Article

Hammill Institute on Disabilities

Journal of Learning Disabilities
2017, Vol. 50(2) 180–194

DOI: 10.1177/0022219415609187
journaloflearningdisabilities.sagepub.com
SAGE

Readers in Adult Basic Education: Component Skills, Eye Movements, and Fluency

Adrienne E. Barnes, PhD[1], Young-Suk Kim, EdD[2], Elizabeth L. Tighe, PhD[1], and Christian Vorstius, PhD[3]

Abstract

The present study explored the reading skills of a sample of 48 adults enrolled in a basic education program in northern Florida, United States. Previous research has reported on reading component skills for students in adult education settings, but little is known about eye movement patterns or their relation to reading skills for this population. In this study, reading component skills including decoding, language comprehension, and reading fluency are reported, as are eye movement variables for connected-text oral reading. Eye movement comparisons between individuals with higher and lower oral reading fluency revealed within- and between-subject effects for word frequency and word length as well as group and word frequency interactions. Bivariate correlations indicated strong relations between component skills of reading, eye movement measures, and both the *Test of Adult Basic Education* (*Reading* subtest) and the *Woodcock-Johnson III Diagnostic Reading Battery Passage Comprehension* assessments. Regression analyses revealed the utility of decoding, language comprehension, and lexical activation time for predicting achievement on both the *Woodcock Johnson III Passage Comprehension* and the *Test of Adult Basic Education Reading Comprehension.*

Keywords

adult literacy, adult basic education, reading, eye tracking, simple view of reading

The 2003 *National Assessment of Adult Literacy* revealed that more than 30% of adults in the United States read at or below a basic literacy level (U.S. Department of Education, 2015). Low levels of literacy have been associated with poor health literacy, low income, high crime levels, and disadvantaged children (Cree, Kay, & Steward, 2012). Adult education programs typically enroll students between the ages of 16 years and senior citizenship. Individuals are eligible to receive academic support through these programs if they have not received a high school diploma and are not concurrently enrolled in public education or a community college remedial/developmental program. In Florida, adult education programs provide instruction to support the earning of a High School Equivalency Diploma (GED). Some individuals are enrolled simply because they are required to attend classes, and other individuals are highly dedicated to continuing their education and enjoy engaging in classes (for a review of student motivations, see Greenberg et al., 2013; Mellard, Krieshok, Fall, & Woods, 2013; Tighe, Barnes, Connor, & Steadman, 2013).

Rigorous research on adult education occurs less frequently than on other populations of readers. However, recent research devoted to understanding component reading skills for this population has begun to unravel the intricacies of the relations between word-level skills, language skills, and reading comprehension (i.e., Binder & Lee, 2012; Fracasso, Bangs, & Binder, in press; Mellard & Fall, 2012; Sabatini, Sawaki, Shore, & Scarborough, 2010).

Component Reading Skills

The simple view of reading (Gough & Tunmer, 1986; Hoover & Gough, 1990) has been supported for both children and adults with low literacy (e.g., Braze, Tabor, Shankweiler, & Mencl, 2007; Catts, Adlof, & Ellis Weismer, 2006; Joshi, Tao, Aaron, & Quiroz, 2012). Recent studies investigating component skills with adult struggling readers (Hall, Greenberg, Laures-Gore, & Pae, 2014; MacArthur, Konold, Glutting, & Alamprese, 2010; Taylor, Greenberg,

[1]Florida State University, Tallahassee, USA
[2]Florida Center for Reading Research, Tallahassee, USA
[3]University of Wuppertal, Germany

Corresponding Author:
Adrienne E. Barnes, Learning Systems Institute, Florida State University, C4600 University Center, Tallahassee, FL 32306-4459, USA.
Email: adriennebarnes76@gmail.com

Laures-Gore, & Wise, 2012) reveal that adults in basic education settings often exhibit low levels of decoding, fluency, and reading comprehension, given their language comprehension abilities. Oral reading fluency may also be important for reading comprehension above and beyond the simple view model (Kim, Wagner, & Lopez, 2012). Therefore, separating out and comparing more and less fluent readers may reveal different patterns for component skills and reading comprehension.

Decoding and Reading Fluency

Decoding skill and word reading fluency progress as a series of approximately four developmental periods. The first two periods, prereading and early reading, are referred to as cue (Gough & Hillinger, 1980) or logographic (Frith, 1985) reading since no actual decoding takes place. During this time, the reader gains exposure to letters and books (Chall, 1983), begins to recognize letters and environmental print patterns (Frith, 1985; Mason, 1980), and develops the alphabetic principle (Ehri, 1999). When readers enter the third period, decoding, they begin to engage in letter-sound analysis (Mason, 1980) and can attend to the sounds of individual letters within words (Chall, 1983; Ehri, 1999). The final period, fluent reading, is characterized by skilled decoding and automatic recognition of words as single units (Chall, 1983; Ehri, 1999; Frith, 1985). Theories of automaticity (LaBerge & Samuels, 1974) and verbal efficiency (Perfetti, 1985) indicate that as readers become more proficient in decoding at the word level, attentional processes are freed up to focus on comprehending.

Language Comprehension

Language comprehension is foundational to reading comprehension. Both receptive vocabulary (the ability to understand language presented in speech or text) and expressive vocabulary (the language used to speak or write) are related to early reading skills (Chiappe, Chiappe, & Gottardo, 2004; Wise, Sevcik, Morris, Lovett, & Wolf, 2007), and listening comprehension skills support real word identification (Nation & Snowling, 2004). Research has also revealed an association between vocabulary size and reading comprehension skill (Torgeson, Wagner, Rashotte, Burgess, & Hecht, 1997; Verhoeven, 2000), although these two may have a reciprocal relationship (Verhoeven & Van Leeuwe, 2008). Reading comprehension is dependent on the reader's ability to access word meanings and is constrained by the comprehension of oral language such that compared to more skilled readers, poorer readers tend to exhibit poorer listening comprehension skills (Cain & Oakhill, 1998; Yuill & Oakhill, 1991).

Eye Movement Research and the Eye-Mind Link

The 1970s ushered in what Rayner (1998) referred to as the "third era of eye movement research" (p. 372), wherein technological advances allowed studies of eye movement behavior during information-processing tasks. Research topics included studies of visual search, scene perception, music reading, typing, and reading behaviors. A large majority of reading research conducted through eye movement studies focused on the lexical level of reading (e.g., foveal/parafoveal processing [Lima & Inhoff, 1985; Rayner & Bertera, 1979], the perceptual span [McConkie & Hogaboam, 1985; Underwood & Zola, 1986], word skipping [Carpenter & Just, 1983; Rayner & McConkie, 1976], regressions while reading [Kennedy, 1983], fixation durations [Heller, 1982], etc.). These studies established the eye-mind link theory, which posits online analysis of eye movements to reveal the underlying cognitive processes (Rayner, 1998; Reichle, 2006). For instance, fixations are shorter when words (a) are familiar to the reader, (b) are shorter in length, and (c) occur more frequently in printed text (Clifton, Staub, & Rayner, 2007). Fixation duration may be related to decoding (Reichle, 2006), and gaze duration appears to capture lexical activation time (Rayner, 1998; Rayner, Chace, Slattery, & Ashby, 2006). Additionally, short, high-frequency function words such as *and, but*, and *is* are processed parafoveally by skilled readers and are often skipped (Pollatsek, Reichle, & Rayner, 2003).

The eye-mind link for reading tasks has been explored in studies with children and adults (e.g., Blythe & Joseph, 2011; Joseph, Nation, & Liversedge, 2013; Rayner et al., 2006). Although eye-tracking research has primarily focused on proficient college readers, the available research with adult dyslexic readers reveals deficits in processing speed that appear to be related to longer fixation durations and shorter saccade amplitudes (Dahhan et al., 2013; De Luca, Judica, Spinelli, & Zoccolotti, 2002; Kunert & Scheepers, 2014). However, many of these phenomena have not been explored specifically with adult struggling readers.

