Fluent reading is considered to be a necessary component for reading comprehension because it frees attentional resources that can then be used to understand what it being read (Laberge & Samuels, 1974). Despite a large research base demonstrating the importance of assessing and teaching reading fluency, much is unknown regarding what underlying behaviors are associated with the development of reading fluency. Recent advances in eye-tracking technology allow for the investigation of what behaviors contribute to fluent reading in elementary students.

The current document outlines two studies completed to fulfill the doctoral dissertation requirement of the school psychology program at the University of Georgia. The purpose of Study 1 was to determine the similarities and differences between eye movements during silent and oral reading in children. It is well documented that adult eye movements differ during silent and oral reading; however, the extent to which these results generalize to developing readers was previously unknown. Thus, a sample of 57 third grade students’ eye movements were recorded while they were reading a passage either silently or aloud. T-tests were conducted to compare
the two groups across multiple eye-movement variables. Results suggest that, similar to adults, third grade students’ eye-movement behavior also differs during silent and oral reading.

Study 2 evaluated the effects of providing students with listening passage preview (LPP) in conjunction with repeated reading (RR). The same 57 third grade students from Study 1 were assigned to either a condition in which they read a passage 4 times (RR) or a condition in which they first listened to a fluent reading of the passage and then read the passage 3 times (LPP+RR). Results indicated that students’ in both conditions increased their reading fluency and decreased the number of errors they made during reading. Students’ reading behavior were similar during the two intervention conditions across all variables except for one. Students in the LPP+RR condition made significantly more regressions across all trials. Students in both conditions significantly reduced the average number of regressions, decreased their average total fixation time, and made fewer fixations on average on all words in the passage across trials. Significant differences across trials were also found on the reading of high- and low-frequency words.

INDEX WORDS: curriculum-based measurement, eye movements, reading, oral reading, silent reading, repeated readings, listening passage preview, reading fluency
INVESTIGATING EYE-MOVEMENT BEHAVIOR DURING READING UTILIZING EYE-TRACKING TECHNOLOGY

by

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INVESTIGATING EYE-MOVEMENT BEHAVIOR DURING READING UTILIZING EYE-TRACKING TECHNOLOGY

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CHAPTER 1
DISSERTATION INTRODUCTION AND LITERATURE REVIEW

The National Reading Panel identified fluency instruction as one of the five essential components of effective reading instruction (NICHHD, 2000), which inspired a plethora of research on effective strategies for increasing reading fluency. The amount of attention fluency has received in the literature over the past three decades certainly highlights its importance. Fluent reading is considered to be a necessary component for reading comprehension (Laberge & Samuels, 1974). In their theory of automatic reading processes, Laberge and Samuels (1974) proposed that the attentional resources available during reading are limited. Therefore, fluent decoding abilities allow the reader to apply those attentional resources to understanding the text (Stanovich, 1984). If word reading is not automatic (i.e., fluent), then a majority of attentional resources will be needed to decode the text, limiting the resources available for comprehension. As such, having reliable and valid methods for assessing fluency and effective methods for improving fluency are of the utmost importance. The foci of the two studies conducted as part of this doctoral dissertation were to examine (a) differences in students’ reading fluency as a function of whether they are reading aloud or silently, and (b) commonly employed procedures for improving students’ reading fluency. These studies extend fluency based assessment and intervention research by employing eye-tracking procedures that enable researchers to examine the behaviors that underlie reading.
The Assessment of Reading Fluency

Fluent reading is characterized by quick, accurate decoding and proper expression (NICHHD, 2000). It is often measured using curriculum-based measurement for oral reading (CMB-R). CBM-R is a type of formative assessment teachers use to monitor students’ progress and inform instructional decision-making. It involves having a student read aloud for 1 min while an adult follows along marking any errors the student makes. Errors include miscues, omissions, and substitutions. The resultant score is words read correctly in a minute (WRCM). This score can be graphed and used for making comparisons both across students, in order to identify those at risk for reading difficulty, and within students across time in order to evaluate student progress (Deno, 1985). CBM-R is well established as a good indicator of reading achievement and is highly correlated with measures of other reading skills such as decoding, word identification, vocabulary, and comprehension (Reschly, Busch, Betts, Deno, & Long, 2009). Schools across the United States use CBM-R to monitor students’ progress in reading fluency because of its quick, simple procedures and sound psychometric properties (Wayman, Wallace, Wiley, Ticha, & Espin, 2007). Despite extensive empirical support, criticisms of CBM-R are abundant (e.g., Goodman, 2005) and have made it into the press. Teachers who encounter these criticisms might question their students’ CBM-R data without realizing that the criticisms are not empirically based.

