 'To what extent is language comprehension related to reading comprehension for these two groups of readers?' regression models were built using the participants' raw scores. Step one of the regression models included Letter Word Identification and step two included Oral Comprehension as predictors. Standardized beta weights and unstandardized beta weights are presented in Tables 6 and 7.

Passage Comprehension Outcome

Table 6 displays these models. For the adults, Letter Word Identification accounted for 21% of the variance in Passage Comprehension ($p = .02$), with a standardized regression weight of $\beta = .46$. In step two, Letter Word Identification and Oral Comprehension accounted for 56% of the variance in Passage Comprehension ($p < .001$). The standardized regression weights were as follows: Letter Word Identification ($\beta = .38$, $p = .02$) and Oral Comprehension ($\beta = .59$, $p < .001$), and both variables were significant predictors in the model. Including Oral Comprehension resulted in .35 change in r-square. For the children, Letter Word Identification accounted for 50% of the variance in Passage Comprehension ($p < .001$), with a standardized regression weight of $\beta = .71$. Letter Word Identification and Oral Comprehension accounted for 78% of the variance in Passage Comprehension ($p < .001$). The standardized regression weights were as follows: Letter Word Identification ($\beta = .40$, $p = .003$) and Oral Comprehension ($\beta = .61$, $p < .001$), and both variables were significant predictors in the model. Including Oral Comprehension resulted in .28 change in r-square. While the model was highly significant for both groups, Oral Comprehension (verses Letter Word Identification) appeared to be more predictive for the adults (compared to the children). Including both Letter Word Identification and Oral Comprehension in the model resulted in a larger r-square value in the child model (compared to the adult model).

TOSREC Outcome

Table 7 displays these models. For the adults, Letter Word Identification accounted for 19% of the variance in Passage Comprehension ($p = .03$), with a standardized regression weight of $\beta = .44$. In step two, Letter Word Identification and Oral Comprehension accounted for 33% of the variance in Passage Comprehension ($p = .01$). The standardized regression weights were as follows: Letter Word Identification ($\beta = .39$, $p = .04$) and Oral Comprehension ($\beta = .38$, $p < .04$), and both variables were significant predictors in the model. Including Oral Comprehension resulted in .14 change in r-square. For the children, Letter Word Identification accounted for 20% of the variance in Passage Comprehension ($p = .02$), with a standardized regression weight of $\beta = .45$. In step two, the model was non-significant ($p = .07$) with standardized regression weights of: Letter Word Identification ($\beta = .38$, $p = .10$) and Oral Comprehension ($\beta = .15$, $p = .50$). Including Oral Comprehension did not significantly improve the model. The differences in regression outcomes reflect differing trends of correlations found for each group of participants. The adults exhibited more statistically significant correlations (and correlations of higher magnitude). A single point difference in language comprehension for adults was related to nearly a three-fourths point difference on Passage Comprehension and a one-and-one-fourth point difference on TOSREC, whereas for children a single point difference in language comprehension was related to less than one-half of a point difference on Passage Comprehension and no significant difference on TOSREC.

Research Question 3

In order to address the third and final research question, 'Do eye movement variables account for unique variance, above and beyond word reading skill and language comprehension, when added to the simple view of reading model for the two groups of readers?' the models from research question 2 were extended to include eye movement variables. In addition to word reading and language comprehension, Step three in the hierarchical regression models included processing time (gaze duration) and proportion of regressive saccades as predictor variables. Standardized beta weights and unstandardized beta weights are presented in Tables 6 and 7.

Passage Comprehension Outcome

Table 6 displays these models. For the adults, 56% of the variance had been accounted for in step two. Step three explained an additional 12% of variance, resulting in 68% of variance explained ($p < .001$). The regression weights were as follows: Letter Word Identification ($\beta = .17$, $p = .28$), Oral Comprehension ($\beta = .59$, $p < .001$) Gaze Duration ($\beta = -.42$, $p = .02$) and Regressive Saccades ($\beta = .02$, $p = .87$). For the children, step two significantly accounted for 78% of the variance and step three did not explain any additional variance. Letter Word Identification ($\beta = .38$, $p = .003$) and Oral Comprehension ($\beta = .60$, $p < .001$) remained significant predictors while Gaze Duration ($\beta = -.02$, $p = .84$) and Regressive Saccades ($\beta = .06$, $p = .56$) did not significantly contribute to the model.