Complex models of reading have emerged (*E-Z Reader* [Reichle, Pollatsek, Fisher, & Rayner, 1998; Reichle, Rayner, & Pollatsek, 1999] and *SWIFT* [Engbert, Nuthmann, Richter, & Kliegl, 2005]), and the eye-mind link has been used to infer higher order language processes taking place (e.g., sentence parsing [Kidd, Stewart, & Serratrice, 2011], semantic structure [De Corte, Verschaffel, & Pauwels, 1990], mindless reading [Reichle, Reineberg, & Schooler, 2010], etc.). However, few studies have investigated eye movements during oral reading activities (Rayner & Juhasz, 2004).

Reading out loud requires a pronunciation of each word, restricting eye movement speed to the speed of the articulation processes of speech. This results in an increase in fixation durations and a decrease in saccade amplitudes (Rayner,

1998) and appears to limit parafoveal preview benefits (Ashby, Yang, Evans, & Rayner, 2012). Reading aloud is different than reading silently, and many readers, even highly skilled readers depending on the activity and text, tend to read aloud or subvocalize. In particular, low-skilled readers engage in oral reading more frequently (Gilliam, Dykes, Gerla, & Wright, 2011). Therefore, eye movement data during oral reading may reveal important information about reading processes, particularly for low-skilled readers.

We were able to locate only one eye movement study with struggling adult readers, which examined the participants' ability to differentiate between relevant and irrelevant information on food labels when searching for health-related information (Mackert, Champlin, Pasch, & Weiss, 2013). Examining the patterns of eye movement behavior may lead to a better understanding of the relationship between specific eye movement measures and reading skills for individuals who are engaged in adult education programs. The emerging studies of adult struggling readers (i.e., Binder & Lee, 2012; Fracasso et al., in press; Mellard & Fall, 2012; Sabatini et al., 2010) primarily used offline behavioral measures to examine reading skills. In the current study, we used a read-aloud paradigm to observe the relations between eye movement behaviors and reading component skills. Additionally, we explored how word characteristics of length and frequency affect eye movement variables for a subset of more and less fluent readers from the sample, based on oral reading fluency rates.

Present Study

The current study examined offline and online reading behaviors together, utilizing both traditional standardized measures and eye-tracking technology. Specifically, the current study investigated how low-skilled adult readers approached connected text, how patterns of eye movements were related to reading component skills, and how eye movement behavior varied as a function of oral reading rate. The eye movement data were collected in a connected-text oral reading paradigm.

Research Questions

The following research questions guided the current study:

1. For a population of low-skilled adult readers, what are the relations between eye movement variables and component skills of reading?
2. How do word identification, language comprehension, and lexical activation time relate to the *Woodcock-Johnson III Passage Comprehension* assessment and the *Test of Adult Basic Education* (TABE) *Reading* assessment for this population?
3. Do readers with relatively high oral reading fluency exhibit component skill or eye movement patterns that are different from those of readers with relatively low reading fluency?
4. Are word length and frequency effects similar for readers with high and low oral reading fluency?

In support of previous research (Hall et al., 2014; Taylor et al., 2012), we anticipated finding lower levels of decoding and reading comprehension in the current sample. We anticipated that the reading component skills would be positively correlated and that decoding would be negatively related to fixation duration. Based on previous applications of the Simple View of Reading model with this population (Braze et al., 2007; Mellard & Fall, 2012; Sabatini et al., 2010), we expected that decoding and language comprehension would together account for a large amount of variance in the two reading comprehension outcomes (*Woodcock-Johnson III Diagnostic Reading Battery* [WJIII-DRB] *Passage Comprehension* and TABE). In terms of online processing using eye movement variables, we used gaze duration and proportion of regressive saccades as predictors of reading comprehension because current research indicates that gaze duration may be a proxy for lexical-semantic connections (Reichle, 2006) and regressive saccades may be caused by a breakdown in the ability to integrate new information (Rayner, 1998).

Methods

Participants

The participants in the current study included 56 adults enrolled in a north Florida adult education center, with 48 of these participants included in the analysis. These participants were enrolled in literacy classes of varying levels of primary and secondary literacy for the pre-GED program and voluntarily participated in the study in exchange for a $10 gift card. Nearly all the regular-attending students in the basic education (pre-GED) program participated in data collection, as they were all invited to participate in the study. Individuals with known cognitive deficits (and staffed in low-cognitive classrooms) were not included in this study, nor were adults enrolled in either the English Speakers of Other Languages program or the GED-level literacy courses (as the focus of the current study was adults reading below high school level). To address the needs of low-literate participants, informed consent was attained by reading the Institutional Review Board–approved consent form aloud to all participants. Full data collection (excluding TABE scores) was achieved with 48 of the 56 participants, who presented profiles similar to other samples of adult education students (e.g., Binder & Lee, 2012; Fracasso et al., in press; Mellard & Fall, 2012). These 48 participants (48%

Table 1. Descriptive statistics.

Variable	*n*	*M*	*SD*	Range
Participant age	48	26.00	9.90	410
Test of Adult Basic Education Reading	44			
Standard score		528.00	54.70	247.0
Grade equivalency		6.04	2.44	9.0
Letter-Word Identification	48			
Raw score		56.70	8.70	40.0
Standard score		80.90	15.05	82.0
Age equivalency (months)		113.00	69.41	257.0
Grade equivalency		6.90	3.53	16.0
Passage comprehension	48			
Raw score		27.40	4.12	18.0
Standard score		75.50	11.23	47.0
Age equivalency (months)		87.00	49.30	175.0
Grade equivalency		4.00	1.82	9.0
Oral Comprehension	48			
Raw score		21.60	3.50	13.0
Standard score		89.90	7.92	32.0
Age equivalency (months)		124.00	75.10	268.0
Grade equivalency		7.05	3.61	13.0
Reading fluency (words correct per minute)	48	136.70	39.95	188.0
Fixation duration	48	269.00	57.92	329.0
Gaze duration	48	404.10	131.71	626.0
Total viewing time	48	635.90	295.05	1438.0
Initial landing position	48	2.20	0.28	1.2
Saccade amplitude	48	2.40	0.60	3.6
Skipping rate	48	0.16	0.08	0.4
Proportion (%) of regressive saccades	48	30.70	7.47	32.0
Refixations (gaze count)	48	2.40	0.85	5.0

female) represented a range of self-designated ethnicities and were 38% Caucasian, 54% African American, 2% Asian, and 6% mixed ethnicities. Their ages ranged from 16 to 57 years, with a mean age of 26 years (SD = 9.9). Grade-level comprehension equivalencies ranged from 1.1 to 10.0 on *Passage Comprehension*, with a mean of 4.0 (SD = 1.82), and from 3.0 to 12.1 on TABE, with a mean of 6.4 (SD = 2.44). Despite the disparities in age and reading skill all students expressed the desire to earn a GED, and most expressed the desire to continue their education and complete AA, BS, or vocational programs. English was the native language for all but 2 participants, who exhibited skilled use of English and were not enrolled in English for speakers of other languages classes. When surveyed about difficulties in school, 46% of participants stated that they had difficulty learning to read and spell (see Table 1 for component skill grade-level equivalencies). Of the 17 participants who identified as having a diagnosed learning disability, 6 stated that they did not receive any additional tutoring or specialized reading instruction while in public school. Many of these participants experienced retention in public school, as 9 participants indicated they had been held back for at least 1 year and 2 participants had experienced two or more retentions. Of the 48 participants, 14 were high school graduates, and 11 of these students graduated with an alternate high school diploma (a Special Diploma, which requires an additional GED for college or vocational program attendance [Florida Department of Education, 2005]).

Measures

Word reading. Participants' word reading skill was measured by the *Letter-Word Identification* (LWID) subtest of the WJIII-DRB. This assessment consists of a list of words for the participant to read, beginning with single letters and progressing to common words and then to less frequent polysyllabic words. The LWID subtest has a median reliability of .94 for adults (Schrank, Mather, & Woodcock, 2004).

Language comprehension. The *Oral Comprehension* subtest of the WJIII-DRB was used. This assessment consists of an oral cloze procedure wherein participants are presented with an auditory stimulus (a sentence, analogy, or passage) that is missing the final word. Participants must utilize their

Table 2. *Test of Adult Basic Education* score conversions.