Many critics of CBM-R believe oral reading rate is not a good indicator of reading comprehension (Foegen, Espin, Allinder, & Markell, 2001). They believe oral reading rate does not accurately reflect comprehension skills because they feel that some children who, despite being able to read quickly and accurately, are unable to comprehend what they are reading (i.e. “word callers”; Hamilton & Shinn, 2003). As support for this claim, critics may turn to
empirical evidence that suggests oral reading rate is most strongly correlated with word identification skills (e.g., Reschly et al., 2009). They might argue that this high correlation indicates that CBM-R is primarily a measure of word identification speed and thus is not an adequate predictor of comprehension.

Hamilton and Shinn (2003) provided evidence to dispel the claim that word callers are fluent readers who lack comprehension skills. They asked teachers to identify word callers (fluent readers who have difficulty comprehending text) in their classrooms and similarly fluent peers who were able to understand text. The researchers then compared the two groups on their fluency and comprehension skills and found that students whom teachers judged to be word callers did in fact have less developed comprehension skills, but unlike what the teachers predicted, the word caller sample was significantly less fluent than their peers who were judged to be similarly fluent. Thus, results suggested that the teachers’ judgments about the word callers’ fluency were inaccurate. This correlation between less fluent reading and lower comprehension in word callers further supports the finding that reading fluency is linked to and reflects reading comprehension.

Jenkins et al. (2003a) also investigated the relationship between oral reading rate and comprehension. They compared students’ performance on word list and passage reading (i.e., CBM-R) to reading comprehension skills and found that students’ CBM-R performance explained more variance in reading comprehension than performance on word lists. In an extension of these findings, Jenkins et al. (2003b) found that not only did CBM-R explain more variance in reading comprehension than word list reading but also that comprehension explained over twice as much unique variance in CBM-R performance than did word list reading. These
findings provide strong evidence to suggest that CBM-R is a reflection of comprehension and not just a measure of word identification fluency.

Other common criticisms of CBM-R are that it must be individually administered (Faykus & McCurdy, 1998; Shinn, Good, Knutson, & Tilly, 1992; Wesson, King, & Deno, 1984) and that it measures oral reading when most reading is done silently. One procedure, the maze task, addresses these three criticisms of CBM-R. The maze reportedly has greater face validity as a measure of reading comprehension (Faykus & McCurdy, 1998; Fuchs & Fuchs, 1992), can be grouped administered, and requires students to read the text silently (Hosp & Hosp, 2003). However, despite high face validity, research suggests that CBM-R is a better predictor of comprehension than the maze. In fact, the maze fails to explain variance in reading comprehension beyond CBM-R (Ardoin et al., 2004). Furthermore, January and Ardoin (2012) suggest that the maze may be little more than a measure of reading fluency that fails to account for reading errors, making it a less accurate measure of reading fluency than CBM-R. This may explain why the maze does not predict reading skills as well as CBM-R. It is also possible that differences in the degree to which these measures predict comprehension are partially due to differences in how students read passages aloud versus silently. Unfortunately, to date, research examining difference in reading behavior between silent and oral reading is limited to that conducted with adult participants (e.g., Anderson & Swanson, 1937).

Research evaluating differences in eye movements when adults read aloud versus silently suggests clear differences in reading behavior across these two types of reading. Specifically, when in engaged in oral reading, adults’ total fixation durations tend to be longer and saccade lengths (i.e., the distance eyes move between fixations) tend to be shorter as compared to silent reading (Anderson & Swanson, 1937; Rayner, 1984). The extent to which these results
generalize to young readers is unknown but has implications to both school based assessment and instructional practices. For instance, evidence that students comprehend better when reading aloud might (a) provide further support for the evaluation of students’ oral (i.e., CBM-R) as opposed to silent reading; (b) encourage development of reading comprehension measures that require students to read aloud; and (c) highlight the value of providing reading comprehension instruction to students when they are reading aloud in small groups as opposed to when reading silently and independently.

**Interventions for Reading Fluency**

Repeated Readings (RR) is the most frequently cited intervention for improving reading fluency (Meyer & Felton, 1999), and it has extensive empirical support for its use as an effective fluency intervention (e.g., Ardoin, Carfolite, Klubnik, & McCall, 2009; Dowhower, 1987; Eckert, Ardoin, Daly, & Martens, 2002; Therrien, 2004). The results of several meta-analyses support the use of RR for students with various disabilities (Meyer & Felton, 1999; NICHHD, 2000; Therrien, 2004). RR is not only effective in increasing fluency ($ES = .83$) and comprehension ($ES = .67$) on the passage used during the procedure, but it also appears that RR has generalization effects to passages not read repeatedly and thus helps improve overall reading fluency ($ES = .5$) and comprehension ($ES = .25$; Therrien).