TOSREC Outcome

Table 7 displays these models. For the adults, 33% of the variance had been accounted for in step two. The inclusion of the eye movement variables in step three resulted in an additional 40% of variance explained ($p < .001$). Gaze Duration ($\beta = -.61$, $p < .001$) was a significant predictor, as was Regressive Saccades ($\beta = -.45$, $p = .001$) and Oral Comprehension

($\beta = .27$, $p = .04$). Letter Word Identification ($\beta = .08$, $p = .55$) was no longer a significant predictor. For the children, 20% of the variance had been accounted for in step two. Step three explained an additional 30% of the variance and made the model statistically significant. The only predictor with a significant beta weight was Gaze Duration ($\beta = -.59$, $p = .003$). The remaining three: Letter Word Identification ($\beta = .28$, $p = .14$), Oral Comprehension ($\beta = -.02$, $p = .93$), and Regressive Saccades ($\beta = -.19$, $p = .25$). Overall, with each increase of 100ms in processing time, TOSREC raw score decreased by 8 points for adults and 6 points for children.

CHAPTER FOUR

DISCUSSION

This study revealed interesting reading and comprehension patterns for two groups of readers. Significant differences were not found on the level of skills but correlation and multiple regression analyses revealed slightly different patterns of relations between components of word reading, language comprehension, passage reading comprehension, sentence comprehension efficiency, and eye movement measures. The moderate-to-high-magnitude correlations between word reading, language comprehension, and reading comprehension measures validate the measurement of these variables (e.g., Cutting & Scarborough, 2006).

The children were, on average, one standard deviation above their normative group in language comprehension ability. The adults (with many more years of language experience) did not perform any higher than the advanced first grade students on language comprehension. This finding reveals a serious deficit in language skills for these adults. Similar non-significant differences were found for reading comprehension and eye movement measures. This means that the adults exhibited reading skills very much like those exhibited by skilled first grade students.

While standardized scores are not available for eye movement measures, the children appeared to perform higher than their peers (see norms mentioned above by Huestegge, Radach, Corbic, & Huestegge, 2009; McConkie, Zola, Grimes, Kerr, Bryant, & Wolff, 1991; Rayner, 1986) while the adults appeared to perform much lower than their peers on these measures (see norms mentioned above by Blythe & Joseph, 2011; Rayner, Chace, Slattery, & Ashby, 2006; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989). Statistically non-significant differences in the eye movement variables revealed that the two groups of readers essentially behaved in similar ways when presented with the text stimulus. Their eyes initially landed at approximately the same location - the first or second letter in the word; the temporal length of their initial fixation, first gaze, and total viewing time for words was similar; and the length and direction of their eye movements during saccades was also similar (saccade amplitudes of 1 to 2 characters and approximately one-third of saccades were regressive). Analysis of the readers' regressive saccades revealed that both groups of readers regressed, on average, approximately 2 words back to re-read text. Although we do not know whether regressions were due to semantic clarifications, comprehension breakdown, or the oral reading paradigm (i.e., concerns for making oral reading mistakes, articulation processing difficulties, etc.), we can see that the two groups of readers behaved in very similar ways. Typically, increased reading experience is correlated with increased saccade amplitude (Rayner, et al., 2006), but the adults in the current study did not exhibit saccade amplitudes typical of more advanced reading skills. We had no way of measuring the adult's actual reading experience, so we are unable to say if the adults were, in fact, more experienced readers compared to the children. Pairing temporal and spatial findings with nearly identical skipping rates means that the adults essentially looked like beginning readers in terms of eye movement behaviors during reading.

The patterns of relations were different between the children and the adults such that the children exhibited correlations of stronger magnitude between the component skill assessments. These stronger-magnitude correlations resulted in more variance explained in the children's regression model predicting passage reading comprehension. On the other hand, more and higher-magnitude correlations between eye movement measures and the sentence comprehension reading resulted in more variance explained in the adult's regression model predicting sentence comprehension efficiency.

Step one of the regression analyses allowed an observation of the effect that word reading skills had on reading comprehension outcomes, and step two allowed for observation of the effect that language comprehension had on reading comprehension. In both models, the r-square change between step one and step two was larger for the adults. This indicates that after controlling for word reading, language comprehension appeared to more strongly impact the low-skilled adults' comprehension processes than it did the children's comprehension processes.

In step three in the model predicting passage reading comprehension, the eye movement measures of processing time (gaze duration) and regressive saccades were highly significant for the adults in both models but provided no additional information for the children. This regression model revealed that an increase of 100ms (one-tenth of one second) in processing time was related to a Passage Comprehension score decrease of two points for the adults. This measure of processing time (gaze duration) appeared to uniquely capture the adult's word reading struggle in connected text reading above and beyond word reading and language comprehension, yet did not capture the same information for the children.