Score	Grade-level equivalency
300–392	Kindergarten–Grade 2
393–490	Grade 2–Grade 4
491–523	Grade 4–Grade 6
524–559	Grade 6–Grade 8
560–600	Grade 9–Grade 12

listening, reasoning, and vocabulary skills to complete the item. For adults, this assessment has a median reliability of .89 (Schrank et al., 2004).

Reading comprehension. The *Passage Comprehension* subtest of the WJIII-DRB and the TABE *Reading* were used. In the *Passage Comprehension* task, participants are asked to provide the missing word in each progressively more complex passage. The *Passage Comprehension* subtest has a median reliability of .88 for adults (Schrank et al., 2004). Reading comprehension was also measured using the TABE *Reading* (CTB/McGraw-Hill, 2008) subtest. This assessment is a test used as a placement measure when students enter the program and also to measure growth in reading skill as students progress through adult education programs. The reading subtest consists of passages paired with multiple-choice comprehension questions. The test items contain brief passages including fiction, nonfiction, and functional texts such as newspapers and bus schedules, followed by questions that range from letter recognition and simple vocabulary definition to the construction of meaning via graph interpretation and inference. The scores for the TABE tests are scale scores that range from 300 to 600 (see Table 2). The participants' current semester TABE *Reading* scores were collected. Internal consistency reliability is reported to range between .88 and .95 across all levels of the test (CBT/McGraw-Hill, 2008).

Eye Movement Assessment

Eye movement variables were collected using the EyeLink1000 system (SR Research, 2013). The material consisted of three passages from the *Florida Assessments for Instruction in Reading* (FAIR; Florida Department of Education, 2009)—2 fourth-grade passages and 1 fifth-grade passage. The passages contained an average of 300 words (299, 310, and 292), and the lexile level averaged 600 (470, 540, and 790). These passages were chosen because previous studies suggested that a large proportion of the adult education population exhibits between a third- and fifth-grade word-reading level (Hall et al., 2014; Taylor et al., 2012). These passages were adapted for eye tracking by creating consecutive screens for each story. Words in the eye-tracking experiment were coded by frequency of occurrence in 1 million words (Zeno, Ivens, Millard, & Duvvuri, 1995), and were identified as high frequency and low frequency, similar to the methods of Joseph and colleagues (2013). High-frequency words had a mean frequency of 75 per million or higher, and low-frequency words had a frequency of 19 per million or lower.

For the experiment, the passages were partitioned with 4 to 11 lines of text on each screen and approximately 10 to 15 words per line, splitting the stories across as many as three screens. Participants read aloud and pressed a button to move to the next screen of text. An initial practice passage served to familiarize the participants with the format of the text, the button press action, and the question following the story. While each participant read the passages aloud, a running record (Harp & Brewer, 2000; Hasbrouck & Tindal, 1992) was maintained for the first 60 s of each passage. The total number of words correctly read (excluding repetitions, insertions, omissions, and substitutions) per minute provided a number representing words correct per minute (WCPM). In instances wherein the screen was completed in less than 60 s, an oral reading fluency score was extrapolated from the data. These scores were then compared to the FAIR Oral Reading Fluency Ongoing Progress Monitoring norms (Florida Center for Reading Research, 2009), and adjusted oral reading fluency scores were assigned. The final score assigned to each participant as his or her reading fluency represents the participant's mean number of adjusted WCPM across all read-aloud stories. Percentiles were obtained from the Florida FAIR oral reading fluency norms.

Eye-tracking variables in the current study were collected at 500 Hz. Fixation duration was the length of the first fixation on each word. Refixations represented the number of fixations following the initial fixation on the word with the gaze. Gaze duration was the summation of all fixations before leaving the word. Total viewing time was the summation of all gaze durations for a word. The mean for all variables is reported for each participant; that is, these values reflect the mean value across all trials of the connected-text task for each participant. The current standard in eye-tracking research is to use the fixation durations without including saccade times (e.g., Ashby et al., 2012; Vorstius, Radach, Mayer, & Lonigan, 2013). Therefore, in the current study, saccade times were not included in either the gaze duration or total viewing times.

Initial landing position was computed using whole numbers to indicate the position of the letter where the eyes land when participants first look at a word, counting from the beginning of the word, including the blank space preceding the word as position 0. Saccade amplitude was the distance (in character spaces) the eyes move between fixations for progressive (rightward-moving) saccades. Proportion of regressive (leftward-moving) saccades was the number of regressive saccades divided by the total number of both forward and regressive interword saccades. Skipping rate was the proportion of skipped words; a participant's skipping rate represented the overall proportion of words that were never directly fixated.

Eye-Tracking Apparatus and Procedure

The second assessment session focused solely on eye tracking. All text was presented on a gray background on a 21-in. Viewsonic monitor at a resolution of 1024 × 768 (32 bits per pixel) with a refresh rate of 75 Hz. This refresh rate was appropriate, as there were no instances of text masking or shifting in the current study. Text was presented in Courier New 15 point type so that each character filled the same amount of horizontal space. There was 78 cm of viewing distance between the participants' eyes and the monitor, with one character of text filling .5° of visual angle. Viewing and data collection were binocular using an EyeLink1000 eye-tracking system (SR Research, 2013) sampling at a rate of 500 Hz. Participants were asked to keep their heads positioned on a chin rest and against a forehead bar to minimize head movements. Before each passage, the tracker's accuracy was checked and recalibrated if necessary. Measurement accuracy was maintained via repeated calibration and validation (McConkie, 1981).

The experiment began with a nine-point calibration of the eye-tracking system. The operator initiated a sequential presentation of nine fixation points, spread across the screen in a grid pattern to cover the areas on which the text would appear and presented in random order. The calibration step was considered successful when all points were fixated to within .5° of visual angle of the marked point. To maintain accuracy, this calibration step was repeated as necessary. After each screen of text, the participant pressed a button to continue. Each story was followed by a single low-level comprehension question intended to prompt the participant to read for comprehension.

Assessment Procedures

Participants were first asked to complete a demographic survey that included questions addressing motivations for attendance, family education history, future goals, age, ethnicity, and school experiences. The participants were then administered the WJIII-DRB (Woodcock, Mather, & Schrank, 2004) subtests and participated in the eye-tracking experiment. Participants also gave permission for the school to release their most recent scale scores from the TABE *Reading.*

Data Preparation and Analysis

Fixation and saccade data points were visually inspected using EyeMap software (Tang, Reilly, & Vorstius, 2012) to detect any problems with the data. All data files were used in the analysis. Pairs of fixations and incoming saccades were aggregated to fixation-based and word-based matrices and imported into SPSS (IBM Corp., 2012). The data were then checked for extreme scores, and inclusion criteria were established, wherein some data points were excluded from the analysis.[1]

Results

Descriptive Statistics and Correlations

Table 1 summarizes the level of skill exhibited on reading and language measures by the sample of adults in basic education classes. Results showed the participants scored lower for their age than the normative group on all measures. This was expected, as the participants were sampled from a population of adult basic education (ABE) participants who generally perform lower than expected for their age. Standard scores for the current sample were as follows: M = 81.7 (SD = 13.50) in LWID; M = 77.3 (SD = 11.03) in *Passage Comprehension;* and M = 90.7 (SD = 8.51) in *Oral Comprehension.* Word reading for this group fell more than one standard deviation below the adult normative group, with a mean grade level of 6.8. Passage comprehension was also about 1.5 standard deviations lower than the adult normative mean with a corresponding mean grade level of 4.0. Although oral comprehension skills fell within one standard deviation, with a grade level of 7.6, the raw score mean of 90 (25th percentile) was still relatively low in comparison to the adult norming group. According to the FAIR oral reading fluency norms (Florida Center for Reading Research, 2009), participants' adjusted reading fluency score (M = 136.7, SD = 39.95) represented a typical score around the 64th percentile for a fourth-grade student or the 46th percentile for a fifth-grade student. These findings are similar to observations of component skill levels in other ABE populations (e.g., Hall et al., 2014).