Listening Passage Preview (LPP) is another widely used intervention for increasing reading fluency (Begeny, Krouse, Ross, & Mitchell, 2009). Few studies have, however, empirically investigated the effects of LPP (Begeny et al., 2009; Begeny & Silber, 2006; Skinner, Cooper, & Cole, 1997). Begeny et al (2009) directly compared RR, LLP, and a listening only condition to a no intervention control group with 4 second grade students using an alternating treatments design. Results indicated that all three interventions produced greater
gains in reading fluency than the control group. Furthermore, both RR and LPP outperformed the listening only condition in which students listened to an adult read a story without reading along themselves as in LPP. RR produced greater immediate gains than LPP; however, based on retention data from assessments conducted 2 days after intervention, neither LPP nor RR consistently outperformed the other.

Researchers have attempted to strengthen the effects of RR by first providing LPP (e.g., Daly & Martens, 1994; Daly, Martens, Dool, & Hintze, 1998; Klubnik & Ardoin, 2010). For instance, Daly and colleagues added LPP to RR in a brief experimental analysis procedure when RR alone was ineffective in increasing the reading fluency of struggling readers (Daly, et al., 1998; Daly, Murdoch, Lillenstein, Webber, & Lentz, 2002). Researchers and practitioners readily add LPP to RR despite limited empirical evidence to support this practice. Begeny and Silber (2006) provided 4 third grade students with various combinations of LPP, RR, and word list training (WLT). Using an alternating treatments design, they determined that a combination of LPP and RR was more effective than when the interventions were used separately. Although these results provide support for the use of LPP with RR, further research is needed to confirm these results as well as to better understand exactly what changes in students’ reading are influenced by adding LPP to RR if any.

Eye Tracking

Despite the vast knowledge regarding the assessment and intervention of reading fluency, many questions remain unanswered due to prior technological limitations. Oral reading rate is the readily observable outcome of the underlying, previously cumbersome to observe, behavior of reading. To date CBM-R, a measure of oral reading rate, is the primary measure used in schools across the United States for progress monitoring student performance in reading
(Reschly et al., 2009). However, with advances in eye-tracking technology, researchers can easily observe the underlying behavior of reading, which are the movements a reader’s eyes make during reading. This technology is more accessible and easier to use than ever before (Rayner, 2009; Rayner, Ardoin, & Binder, 2013). Recent advances in technology make it easier to observe differences between silent and oral reading. For instance, whereas with previous technology a bulky desktop computer and a movement-restricting bite plate were required (e.g., Everatt & Underwood, 1994), now the eye-tracking camera can be used with a laptop computer, and the participants’ movements no longer have to be restricted. Research can also determine whether or not interventions actually alter the eye-movement behaviors involved in reading and how (Hyönä, 1995; Hyönä & Niemi, 1990; Raney & Rayner, 1995; Rayner, Ardoin, & Binder, 2013).

Eye-tracking technology allows researchers to track exactly what the eyes do during reading. For instance, two components of eye movements that are of particular interest in reading research are saccades and fixations. Saccades occur when the eyes move quickly from one fixation point to another. Because of this rapid movement, information is generally not perceived from the visual field during a saccade (Matin, 1974). In contrast, it is believed that new information is acquired during a fixation, which is when the eyes remain relatively still and focused on a portion of the visual field. Eye-movement researchers measure these two components in several ways to obtain an accurate representation of an individual’s eye movements during reading (Rayner, 2009). A description of the various dependent measures frequently employed within the eye-tracking literature to understand reading behavior is provided in the Appendix.
Despite an extensive base of research on eye movements during reading (e.g., Anderson & Swanson, 1937; Hyönä, 1995; Hyönä & Niemi, 1990; Raney & Rayner, 1995), much remains to be examined. For instance, early technology limited the use of eye-tracking devices to the study of adult reading since it was difficult to use with children. The one known study examining the differences between oral and silent reading (Anderson & Swanson, 1937) was conducted prior to the technological advances that now allow the application of this technique to studying eye movements in children while reading aloud. Results of this early study need to be replicated with the improved measures these technological advances allow and with children. Similarly, adults serve as the participants in much of the extant literature on the effects of rereading (Hyönä, 1995; Hyönä & Niemi, 1990; Raney & Rayner, 1995). It is unknown whether these findings generalize to children. Now that the technology is more portable and user friendly, these same research questions can easily be applied to the reading of elementary school children. Furthermore, a majority of the current literature examines eye movements during silent reading (e.g., Foster, Ardoin, & Binder, 2013; Hyönä, 1995; Hyönä & Niemi, 1990; Raney & Rayner, 1995), yet many assessments used when evaluating children’s reading, such as CBM-R, measure oral reading. Research has established that silent and oral reading are different in adults (Anderson & Swanson, 1937); however, research has yet to investigate this relationship in young readers.