Conversely, for sentence comprehension efficiency (TOSREC), processing time (gaze duration) was significant for both groups of readers and re-reading text (regressive saccades) was predictive for the adults. Re-reading text slowed down the reading process and decreased efficiency, and regressions to previously read text resulted in fewer items completed within the time limit. For the adults, rereading text (regressive saccades) accounted for variance above and beyond gaze duration, language comprehension, and word reading such that regressing an average of once per sentence was related to a score decrease of nearly 47 points (out of 55 total possible). It is unclear whether regressive saccades were made to verify comprehension or facilitate integration, but regressions ultimately resulted in lower final scores on TOSREC for the adults but had no significant impact on the children's scores. It is not clear if this was because rereading slowed the adult readers down significantly more so than the children, whether the rereading behavior indicated poorer comprehension by the adults, or some combination of the two.

Since total viewing time includes all time spent reading (decoding, processing time, and higher-level text integration), additional models (not shown) were built using total viewing time instead of gaze duration. Using total viewing time instead of gaze duration resulted in models where regressive saccades were non-significant for both adults and children, indicating that it was not the number of times a reader regressed that was important, but rather the amount of time spent rereading the text.

Analysis of all the models reveals that for adults more so than for children, processing time matters over and above word reading and language comprehension. For adults, recognizing the same words out of context may be different than recognizing words in context. This means that when considering reading outcomes, the ability to recognize words is important for comprehension at both the sentence and passage levels, but the time needed to access those words is also important.

Adults enrolled in basic education programs often bring with them a limited set of literacy skills. The current findings reveal the adults' increased reliance on language skills, yet in addition to language skills, an ability to decode the written form of language is required for reading comprehension (Hoover & Gough, 1990). Furthermore, research indicates that reading fluency (children - Fuchs, Fuchs, Hosp, & Jenkins, 2001; Kim, Wagner, & Lopez, 2012; Klauda, & Guthrie, 2008; adults - Rasinski, et al., 2005) as well as vocabulary knowledge (children - Ouellette, 2006; Ouellette, & Beers, 2010; adults - Braze, et al., 2007; Sabatini et al., 2010) play unique roles in comprehension. The current preliminary findings, taken together with other studies of adults (e.g., Braze, et al., 2007; Catts, Adlof, & Weismer, 2006; Joshi, Tao, Aaron, & Quiroz, 2012; Mellard & Fall, 2012; Ouellette, 2006; Sabatini et al., 2010), suggest that improving word reading and oral language skills are important for improving reading comprehension in this population of adult learners.

CHAPTER FIVE

CONCLUSION

Matching two groups of readers on word reading skill, the current study empirically compared adults in basic education to typically-developing children on measures of eye movements, reading comprehension, and language skills. The methodology used to identify participants and match these two groups of readers introduced several limitations.

Limitations and Future Directions

Multiple viable threats to statistical conclusion, construct, and external validity existed in the current study. First, these were relatively small samples, so the statistical results must be interpreted with caution. Several comparisons were made and alpha was adjusted to .007 (based on seven separate t-tests) to overcome the error rate problem of inflated statistical significance associated with conducting tests of all possible pairwise comparisons. Therefore, low-powered statistical t-tests may have erroneously supported the null hypothesis that the difference between sample means (and the represented populations) was zero. Additionally, within-group heterogeneity of ABE participants and the increased variability associated with that heterogeneity may have increase error variance and made relations between variables more difficult to detect. Correlational findings were different between the two groups, and this too may have been due to ABE group heterogeneity.

Each construct in the present study was measured using a single measurement tool (achievement test or computer observation). This means that construct and time sampling error (as well as the true score) were included in the participants' raw scores and the creation of latent variables was not possible. Moreover, the language comprehension measure used in the current study may not have captured complex language skills such as inferencing and exhibits a lower than expected reliability for the adults in the study; therefore, the regression analyses using this variable as a predictor must be interpreted with caution. Assessments focusing on more specific language skills may have revealed more strengths and weaknesses in both the children's and adult's language use skills in all languages spoken. The assessments included in the current study were not normed specifically on adults with low literacy, so it is unknown how reliably the component skills were measured for the adults. In particular, the TOSREC used was the grade one form and standardized scores for the adults were not available. Additionally, the relatively small number of adults in the current study were sampled from a single site and collected during a single 12-month period. The typically-developing skill-matched beginning readers were sampled across two school districts. The readers in each group may not be representative of all individuals within those two populations of readers. Results from the current study must be interpreted with these threats to validity in mind.