As with the other measures, large variation existed in the TABE scale scores for this sample. The mean of 527 indicated that these students, on average, were reading at the lower end of the sixth- to eighth-grade level. Variation was large, such that this sample spread across all functional reading levels, ranging from about 2nd or 3rd grade to about 12th grade.

Table 1 also displays means for the global temporal and spatial eye movement characteristics of this sample of ABE participants. Temporal variables are measured in milliseconds. With a mean of 269 ms, the fixation durations for these participants were slightly longer than expected for adults (which are typically 200–250 ms, depending on the difficulty of the text; Rayner et al., 2006). Gazes lasted approximately 404 ms, and total viewing times averaged 636 ms. The mean initial landing position for this sample is 2.2, indicating that on average, as these readers' eyes moved to a new word the fixation point was the second letter in the word. The mean saccade amplitude for the sample was 2.4 character spaces, which indicates that with each move of the eyes, the next landing position was approximately two and a half character spaces away from the previous fixation. The proportion of regressive saccades exhibited by the current sample of adults was high—approximately 31% of saccades represented a backward movement of the eyes through the text. Proficient adult readers typically exhibit saccade amplitudes of about six letter spaces (during oral reading) and regress about 10% to 15% of the time (Rayner, 1998). The high rates of regressions observed here could be a consequence of the readers' lack of comfort (or even experience) in read-aloud situations.

Skipping rate represented the proportion of words skipped (not fixated) by the reader. To ensure that the participants approached each of the tasks with the same intention to read, skipping rate was determined for each of the eight screens of text, and a reliability estimate was generated. Since some participants were very low-proficiency readers, a time limit of 5 min per story was allowed, and the lowest readers timed out while reading two of the three stories. In these trials, the low-proficiency readers were able to complete approximately 25% of the text on the screen before being asked to button-press and move on the next story. To account for this phenomenon, participant data were included in the skipping analysis if at least 25% of the words on the given trial were fixated. This led to the exclusion of one trial for 2 participants and seven trials for another participant. Cases were excluded listwise in the reliability analysis if there were not scores for each of the eight screens of text. The reliability of skipping rate was high across all tasks (Cronbach's alpha = .93, n = 45). Therefore, the skipping rate was based on the total words read on screens where at least 25% of the words were fixated, and text occurring after a time-out prompt was excluded from this analysis. Participants skipped approximately 16% of words. One- to three-letter words accounted for 47.2% of the text read, and for 73.8% of skipped words, with the majority of skips happening with two-letter words such as *at, he, in, it, of, on*, and *to.*

Research Question 1: What Are the Relations Between Eye Movement Variables and Component Skills of Reading?

Table 3 provides bivariate correlations between reading component skills, the WJIII-DRB *Passage Comprehension* assessment, and the TABE assessment. All components of the *Woodcock-Johnson III* tests, the TABE *Reading*, and oral reading fluency (WCPM) were significantly correlated (all rs > .35). Table 3 also shows correlations involving eye movements. Two of the temporal variables were significantly and negatively related to all offline reading measures (fixation duration: all rs < –.33; gaze duration: all rs < –.32). Total viewing time was significantly and negatively related to LWID (r = –.44), *Passage Comprehension* (r = –.46), and WCPM (r = –.83). Refixations were related only to oral reading fluency (r = –.63), gaze duration (.44), and total viewing time (.84). With regard to spatial eye movement variables, saccade amplitude was positively related to LWID (r = .54) as well as WCPM (r = .45), fixation duration (r = –.31), and gaze duration (r = –.49). Participants' skipping rate and proportion of regressive saccades were related only to saccade amplitude (rs = .47 and .53, respectively) and to one another (r = .30).

Research Question 2: How Do Word Identification, Language Comprehension, and Lexical Activation Time Relate to the Woodcock-Johnson III Passage Comprehension *Assessment and the TABE* Reading *Assessment for This Population?*

We recognize that the current sample is small for inferential analyses (ns = 44–48). However, given that we met the criteria for a minimum of 10 data points per predictor (Cohen, Cohen, West, & Aiken, 2003) we felt these analyses were worth investigating. Raw scores were used in the regression models, and standardized beta weights are reported and discussed (see Table 4).

The first set of multiple regression models used WJIII-DRB *Passage Comprehension* as the dependent variable (n = 48). Step 1 included word reading and oral comprehension raw scores, and significantly accounted for variance (R^2 = .57, p < .001). Beta weights were as follows: word reading (β = .35, p = .002) and oral comprehension (β = .55, p < .001). Step 2 included gaze duration, an online measure of lexical activation. Beta weights were the following: word reading (β = .18, p = .145), oral comprehension (β = .52, p < .001), and gaze duration (β = –.28, p = .026). Total R^2 was .61. This means that gaze duration was a significant negative predictor of the *Passage Comprehension* measure and that lexical activation time (gaze duration) remained important after controlling for word reading and oral comprehension.

The second set of multiple regression models used TABE *Reading* scale score as the dependent variable (n = 44). TABE test/retest information was unavailable; therefore, only time lag effects could be controlled for. In this model, the time lag between TABE test data and data collection for the current study was added as a control variable in Step 1. This step significantly accounted for variance (R^2 = .43, p < .001). Beta weights were the following: test lag (not shown; β = –.12, p = .321), word reading (β = .29, p = .020), and oral comprehension (β = .49, p < .001). Step 2 beta weights were as follows: test lag (not shown; β = –.12, p = .334), word reading (β = .31, p = .058), oral comprehension (β = .49, p < .001),

Table 3. Bivariate correlations among all measures.

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Age	—															
2. TABE	−.01	—														
3. LWID (RS)	−.10	.45**	—													
4. LWID (SS)	.23	.47**	.94***	—												
5. PC (RS)	.06	.64***	.56***	.49***	—											
6. PC (SS)	.40**	.60***	.53***	.61***	.83***	—										
7. OC (RS)	.07	.59***	.37**	.35*	.68***	.60***	—									
8. OC (SS)	.14	.57***	.38**	.40**	.66***	.68***	.97***	—								
9. WCPM	−.05	.51***	.67***	.60***	.63***	.54***	.38**	.38**	—							
10. Fix Dur	.04	−.38*	−.60***	−.46**	−.59***	−.43**	−.35*	−.33*	−.67**	—						
11. Gaze Dur	.09	−.33*	−.64***	−.47**	−.57***	−.39**	−.33*	−.32*	−.80***	.87***	—					
12. TV Time	.17	−.24	−.44**	−.31*	−.46**	−.28*	−.17	−.18	−.83***	.63***	.81***	—				
13. ILP	−.19	.20	.22	.31*	.14	.30*	.17	.19	.12	−.23	.05	.08	—			
14. Sacc Amp	−.03	.14	.54***	.48**	.16	.16	.13	.15	.45**	−.31*	−.49***	−.27	.17	—		
15. Skip Rate	−.13	.21	.18	.16	.09	.01	−.02	−.02	.19	.09	−.02	.04	−.04	.47**	—	
16. Reg Sacc	−.03	−.07	.17	.09	.04	−.10	−.01	−.06	−.10	−.18	−.24	.08	−.20	.53***	.30*	—
17. RFX	.23	−.11	−.18	−.09	−.22	−.04	.04	.03	−.63***	.14	.44**	.84***	.30*	−.14	−.12	.16

Note. TABE = *Test of Adult Basic Education*; LWID = *Letter-Word Identification*; RS = raw score; SS = standard score; PC = *Passage Comprehension;* OC = *Oral Comprehension;* WCPM = reading fluency; Fix Dur = fixation duration; Gaze Dur = gaze duration; TV Time = total viewing time; ILP = initial landing position; Sacc Amp = saccade amplitude; Skip Rate = skipping rate; Reg Sacc = proportion (%) of regressive saccades; RFX = refixations (gaze count).

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4. Hierarchical multiple regression analyses predicting reading comprehension.

	WJIII-DRB *Passage Comprehension*		TABE *Reading*[a]	
Measure	ΔR^2	β	ΔR^2	β
Step 1	.568***		.647***	
WJIII-DRB LWID		.35**		.29*
WJIII-DRB OC		.55***		.49***
Step 2	.046*		.001	
WJIII-DRB LWID		.18		.31
WJIII-DRB OC		.52***		.49***
Gaze duration		–.28*		.03
Total R^2	.614***		.648***	
n	48		44	

Note. All βs are standardized coefficients. WJIII-DRB = *Woodcock-Johnson III Diagnostic Reading Battery;* TABE = *Test of Adult Basic Education;* LWID = *Letter-Word Identification;* OC = *Oral Comprehension.*
[a]Analysis controlled for lag between TABE *Reading* test and component skill assessment.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 5. Univariate effects for group.

Variable	Difference—Quartile 1–Quartile 4	95% confidence interval—lower	95% confidence interval—upper	*t*	*df*	*p*
TABE *Reading*	–75.7	–128.59	–23.88	–3.06	19	.006
LWID	–15.8	–21.07	–10.60	–6.27	22	<.001*
PC (RS)	–6.3	–9.67	–3.00	–3.94	22	.001*
OC (RS)	–3.8	–6.75	–0.75	–2.63	22	.017
Fixation duration	93.6	48.04	139.04	4.26	22	.056
Gaze duration[a]	261.5	164.28	358.79	5.81	22	<.001*
Total viewing time[a]	560.3	316.53	804.03	5.03	22	<.001*
Initial landing position	–0.1	–0.32	0.13	–0.87	22	.395
Saccade amplitude[a]	–0.9	–1.42	–0.34	–3.50	22	.004*
Skipping rate	–0.08	–0.14	0.01	–1.86	22	.075
Regressive saccades	0.0	–0.05	0.06	–0.33	22	.747
Refixations[a]	1.2	0.41	2.04	3.26	22	.007

Note. TABE = *Test of Adult Basic Education;* LWID = *Letter-Word Identification;* PC = *Passage Comprehension;* RS = raw score; OC = *Oral Comprehension.*
[a]Equal variances are not assumed.
*Significant at $p < .05$ with a Bonferroni correction for testwise error.

and gaze duration (β = .03, p = .987). Total R^2 was .65. In this model, gaze duration accounted for very little variance and was not a significant predictor of TABE.

Research Question 3: Do Readers With Relatively High Oral Reading Fluency Exhibit Component Skill or Eye Movement Patterns That Are Different From Those of Readers With Relatively Low Reading Fluency?

To investigate the differences between more and less fluent readers, the top quartile (n = 12; M = 182, SD = 21, range = 60 for WCPM) and the lowest quartile (n = 12; M = 83, SD = 27, range = 82 for WCPM) were compared. After making a Bonferroni correction for testwise error, group effects were found for *Passage Comprehension*, word reading, gaze duration, total viewing time, and saccade amplitude (all ps $\leq$ .004), but not for language comprehension (see Table 5). A comparison of the two groups' regression patterns revealed that both groups looked back to approximately the third word previously read, $t(22) = 1.00$, p = .328.

Research Question 4: Are Word Frequency and Word Length Effects Similar for Readers With High and Low Oral Reading Fluency?

Frequency effects. A 2 (Quartile) × 2 (Frequency) MANOVA revealed within-subject and between-subjects effects as well as interactions. After making a Bonferroni adjustment for testwise error, within-subject effects were found for the following variables: gaze duration, total viewing duration, refixations, initial landing position, and regressive saccades. There were statistically significant interactions between quartile and frequency for refixations and the temporal variables beyond initial fixation duration (gaze duration and total viewing time). This means that both groups of readers exhibited frequency effects for temporal and spatial variables. However, the low frequency words required extensive analysis (refixations) and processing time (gaze duration and total viewing time) for the less fluent readers. The interaction between quartile and frequency means that these words caused severe disruptions of reading patterns for the less fluent readers.

Length effects. The text included word lengths from 1 to 11 letters long. A 2 (Quartile) × 11 (Length) MANOVA revealed a significant Mauchley's Test of Sphericity for all measures; therefore, the Greenhouse-Geisser correction was used. After the Bonferroni adjustment for testwise error, within-subject and between-subjects effects were found. Within-subject effects included gaze duration, total viewing time, refixations, initial landing position, and regressive saccades. Between-subjects effects included gaze duration and total viewing time. Not only were differences between the two groups observed (with more fluent readers exhibiting shorter fixation times than less fluent readers on all word lengths), but length effects were also observed such that longer words caused an increase in analysis and processing time for all readers.

Discussion

Adults participating in the current study had, on average, 4th-grade reading comprehension skills when measured by the *Passage Comprehension* and 6th-grade reading comprehension skills when measured by the TABE. This slight difference might be attributed to at least two factors. First, the current sample of adult participants is different from the sample of adults used to create norms for the *Passage Comprehension*, and these differences may cause variation in the outcomes. Second, the *Passage Comprehension* is a cloze task in which the participants read and fill in blanks based on their understanding of the text. The TABE *Reading* section includes reading passages paired with multiple-choice questions. Research attests to different reading comprehension assessments measuring different underlying component reading skills (Cutting & Scarborough, 2006; Keenan, Betjemann, & Olson, 2008; Mellard, Fall, & Woods, 2010) and does not necessarily indicate improper measurement by either assessment.

Due to low performance on the offline skill assessments, these individuals may benefit from skill-based word-level instruction similar to instruction received by students in the early years of school. In this way, the readers could pair decoding strategies and language skills to advance their literacy skills and ultimately improve their reading comprehension. A direct comparison to typically developing young readers could reveal underlying patterns of strength (as well as disability) exhibited by the struggling adult readers.

Since eye movements are measured in milliseconds and text spaces, they offer information beyond what can be attained via offline reading assessments. Analyses of eye movements revealed some characteristics that deviate from the conventional patterns expected with adults. The current sample of adults who demonstrated lower levels of literacy than typical adults exhibited slightly higher fixation durations, shorter saccade amplitudes, and higher proportions of regressive saccades than are expected for adults (Rayner, 1998). Overall, the eye movements of the current sample of adults reflect the difficulty that these readers had with decoding and understanding the text.

Long fixation durations (compared to typical adults) indicate increased processing time during word identification. In addition, fixation duration was negatively correlated ($r = -.38$) with word reading. This may be indicative of an underdeveloped sight-word vocabulary or poor decoding skills. Mean saccade amplitudes revealed that the adults in the current study averaged forward eye movements of about 2.5 character spaces. This is more similar to findings with typical first-grade students or poor readers in fifth grade (approximately three letter characters; Blythe & Joseph, 2011; Guoli, Jingen, & Lihong, 2013) than findings with adults (about six letter spaces for oral reading; Rayner, 1998) or typical fourth- or fifth-grade readers (approximately six letter spaces; Feng, Miller, Shu, & Zhang, 2009; McConkie et al., 1991). It is noteworthy to mention that the present study used an oral reading methodology, and the similarity to younger readers may be a product of this alternative methodology.

The participants exhibited a higher proportion of regressive saccades (30.7%) than was observed for either typical adults (10% to 15%; Rayner et al., 2006; Rayner, Sereno, Morris, Schmauder, & Clifton, 1989) or sixth-grade students (19%; Sovik, Arntzen, & Samuelson, 2000). It is unclear whether this high rate of rereading text was due to the participants' first experience with an eye-tracking machine, unfamiliarity reading from a computer screen versus a paper copy of text, a desire to perform well in an oral reading task, or another unidentified variable.

Measures of lexical activation that lead to higher levels of comprehension are believed to happen downstream in the time-course of reading and are considered to be captured in gaze duration and total viewing time (Ashby, Rayner, & Clifton, 2005; Rayner, 1998). Gaze duration represents the summed fixation durations on a word before the eyes move away from the word and is a commonly used proxy for cognitive processing time (Rayner, 1998; Rayner et al., 2006). For the current sample of adults, we observed gaze durations of about 400 ms and an approximate regression rate of 31%. The current sample of readers spent a large portion of their time going back to reread text, which seems to indicate lower reading fluency, poor word reading skills, and poor comprehension. Gaze duration is dependent on the text difficulty, and the mean duration varies across experimental studies. These patterns of long fixation durations, short saccades, and a high proportion of regressions indicate that the adults in the current study exhibited slow and laborious processing of fourth- and fifth-grade-level text.