Another major limitation in the current study was the less than ideal reliability for the Oral Comprehension measure for the adults (Cronbach's alpha of .60). This low reliability may have affected multiple regression analysis such that lower or non-significant beta weights for language comprehension for the current adult sample may have been observed. A larger battery of assessments may have enabled latent trait analysis, which may have provided more reliable results. The last limitations are related to the eye tracking procedure itself. First, visual acuity was not measured for the adults, so any need for corrective lenses was not documented and may have resulted in poorer reading than was possible with any needed correction. Second, the current study used an oral reading procedure. The majority of eye tracking research is completed using a silent reading procedure. The current study implemented an oral reading procedure for both the adults and the children. Therefore, while comparisons between groups are feasible, generalizations should be limited to oral reading contexts. Future research should include both oral and silent reading paradigms to determine what pattern differences emerge between reading skill and eye movements. Furthermore, this study may not have been well-powered to detect differences between the groups on any measures. Perhaps the current finding of no differences between groups is an artifact of the combination of the high normative mean for the children and the low normative mean for the adults. Exploration of these variables of word reading, language and reading comprehension, and eye movements with larger groups (of both adults and children) may reveal detectable differences in underlying patterns of reading skills.

APPENDIX A

TABLES

Table 1

Descriptive Statistics and Internal Consistency

Variable	Adult					Child				
	Mean (SD)	Range	Skew	Kurtosis	Alpha	Mean (SD)	Range	Skew	Kurtosis	Alpha
Participant Age	25 (9.7)	40	1.72	3.34	n/a	7 (0.6)	3	1.28	4.74	n/a
Letter-Word Identification (LWID)										
Raw Score	50 (6.1)	27	-.84	.98	.88	50 (6.0)	27	-.80	1.18	.88
Standard Score	70 (13.5)	64	-1.56	3.88	n/a	125 (14.0)	66	-1.83	5.27	n/a
Age-Equivalency (years, months)	8, 02 (3, 11)	12.05	-1.26	.14	n/a	9, 05 (1, 01)	5	.03	.01	n/a
Passage Comprehension (PC)										
Raw Score	25 (3.8)	13	-.62	-.46	.75	25 (3.2)	12	-.45	-.50	.68
Standard Score	71 (11.0)	40	-.71	-.27	n/a	112 (11.6)	54	-.96	1.78	n/a
Age-Equivalency (years, months)	7, 00 (3, 04)	9.10	-1.36	.26	n/a	8, 01 (0, 10)	3.01	.81	.60	n/a
Oral Comprehension (OC)										
Raw Score	20 (3.2)	11	-.10	.98	.60	18 (4.6)	16	-.45	-.87	.82
Standard Score	87 (7.5)	24	-.32	-1.03	n/a	119 (17.0)	67	-.55	-.34	n/a

Table 1, con't

Variable	Adult					Child				
	Mean (SD)	Range	Skew	Kurtosis	Alpha	Mean (SD)	Range	Skew	Kurtosis	Alpha
Oral Comprehension (OC)										
Age-Equivalency (years, months)	9, 09 (5, 0)	16.04	-.98	-.16	n/a	12, 04 (3, 03)	14.00	.96	1.55	n/a
Reading Efficiency & Comprehension (TOSREC)										
Raw Score	37 (10.4)	40	-1.43	1.60	.86*	36 (7.1)	24	-.51	-.85	.93*
Standard Score**	n/a	n/a	n/a	n/a	n/a	123 (9.4)	32	-.60	-.71	n/a
Eye Movement Measures										
Fixation Duration	296 (44.3)	207	1.13	2.28	n/a	293 (46.3)	191	.74	.78	n/a
Gaze Duration	409 (78.4)	294	.25	-.49	n/a	414 (72.6)	226	.33	-1.23	n/a
Total Viewing Time	650 (175.9)	578	1.25	.48	n/a	647 (117.4)	537	.54	.99	n/a
n+1 fixation duration	297 (78.6)	368	1.11	2.78	n/a	287 (71.7)	338	1.03	1.91	n/a
Initial Landing Position	1.5 (0.19)	0.8	-.49	.25	n/a	1.5 (0.24)	1.1	.35	.99	n/a
Saccade Amplitude	1.7 (0.42)	1.6	.50	-.29	n/a	1.7 (0.36)	1.4	.24	-.32	n/a
Skipping Rate	0.21 (0.090)	0.45	.81	2.16	n/a	0.23 (0.117)	0.41	.63	-.41	n/a
Proportion of Regressive Saccades	0.35 (0.100)	0.39	-.96	.67	n/a	0.31 (0.090)	0.32	.28	-.41	n/a

Note: RS = raw score, SS = standard score, *N*=25 for each group (Adults and Children). *Test-retest reliability (Wagner, Torgesen, Rashotte, & Pearson, 2010). **Grade 1 TOSREC assessment used, not normed for adults.