Initial landing position appears to be dependent on word length, and readers tend to initially fixate somewhere between the beginning and middle of the word (Rayner, 1998).The mean initial landing position of 2.2 may be due to the fact that 91.1% of the words in the current tasks were six or fewer letters in length. A separate analysis of initial landing position revealed that word length was positively correlated with initial landing position ($r = .45$, $p < .001$), and the mean initial landing position for each word length was on a letter at approximately the middle of the word. Similar to previous findings of word length effects on initial landing position (Plummer & Rayner, 2012), the initial landing position for words with nine or more letters remained around the fourth or fifth letter.

One goal of the current study was to evaluate the relations between component skills of reading and eye movement measures for adults in basic education programs. Analyses revealed moderate significant correlations between all components of reading and temporal measures of eye movements. The significant and positive relations between component skills of word reading and language comprehension to reading comprehension indicate valid measurement of these constructs, as other studies have found correlations of similar strength and direction (e.g., Braze et al., 2007; Cain, Oakhill, & Bryant, 2004; Goff, Pratt, & Ong, 2005). Negative correlations between component skills and temporal eye movement measures indicate that faster word identification and lexical access times are associated with higher scores on component measures. This was anticipated, as text reading fluency is related to reading comprehension (Kim et al., 2012; Taylor et al., 2012).

A second goal of the current study was to examine the utility of word reading, language comprehension, and lexical activation time in predicting reading comprehension. The simple view of reading purports that decoding and language comprehension work together to produce reading comprehension. However, the online measure of lexical activation time did account for unique variance in the *Passage Comprehension* measure over and above word reading and oral comprehension. The predictive utility of word identification and language comprehension was similar across the two reading comprehension outcomes (*Passage Comprehension* and TABE), although language comprehension was the stronger predictor in both cases. These two predictors explained 57% of total variance in *Passage Comprehension* and 65% of the total variance in TABE.

Since gaze duration contains the components of initial fixation duration (associated with word identification) and refixation time (associated with lexical activation), it was logical that gaze duration appeared to account for variance that was shared with word identification (LWID goes nonsignificant in Step 2 of both models). However, gaze duration accounted for unique variance in *Passage Comprehension* but not in TABE. The differences in predictability may be due to the fact that *Passage Comprehension* relies on word reading (and perhaps word-level skills) to a much greater extent than TABE does, even after accounting for offline measures. Previous research with adults suggests that additional variance might be accounted for by adding vocabulary knowledge (Braze et al., 2007; Hall et al., 2014), syntactic skill (Taylor et al., 2012), or reading fluency (MacArthur et al., 2010) to these models.

Group Comparisons

The participants were grouped into four quartiles by oral reading fluency score, and the top and bottom quartiles were compared. This disparity in oral reading fluency was also related to differences in word reading and passage reading comprehension, despite no differences in language comprehension. The eye-tracking measures revealed that the less fluent group of readers spent more time in their first gaze and spent more time looking in subsequent gazes. These findings indicate that the less fluent readers spent more time identifying and accessing lexical-semantic information for each word, even though their language comprehension skills were similar to the more fluent readers. This delay of information access may have influenced reading comprehension, as the passage comprehension measure was found to be significantly different between the two groups. The less fluent readers also exhibited a saccade amplitude approximately one character space shorter than the more fluent readers. The difference in saccade amplitude could be due to less experience in reading or could be related to the read-aloud paradigm of the current study.

As expected, all readers showed length and frequency effects (e.g., Inhoff & Rayner, 1986; Hyönä & Olson, 1995). However, the less fluent readers showed larger frequency effects than the more fluent readers. Not only did the less fluent readers gaze at the low frequency words longer, but they also refixated them more frequently and spent more total time looking at them. The low-frequency words clearly caused an increase in processing load for both groups, but the less fluent readers may have had fewer cognitive resources available to deal with the processing load increase.

Analysis of regression patterns revealed that the two groups exhibited statistically similar patterns of returns to text that had been read immediately prior (on average, the immediately previous text). This means that both groups of readers could have been experiencing immediate integration issues. Alternatively, this finding may be due to the participants' lack of confidence or concern for repetition errors when reading aloud.

Implications

Given the correlational nature of the current study, practical implications are limited. However, in conjunction with previous studies, these findings have implications for practice in adult education settings. In particular, these struggling adult readers exhibit deficits in component skills as well as in reading comprehension. Weak language skills paired with weak word identification skills mean that many of the participants in the current study lack the fundamental ability to decode and recognize unknown words in order to apply language knowledge and understand the text. Although word-level skill instruction is not a traditional focus for adult education courses (Sabatini et al., 2010), education for adults with low literacy skills should provide for explicit instruction in decoding strategies and reading fluency along with comprehension instruction.

Limitations and Future Directions

Limitations of the current study include a relatively small sample ($n = 48$), with even fewer contributing to the TABE analysis ($n = 44$). The current study recruited adults attending literacy classes on a single campus. This means that although many of our findings corroborate previous research, the generalizability of the current findings is limited. First, all constructs measured were done so with a single assessment; therefore, all scores include both the true score and error. Second, participants in ABE settings often experience multiple exposures to the TABE test each year. We were unable to gather test/retest information and control for practice effects in the analysis. Third and most important, the majority of eye-tracking research follows a silent reading procedure. The current study employed an oral reading procedure when piloting revealed that many of the adult participants preferred reading the text orally. This deviation from typical protocol employed with previous studies with proficient adult readers introduced variables associated with reading aloud, such as oral reading confidence and articulation processes. For example, regressive saccades and extended fixation durations may be products of anxiety or low expressive vocabulary rather than decoding or integration difficulties. Some aspects of the present findings may be influenced by methodological effects.

The present findings warrant further research with adults across multiple sites with larger samples from the ABE population, utilizing various tests of reading component skills and eye movements. Additionally, completing these eye-tracking evaluations in both an oral and a silent condition could further disentangle the confounding of population and method effects. From this study we learned that the adults in this sample appear to exhibit reading skills at about the fourth- through sixth-grade level and eye movements congruent with a much lower grade level. It is unclear whether this phenomenon is unique to adults or is observable in other populations of struggling readers, although some research indicates this may be the case (i.e., Guoli et al., 2013). Additionally, it would be of interest to observe patterns of similarity between typically developing early readers with limited decoding (and reading fluency) skills and adults with similar decoding and reading fluency skills.

The current results build on previous eye movement research with adults and extend findings to include adults in ABE programs. We hope that these findings contribute to future studies and promote the discussion of reading research for populations of adults enrolled in adult education programs.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305F1000027 to Florida State University.

Note

1. Fixation durations less than 70 ms and greater than 1,200 ms were excluded, as were gaze durations greater than 2,400 ms and total viewing times greater than 4,800 ms. This resulted in the exclusion of 5.5% of the data points, leaving 94.5% of data useable for the analysis.

References

Ashby, J., Rayner, K., & Clifton, C. (2005). Eye movements of highly skilled and average readers: Differential effects of frequency and predictability. *Quarterly Journal of Experimental Psychology Section A: Human Experimental Psychology*, *58*, 1065–1086.

Ashby, J., Yang, J., Evans, K. H., & Rayner, K. (2012). Eye movements and the perceptual span in silent and oral reading. *Attention, Perception, & Psychophysics*, *74*, 634–640.

Binder, K. S., & Lee, C. S. (2012). Reader profiles for adults with low literacy skills: A quest to find resilient readers. *Journal* *of Research and Practice for Adult Literacy, Secondary, and Basic Education*, *1*(2), 78–90.

Blythe, H. I., & Joseph, H. S. (2011). Children's eye movements during reading. In S. P. Liversedge, I. D. Gilchrist, & S. Everling (Eds.). *The Oxford book of eye movements* (pp. 643–662). New York, NY: Oxford University Press.