Table 2

Adults: Bivariate Correlations Among all Measures

Measure	Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2. LWID (RS)	-.04	--													
3. LWID (SS)	.23	87***	--												
4. PC (RS)	-.35	.46*	.33	--											
5. PC (SS)	.45*	.53**	.65***	.75***	--										
6. OC (RS)	.06	.14	.12	.65***	.49*	--									
7. OC (SS)	.21	.22	.25	.61**	.61**	.96***	--								
8. TOSREC	-.13	.44*	.34	.59**	.52**	.43*	.45*	--							
9. Fixation Duration	.23	-.55**	-.37	-.66***	-.38	-.37	-.31	-.58**	--						
10. Gaze Duration	.11	-.53**	-.31	-.65***	-.46**	-.29	-.26	-.68***	.76***	--					
11. Total Viewing Time	.15	-.51**	-.38	-.60**	-.47*	-.41*	-.40*	-.91***	.73***	.79***	--				
12. n+1 Fixation Duration	-.43*	-.50*	-.19	-.59**	-.21	-.20	-.11	-.47*	.87***	.71***	.58**	--			
13. Initial Landing Position	-.20	.05	-.07	-.07	-.07	.03	-.03	-.14	.01	-.12	.05	-.02	--		

Table 2, con't

Measure	Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
14. Saccade Amplitude	-.39	.30	.35	.05	.33	-.09	.00	-.09	.07	-.28	.00	.14	.47*	--	
15. Skipping Rate	-.01	.50*	.57**	.24	.41*	.21	.32	.24	-.26	-.24	-.30	-.15	-.06	.26	--
16. Regressive Saccades	.02	.01	-.06	.10	-.02	.06	.07	-.36	-.03	-.12	.33	-.12	.18	.37	.05

Note: LWID = Letter Word Identification, PC = Passage Comprehension, OC = Oral Comprehension, RS = raw score, SS = standard score. Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 3

Children: Bivariate Correlations Among all Measures

Measure	Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2. LWID (RS)	-.66*	--													
3. LWID (SS)	-.88***	.91***	--												
4. PC (RS)	-.52***	.71***	.64**	--											
5. PC (SS)	-.85***	.81***	.91***	.85***	--										
6. OC (RS)	-30	.51**	.44*	.81***	.64**	--									
7. OC (SS)	-.52**	.64**	.64**	.85***	.80***	.97***	--								
8. TOSREC	-.29	.45*	.44*	.42*	.44*	.34	.40*	--							

Table 3, con't

Measure	Age	2	3	4	5	6	7	8	9	10	11	12	13	14	15
9. Fixation Duration	.30	-.27	-.37	-.08	-.27	-.07	-.17	-.39	--						
10. Gaze Duration	.25	-.36	-.38	-.43*	-.44*	-.43*	-.46*	-.66***	.74***	--					
11. Total Viewing Time	-.01	-.16	-.11	-.05	-.05	-.08	-.08	-.72***	.54**	.72***	--				
12. n+1 Fixation Duration	-.05	.00	-.02	.00	-.01	-.07	-.08	-.23	.80***	.55**	.44*	--			
13. Initial Landing Position	-.30	.28	.35	.31	.37	.17	.25	.32	-.47*	-.49*	-.32	-.29	--		
14. Saccade Amplitude	-.33	.33	.41*	.51**	.53**	.42*	.48*	.62**	-.19	-.52**	-.24	-.03	.55**	--	
15. Skipping Rate	-.21	.41*	.27	.42*	.31	.38	.37	.33	.05	-.21	-.24	.18	.36	.33	--
16. Regressive Saccades	-.19	.23	.27	.27	.31	.20	.25	-.05	-.23	-.14	.35	-.24	.06	.25	.04

Note: LWID = Letter Word Identification, PC = Passage Comprehension, OC = Oral Comprehension, RS = raw score, SS = standard score. Significance levels: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Table 4
Univariate Effects for Group: Nonparametric Tests

Variable	pairs	Negative Differences	Positive Differences	Ties	Z	p
Fixation Duration	25	13	12	0	-.44	.66
n+1Fixation Duration	25	12	13	0	-.74	.46

Table 5
Univariate Effects for Group: Paired-Samples T-Tests

Variable	difference adult-child	95% CI Lower	95% CI Upper	t	df	p
Oral Comprehension	1.76	-0.31	3.83	1.75	24	.09
Passage Comprehension	0.56	-0.99	2.11	.74	24	.46
TOSREC	1.28	-3.34	5.90	.57	24	.57
Gaze Duration	-5.43	-47.17	36.30	-.27	24	.79
Total Viewing Time	2.79	-81.24	86.81	.07	24	.95

Table 6
Hierarchical Multiple Regression Analyses Predicting Passage Comprehension

Model	Passage Comprehension							
	Adults				Children			
	R^2	β^*	β^{**}	*p*	R^2	β^*	β^{**}	*p*
Step 1:	.21			.02	.50			< .001
Letter Word Identification		.46	.29	.02		.71	.37	< .001
Step 2:	.56			< .001	.78			<.001
Letter Word Identification		.38	.24	.02		.40	.21	.003
Oral Comprehension		.59	.71	< .001		.61	.42	< .001
Step 3:	.68			< .001	.78			< .001
Letter Word Identification		.17	.11	.28		.38	.20	.006
Oral Comprehension		.50	.60	.001		.60	.41	< .001
Gaze Duration		-.42	-.02	.02		-.02	.00	.84
Regressive Saccades		.02	.81	.87		.06	2.32	.56
Total R^2	.68			< .001	.78			< .001

Note. β^* = standardized beta weights. β^{**} = unstandardized beta weights.

Table 7

Hierarchical Multiple Regression Analyses Predicting TOSREC

Model	TOSREC							
	Adults				Children			
	R^2	β^*	β^{**}	p	R^2	β^*	β^{**}	p
Step 1:	.19			.03	.20			.02
Letter Word Identification		.44	.75	.03		.45	.54	.02
Step 2:	.33			.01	.22			.07
Letter Word Identification		.39	.66	.04		.38	.45	.10
Oral Comprehension		.38	1.23	.04		.15	.23	.50
Step 3:	.73			< .001	.52			.004
Letter Word Identification		.08	.14	.55		.28	.34	.14
Oral Comprehension		.27	.89	.04		-.02	-.03	.93
Gaze Duration		-.61	-.08	< .001		-.59	-.06	.003
Regressive Saccades		-.45	-46.94	.001		-.19	-15.55	.25
Total R^2	.73			< .001	.52			.004

Note. β^* = standardized beta weights. β^{**} = unstandardized beta weights.

APPENDIX B

IRB APPROVALS

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 4/22/2013

To: Adrienne Barnes

Address: 1107 West Call Street, FCRR Suite, Tallahassee, FL 32306-4301
Dept.: EDUCATION

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
Reading Characteristics in ABE Participants

The application that you submitted to this office in regard to the use of human subjects in the research proposal referenced above has been reviewed by the Human Subjects Committee at its meeting on 03/13/2013. Your project was approved by the Committee.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 3/12/2014 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Young Kim, Advisor
HSC No. 2013.10051

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673, FAX (850) 644-4392

RE-APPROVAL MEMORANDUM
Date: 2/21/2014

To: Adrienne Barnes

Address: 1107 West Call Street, FCRR Suite, Tallahassee, FL 32306-4301
Dept.: EDUCATION

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research
Reading Characteristics in ABE Participants

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 2/11/2015, you must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Young Kim, Advisor
HSC No. 2014.12046

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
P. O. Box 3062742
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

RE-APPROVAL MEMORANDUM
Date: 12/11/2014

To: Adrienne Barnes

Address: 1107 West Call Street, FCRR Suite, Tallahassee, FL 32306-4301
Dept.: EDUCATION

From: Thomas L. Jacobson, Chair

Re: Re-approval of Use of Human subjects in Research:
Reading Characteristics in ABE Participants

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by, 12/09/2015, you are must request renewed approval by the Committee.

If you submitted a proposed consent form with your renewal request, the approved stamped consent form is attached to this re-approval notice. Only the stamped version of the consent form may be used in recruiting of research subjects. You are reminded that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report in writing, any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc: Young Kim, Advisor HSC No. 2014.14285

The Florida State University
Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 2/19/2015

To: Adrienne Barnes

Address: 1107 West Call Street, FCRR Suite, Tallahassee, FL 32306-4301
Dept.: EDUCATION

From: Thomas L. Jacobson, Chair

Re: Use of Human Subjects in Research
COMPARING LOW-SKILLED ADULT READERS TO TYPICALLY DEVELOPING CHILD READERS

The application that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and one member of the Human Subjects Committee. Your project is determined to be Expedited per per 45 CFR § 46.110(7) and has been approved by an expedited review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If you submitted a proposed consent form with your application, the approved stamped consent form is attached to this approval notice. Only the stamped version of the consent form may be used in recruiting research subjects.