Braze, D., Tabor, W., Shankweiler, D. P., & Mencl, W. E. (2007). Speaking up for vocabulary: Reading skill differences in young adults. *Journal of Learning Disabilities*, *40*, 226–243.

Cain, K., & Oakhill, J. (1998). Comprehension skill and inference-making ability: Issues of causality. In C. Hulme & R. Joshi (Eds.), Reading and spelling: Development and disorders (pp. 329–342). Mahwah, NJ: Lawrence Erlbaum.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: Concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology*, *96*, 31.

Carpenter, P. A., & Just, M. A. (1983). What your eyes do while your mind is reading. In K. Rayner (Ed.), *Eye movements in reading: Perceptual and language processes* (pp. 275–307). New York, NY: Academic Press.

Catts, H., Adlof, S., & Ellis Weismer, S. (2006). Language deficits in poor comprehenders: A case for the simple view of reading. *Journal of Speech, Language, and Hearing Research*, *49*, 278–293.

Chall, J. S. (1983). *Learning to read: The great debate*. Fort Worth, TX: Harcourt Brace.

Chiappe, P., Chiappe, D. L., & Gottardo, A. (2004). Vocabulary, context, and speech perception among good and poor readers. *Educational Psychology*, *24*, 825–843.

Clifton, C., Staub, A., & Rayner, K. (2007). Eye movements in reading words and sentences. In R. P. G. van Gompel, M. H. Fischer, W. S. Murray, & R. L. Hill (Eds.), *Eye movements: A window on mind and brain* (p. 341–371). Amsterdam, the Netherlands: Elsevier.

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences*. New York, NY: Routledge.

Cree, A., Kay, A., & Steward, J. (2012). *The economic and social cost of illiteracy: A snapshot of illiteracy in a global context* (Final report from the World Literacy Foundation). Retrieved from http://www.worldliteracyfoundation.org/The_Economic_&_Social_Cost_of_Illiteracy.pdf

CTB/McGraw-Hill. (2008). *Test of Adult Basic Education (TABE)*. Monterey, CA: Author.

Cutting, L. E., & Scarborough, H. S. (2006). Prediction of reading comprehension: Relative contributions of word recognition, language proficiency, and other cognitive skills can depend on how comprehension is measured. *Scientific Studies of Reading*, *10*, 277–299.

Dahhan, A. D., Georgiou, G. K., Hung, R., Munoz, D., Parilla, R., & Kirby, J. R. (2013). Eye movements of university students with and without reading difficulties during naming speed tasks. *Annals of Dyslexia*, *64*, 137–150.

De Corte, E., Verschaffel, L., & Pauwels, A. (1990). Influence of the semantic structure of word problems on second graders' eye movements. *Journal of Educational Psychology*, *82*, 359–365.

De Luca, M., Judica, A., Spinelli, D., & Zoccolotti, P. (2002). Reading words and pseudowords: An eye movement study of developmental dyslexia. *Brain and Language*, *80*, 617–626.

Ehri, L. C. (1999). Phases of development in learning to read words. In J. V. Oakhill & R. Beard (Eds.), *Reading development and the teaching of reading: A psychological perspective* (pp. 79–108). Oxford, UK: Blackwell.

Engbert, R., Nuthmann, A., Richter, E. M., & Kliegl, R. (2005). SWIFT: A dynamic model of saccade generation during reading. *Psychological Review*, *112*(4), 777–813.

Feng, G., Miller, K., Shu, H., & Zhang, H. (2009). Orthography and the development of reading processes: An eye-movement study of Chinese and English. *Child Development*, *80*, 720–735.

Florida Center for Reading Research. (2009). *Ongoing progress monitoring (OPM) options*. Retrieved from http://www.fcrr.org/lookup/

Florida Department of Education. (2005). *Florida's graduation requirements*. Retrieved from http://www.fldoe.org/bii/studentpro/pdf/DiplomaCriteriaChart.pdf

Florida Department of Education. (2009). *Florida Assessments for Instruction in Reading (FAIR)*. Tallahassee, FL: Institute of Education Sciences.

Fracasso, L. E., Bangs, K., & Binder, K. S. (in press). The contributions of phonological and morphological awareness to literacy skills in the adult basic education population. *Journal of Learning Disabilities*. Retrieved from http://ldx.sagepub.com/content/early/2014/06/16/0022219414538513.full.pdf+html

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. E. Patterson, J. C. Marshall, & M. Coltheart (Eds.), *Surface dyslexia: Neuropsychological and cognitive studies of phonological reading* (pp. 301–330). London, UK: Erlbaum.

Gilliam, B. K., Dykes, F., Gerla, J. K., & Wright, G. L. (2011). Silent reading manifestations of adolescent struggling readers. *Reading Improvement*, *48*, 118–127.

Goff, D. A., Pratt, C., & Ong, B. (2005). The relations between children's reading comprehension, working memory, language skills and components of reading decoding in a normal sample. *Reading and Writing, 18*, 583–616.

Gough, P. B., & Hillinger, M. L. (1980). Learning to read: An unnatural act. *Bulletin of the Orton Society*, *30*, 179–196.

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

Greenberg, D., Wise, J. C., Frijters, J. C., Morris, R., Fredrick, L. D., Rodrigo, V., & Hall, R. (2013). Persisters and nonpersisters: Identifying the characteristics of who stays and who leaves from adult literacy interventions. *Reading and Writing: An Interdisciplinary Journal*, *26*, 495–514.

Guoli, Y., Jingen, W., & Lihong, W. (2013). The perceptual span of good readers and poor readers in fifth grade. *Journal of Psychological Science*, *3*, 19.

Hall, R., Greenberg, D., Laures-Gore, J., & Pae, H. K. (2014). The relationship between expressive vocabulary knowledge and reading skills for adult struggling readers. *Journal of Research in Reading*, *37*, S87–S100.

Harp, B., & Brewer, J. A. (2000). Assessing reading and writing in the early years. In D. S. Strickland & L .M. Morrow (Eds.), *Beginning reading and writing* (pp. 154–167). Newark, DE: International Reading Association.

Hasbrouck, J. E., & Tindal, G. (1992). Curriculum-based oral reading fluency norms for students in grades 2 through 5. *Teaching Exceptional Children*, *24*(3), 41–44.

Heller, D. (1982). Eye movements in reading. In R. Groner & P. Fraisse (Eds.), *Cognition and eye movements* (pp. 139–154). Amsterdam, the Netherlands: North Holland.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing*, *2*, 127–160.

Hyönä, J., & Olson, R. K. (1995). Eye fixation patterns among dyslexic and normal readers: Effects of word length and word frequency. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *21*(6), 1430.

IBM Corp. (2012). *IBM SPSS statistics for Windows* (Version 21.0). Armonk, NY: Author.

Inhoff, A. W., & Rayner, K. (1986). Parafoveal word processing during eye fixations in reading: Effects of word frequency. *Perception & Psychophysics*, *40*(6), 431–439.

Joseph, H. S., Nation, K., & Liversedge, S. P. (2013). Using eye movements to investigate word frequency effects in children's sentence reading. *School Psychology Review*, *42*, 207–222.

Joshi, R. M., Tao, S., Aaron, P. G., & Quiroz, B. (2012). Cognitive component of componential model of reading applied to different orthographies. *Journal of Learning Disabilities*, *45*, 480–486.

Keenan, J. M., Betjemann, R. S., & Olson, R. K. (2008). Reading comprehension tests vary in the skills they assess: Differential dependence on decoding and oral comprehension. *Scientific Studies of Reading*, *12*, 281–300.

Kennedy, A. (1983). On looking into space. In K. Rayner (Ed.), *Eye movements in reading: Perceptual and language processes* (pp. 237–251). New York, NY: Academic Press.

Kidd, E., Stewart, A. J., & Serratrice, L. (2011). Children do not overcome lexical biases where adults do: The role of the referential scene in garden-path recovery. *Journal of Child Language*, *38*, 222–234.

Kim, Y. S., Wagner, R. K., & Lopez, D. (2012). Developmental relations between reading fluency and reading comprehension: A longitudinal study from Grade 1 to Grade 2. *Journal of Experimental Child Psychology*, *113*, 93–111.