If the project has not been completed by 2/18/2016 you must request a renewal of approval for continuation of the project. As a courtesy, a renewal notice will be sent to you prior to your expiration date; however, it is your responsibility as the Principal Investigator to timely request renewal of your approval from the Committee.

You are advised that any change in protocol for this project must be reviewed and approved by the Committee prior to implementation of the proposed change in the protocol. A protocol change/amendment form is required to be submitted for approval by the Committee. In addition, federal regulations require that the Principal Investigator promptly report, in writing any unanticipated problems or adverse events involving risks to research subjects or others.

By copy of this memorandum, the Chair of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Human Research Protection. The Assurance Number is FWA00000168/IRB number IRB00000446.

Cc: Young Kim, Advisor
HSC No. 2015.14765

APPENDIX C

INFORMED CONSENTS

Florida State University
Informed Consent Form

This form is to be read aloud to the participant.

Title of Study: Reading Characteristics of ABE Participants

You are invited to be in a research inquiry studying your understanding of language, how you use different parts of words (prefixes, suffixes), what you know about letter patterns, how fluently you read, how well you understand what you read, and how your eyes move when you read. You were selected as a possible participant because we are looking at these skills in adults enrolled in literacy classes. We ask that you allow this form to be read to you and ask any questions you may have before agreeing to be in the study.

The primary researcher for this study is Adrienne Barnes. The faculty advisor for this research project is Dr. Young-Suk Kim. Please feel free to ask any questions you have now, or at any point in the future.

Background Information:

The purpose of this study is to investigate adults' reading characteristics and eye movement patterns associated with reading across a variety of tasks (such as reading words, sentences, and passages) and how these abilities relate to reading comprehension. This study may help us learn better ways to teach students in adult basic education classrooms.

Procedures:

If you agree to be in this study, you will complete 7 mini tasks over two sessions. The tasks will include questions about text you read, or about pictures you look at. You will also complete some word activities. Then, you will be asked to read words, sentences, and stories while having your eye movements tracked. This process does not require any head gear or restraints of any kind, and you will be able to take breaks to rest your eyes as needed. You will also be asked to complete a survey with questions about your age, ethnicity, gender, and school experiences. Once all tasks have been completed (two sessions of approximately 30 to 40 minutes each), you will receive a $10 gift card as compensation for your time. This is our way of thanking you for your time.

Risks and benefits of being in the Study:

A potential risk is that some of the tasks are hard, and may make you feel frustrated. You may skip any questions that you don't want to answer. There are no grades associated with these tests and the results will be kept confidential and anonymous. These results will not be shared with your classroom teachers and will have no impact on any of your school-related work.

The benefits to participation are that this research will help to understand adults' reading skills and better inform classroom instruction in Adult Basic Education programs.

Compensation:

You will receive payment: $10 gift card as compensation for your time after you have completed the entire battery of tasks.

Confidentiality:

The records of this study will be kept private and confidential to the extent permitted by law. In any sort of report we might publish, we will not include any information that will make it possible to identify you. Research records will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University or the Adult Basic Education Center. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting these relationships. If you do not want to be in this study, then you do not have to participate. Being in this study is up to you, and no one will be upset in any way if you do not want to participate or even if you change your mind later and want to stop. You do not have to decide to participate or not today. You can decide tomorrow or another day.

TABE Scores

We would like to be granted access to your TABE-Reading scores to use in the study. Scores will not be affiliated with your name and only the primary researcher, Adrienne Barnes, will have access to these scores.

If you approve of scores being released, please sign and print below:

Signature: ______________________________

Print: __________________________________

Contacts and Questions:

The primary researcher for this study is Adrienne Barnes. You may reach her at. The faculty advisor for this research project is Dr. Young-Suk Kim. She may be contacted at. Please feel free to ask any questions you have now, or at any point in the future.

If you have any questions or concerns regarding this study and would like to talk to someone other than the researchers, you are encouraged to contact the FSU IRB at 2010 Levy Street, Research Building B, Suite 276, Tallahassee, FL 32306-2742, or 850-644-8633, or by email at humansubjects@magnet.fsu.edu. The project number for this research study is 2013.10051.

You will be given a copy of this information to keep for your records.