Kunert, R., & Scheepers, C. (2014). Speed and accuracy of dyslexic verses typical word recognition: An eye movement investigation. *Frontiers in Psychology*, *5*, 1–16.

LaBerge, D., & Samuels, S. J. (1974). Toward a theory of automatic information processing in reading. *Cognitive Psychology*, *6*(2), 293–323.

Lima, S. D., & Inhoff, A. W. (1985). Lexical access during eye fixations in reading: Effects of word-initial letter sequences. *Journal of Experimental Psychology: Human Perception and Performance*, *11*, 272–285.

MacArthur, C., Konold, T. R., Glutting, J. J., & Alamprese, A. A. (2010). Reading component skills of learners in adult basic education. *Journal of Learning Disabilities*, *43*, 108–121.

Mackert, M., Champlin, S. E., Pasch, K. E., & Weiss, B. D. (2013). Understanding health literacy measurement through eye tracking. *Journal of Health Communication: International Perspectives*, *18*(1), 185–196.

Mason, J. (1980). When *do* children learn to read: An exploration of four-year-old children's letter and word reading competencies. *Reading Research Quarterly*, *15*, 202–227.

McConkie, G. W. (1981). Evaluating and reporting data quality in eye movement research. *Behavior Research Methods & Instrumentation*, *13*(2), 97–106.

McConkie, G. W., & Hogaboam, T. W. (1985). Eye position and word identification in reading. In R. Groner, G. W. McConkie, & C. Menz (Eds.), *Eye movements and human information processing* (pp. 159–172). Amsterdam, the Netherlands: North Holland.

McConkie, G. W., Zola, D., Grimes, J., Kerr, P. W., Bryant, N. R., & Wolff, P. M. (1991). Children's eye movements during reading. In J. F. Stein (Ed.), *Vision and visual dyslexia* (pp. 252–262). London, UK: Macmillan.

Mellard, D. F., & Fall, E. (2012). Component model of reading comprehension for adult education participants. *Learning Disability Quarterly*, *35*(1), 10–23.

Mellard, D. F., Fall, E., & Woods, K. L. (2010). A path analysis of reading comprehension for adults with low literacy. *Journal of Learning Disabilities*, *43*(2), 154–165.

Mellard, D. F., Krieshok, T., Fall, E., & Woods, K. (2013). Dispositional factors affecting motivation during learning in adult basic and secondary education programs. *Reading and Writing*, *26*, 515–538.

Nation, K., & Snowling, M. J. (2004). Beyond phonological skills: Broader language skills contribute to the development of reading. *Journal of Research in Reading*, *27*, 342–356.

Perfetti, C. A. (1985). *Reading ability*. New York, NY: Oxford University Press.

Plummer, P., & Rayner, K. (2012). Effects of parafoveal word length and orthographic features in initial fixation positions in reading. *Attention, Perception, and Psychophysics*, *74*, 950–963.

Pollatsek, A., Reichle, E. D., & Rayner, K. (2003). Modeling eye movements in reading: Extensions of the E-Z Reader model. In J. Hyönä, R. Radach, & H. Deubel (Eds.), *The mind's eye: Cognitive and applied aspects of eye movement research* (pp. 360–390). Amsterdam, the Netherlands: Elsevier.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*, 372–422.

Rayner, K., & Bertera, J. H. (1979). Reading without a fovea. *Science*, *206*, 468–469.

Rayner, K., Chace, K. H., Slattery, T. J., & Ashby, J. (2006). Eye movements as reflections of comprehension processes in reading. *Scientific Studies of Reading*, *10*, 241–255.

Rayner, K., & Juhasz, B. J. (2004). Eye movements in reading: Old questions and new directions. *European Journal of Cognitive Psychology*, *16*, 340–352.

Rayner, K., & McConkie, G. W. (1976). What guides a reader's eye movements. *Vision Research*, *16*, 829–837.

Rayner, K., Sereno, S. C., Morris, R. K., Schmauder, A. R., & Clifton, C. (1989). Eye movements and on-line language comprehension processes. *Language and Cognitive Processes*, *4*, SI21–SI49.

Reichle, E. D. (2006). Computational models of eye-movement control during reading: Theories of the "eye-mind" link. *Cognitive Systems Research*, *7*, 2–3.

Reichle, E. D., Pollatsek, A., Fisher, D. L., & Rayner, K. (1998). Toward a model of eye movement control in reading. *Psychological Review*, *105*, 125–157.

Reichle, E. D., Rayner, K., & Pollatsek, A. (1999). Eye movement control in reading: Accounting for initial fixation locations and re fixations within the E-Z Reader model. *Vision Research*, *39*, 4403–4411.

Reichle, E. D., Reineberg, A. E., & Schooler, J. W. (2010). Eye movements during mindless reading. *Psychological Science*, *21*(9), 1300–1310.

Sabatini, J. P., Sawaki, Y., Shore, J. R., & Scarborough, H. S. (2010). Relationships among reading skills of adults with low literacy. *Journal of Learning Disabilities*, *43*, 122–138.

Schrank, F. A., Mather, N., & Woodcock, R. W. (2004). Comprehensive manual. *Woodcock-Johnson III Diagnostic Reading Battery*. Itasca, IL: Riverside.

Sovik, N., Arntzen, O., & Samuelson, M. (2000). Eye-movement parameters and reading speed. *Reading and Writing*, *13*, 237–255.

SR Research. (2013). *EyeLink1000* [computer software and hardware]. Mississauga, Ontario, Canada. Retrieved from http://www.sr-research.com/index.html

Tang, S., Reilly, R. G., & Vorstius, C. (2012). EyeMap: A software system for visualizing and analyzing eye movement data in reading. *Behavior Research Methods*, *44*(2), 420–438.

Taylor, N. A., Greenberg, D., Laures-Gore, J., & Wise, J. C. (2012). Exploring the syntactic skills of struggling adult readers. *Reading and Writing: An Interdisciplinary Journal*, *25*, 1385–1402.

Tighe, E. L., Barnes, A. E., Connor, C. M., & Steadman, S. C. (2013). Defining success in adult basic education settings: Multiple stakeholders, multiple perspectives. *Reading Research Quarterly*, *48*, 415–435.

Torgeson, J. K., Wagner, R. K., Rashotte, C. A., Burgess, S., & Hecht, S. (1997). Contributions of phonological awareness and rapid automatic naming ability to the growth of word-reading skills in second-to fifth-grade children. *Scientific Study of Reading*, *1*, 161–195.

Underwood, N. R., & Zola, D. (1986). The span of letter recognition of good and poor readers. *Reading Research Quarterly*, *21*, 6–19.

U.S. Department of Education. (2015). *1992 National Adult Literacy Survey and 2003 National Assessment of Adult Literacy*. Retrieved from https://nces.ed.gov/naal/kf_demographics.asp#2

Verhoeven, L. (2000). Components in early second language reading and spelling. *Scientific Studies of Reading*, *4*, 313–330.

Verhoeven, L., & Van Leeuwe, J. (2008). Prediction of the development of reading comprehension: A longitudinal study. *Applied Cognitive Psychology*, *22*(3), 407–423.

Vorstius, C., Radach, R., Mayer, M. B., & Lonigan, C. J. (2013). Monitoring local comprehension monitoring in sentence reading. *School Psychology Review*, *42*, 191–206.

Wise, J. C., Sevcik, R. A., Morris, R. D., Lovett, M. W., & Wolf, M. (2007). The relationship among receptive and expressive vocabulary, listening comprehension, pre-reading skills, word identification skills, and reading comprehension by children with reading disabilities. *Journal of Speech, Language, and Hearing Research, 50*(4), 1093–1109.

Woodcock, R. W., Mather, N., & Schrank, F. A. (2004). *Woodcock-Johnson III Diagnostic Reading Battery*. Itasca, IL: Riverside.

Yuill, N., & Oakhill, J. (1991). *Children's problems in text comprehension: An experimental investigation*. Cambridge, UK: Cambridge University Press.

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