Participant will circle Yes or No for each oral question:

Have I explained the research to you so that you understand?	Yes	No
Do you have any questions that I can answer right now?	Yes	No
Do you understand that you can stop participating at any time?	Yes	No
Do you know who to contact if you have any questions in the future?	Yes	No
Do you understand that by signing this form you agree to participate in this study?	Yes	No

Statement of Consent:

I have read the above information. I have asked questions and have received answers. I consent to participate in the study.

________________________ __________________

Signature Date

________________________ __________________

Print Date

________________________ __________________

Signature of Investigator Date

Assent Form for Minors (16-18)
Florida State University

This form is to be read aloud to the minor participant.

My name is Adrienne Barnes. I am a student researcher from Florida State University. I am asking if you would like to take part in a research study called "Reading Characteristics of ABE Participants", which is about understanding how adults read and understand language, and what their eye movement patterns look like.

If you agree to be in this study, you will complete 7 mini tasks over two sessions. The tasks will include questions about text you read, or about pictures you look at. You will also complete some word activities. Then, you will be asked to read words, sentences, and stories while having your eye movements tracked. This process does not require any head gear or restraints of any kind, and you will be able to take breaks to rest your eyes as needed. You will also be asked to complete a survey with questions about your age, ethnicity, gender, and school experiences. Once all tasks have been completed (two sessions of approximately 30 to 40 minutes each), you will receive a $10 gift card as compensation for your time. This is my way of thanking you for your time.

Some of the tasks are hard, and may make you feel frustrated. You may skip any questions that you don't want to answer. There will be no grades for any of the tasks and your teachers and parents will not be given your scores. This study may help us learn better ways to teach students in adult basic education classrooms.

Please talk this over with your parents before you decide whether or not to participate. I have asked your parents to give their permission for you to take part in this study. But even if your parents said "yes" to this study, you can still decide to not take part in the study, and that will be fine.

If you do not want to be in this study, then you do not have to participate. This study is voluntary, which means that you decide whether or not to take part in the study. Being in this study is up to you, and no one will be upset in any way if you do not want to participate or even if you change your mind later and want to stop. You do not have to decide to participate or not today. You can decide tomorrow or another day.

The primary researcher for this study is Adrienne Barnes. The faculty advisor for this research project is Dr. Young-Suk Kim. Please feel free to ask any questions you have now, or at any point in the future. If you have any questions or concerns about your child's rights as a research subject, you may contact the FSU Institutional Review Board (IRB) at (850) 644-8633 or by email at humansubjects@magnet.fsu.edu. The project number for this research study is 2013.10051.

You can ask any questions that you have about this study. If you have a question later that you did not think of now, you can call me, Adrienne Barnes, at, or ask me next time.
Minor will circle Yes or No for each oral question:

Have I explained the research to you so that you understand?	Yes	No
Do you have any questions that I can answer right now?	Yes	No
Do you understand that you can stop participating at any time?	Yes	No
Do you know who to contact if you have any questions in the future?	Yes	No

Signing your name at the bottom means that you agree to be in this study. You and your parents will be given a copy of this form after you have signed it.

Do you understand that by signing this form you agree to participate in this study?

Yes No

Name of child (please print): ____

Signature of Child: ____

Date: _________________________

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BIOGRAPHICAL SKETCH

Adrienne Elissa Barnes received her Bachelor of Science in Elementary Education from Florida State University, Panama City Campus in 2004 and her Master of Science in Reading and Language Arts Education from the same campus in 2010. In 2011, Adrienne was awarded the Institute of Education Sciences Pre-doctoral Interdisciplinary Research Training fellowship through the Florida Center for Reading Research at Florida State University in Tallahassee, Florida and was accepted into the Curriculum and Instruction doctoral studies program at Florida State University. The fellowship enabled Adrienne to present her research in literacy studies at domestic and international research conferences in Montreal, Canada; Hong Kong, China; Santa Fe, New Mexico; Orlando, Florida; Washington, D.C.; and Kona, Hawaii. She has also been able to work with Learning Systems Institute on an international literacy initiative: Reading for Ethiopia's Achievement Developed - Technical Assistance. On the READ-TA project, Adrienne co-authored the English versions of the new College of Teacher Education (CTE) curriculum and engaged in two separate three-week intensive sessions in-country where 200 Mother Tongue CTE instructors were trained on research-based practices and the new material.

Outside of academics, Adrienne has remained involved in community service. She spent two years providing weekly literacy instruction at the Adult Community Education program in Tallahassee, Florida and maintains a match with her 'Little' through Big Brothers Big Sisters of the Big Bend.