The two studies that follow sought to address these limitations and extend the reading assessment and intervention literature. The purpose of Study 1 was to determine the similarities and differences between eye movements during children’s silent and oral reading. A sample of third grade students were randomly assigned to one of two conditions. Both groups read the same passage. However, one group read the passage aloud, and the other group read it silently.
During their reading of the passage, students’ eye movements were measured and then compared across groups.

Study 2 sought to determine the effects of two reading interventions on the eye movements of elementary aged students. The same third-grade students who participated in Study 1 were randomly assigned to one of two intervention conditions (RR alone or LPP with RR). Differences in the effects of the two interventions on students’ reading behavior were examined. Although the results of one single subject design study by Begeny and Silber (2006) suggests that the two interventions (LPP and RR) create the greatest gains in reading rate when used in conjunction, their effect on eye movements during reading is unknown. More research is needed to better understand the impact of including a LPP component with the RR procedure.
References


CHAPTER 2

A COMPARISON OF ORAL AND SILENT READING IN YOUNG READERS

Rogers, L.S. & Ardoin, S.P. To be submitted to Scientific Studies of Reading.
Abstract

Curriculum-based measurement of oral reading is commonly used as a general outcome measure of reading and measures students’ oral reading fluency (Deno, 1985). However, a majority of students’ reading is done silently. As such, it is important to understand the differences between silent and oral reading. Although extensive research has been conducted comparing silent and oral reading in terms of rate and comprehension, few studies have compared eye-movement behaviors during the two types of reading, and to date, no such studies have been conducted with children. A sample of 57 third-grade students were randomly assigned to either an oral or silent reading condition. Students in both conditions read the same passage while an eye-tracker recorded their eye-movement behaviors. A comparison of eye movements during silent and oral reading revealed that students in the oral reading condition required more time to read the passage and made more fixations than students in the silent reading condition, particularly on low-frequency words. Implications for assessment practices are discussed.

Introduction

Researchers at the University of Minnesota created curriculum-based measurement (CBM) as a tool to assist special education teachers in making data based decisions when evaluating student progress (Deno, 1985). CBM is a standardized set of procedures that practitioners can use repeatedly over time to obtain information regarding a student’s progress in acquiring basic skills, like reading (Deno, Espin, & Fuchs, 2002; Fuchs & Fuchs, 1999; Fuchs, Fuchs, Hamlett, Walz, & Germann, 1993). CBM in reading (CBM-R) requires students to read aloud for 1 min while an examiner marks students’ reading errors. This procedure allows for the easy calculation of the number of words a student reads correctly in a minute (WRCM). CBM-R
can be administered frequently and is sensitive to small changes in performance, inexpensive, and time efficient relative to standardized achievement tests (Deno, 1985). Furthermore, an abundance of empirical support establishes CBM-R as a reliable and valid measure for screening and benchmarking purposes (e.g., Jenkins & Jewell, 1993; Marston, 1989; Reschly, Busch, Betts, Deno, & Long, 2009; Tindal & Marston, 1996; Wayman, Wallace, Wiley, Ticha, & Espin, 2007).

Despite extensive empirical support and wide use in the schools (e.g., Reschly et al., 2009), CBM-R is the target of several criticisms (e.g., Goodman, 2005). Although not necessarily backed by evidence, critics of CBM-R express concerns regarding the use of CBM-R as an indicator of reading comprehension (Foegen, Espin, Allinder, & Markell, 2001). Foegen et al. (2001) surveyed several pre-service teachers and found that even after watching a videotaped presentation regarding CBM-R’s validity and utility the teachers did not consider CBM-R to be a good indicator of comprehension. Critics’ concerns lie specifically in the use of CBM-R as a general outcome measure and indicator of comprehension with students who they describe as fluent readers who are not able to comprehend what they, otherwise referred to as “word callers” (Hamilton & Shinn, 2003). Critics argue that for word callers, using CBM-R as an indicator of reading comprehension overestimates their comprehension skills. Underlying this concern is the belief that CBM-R primarily measures students’ decoding skills. To support their claims, skeptics may use data suggesting a stronger relationship between CBM-R and word identification skills than with other sub-skills of reading (e.g., as was found by Reschly et al., 2009).

Hamilton and Shinn (2003) dispelled the fallacy that word callers are fluent readers who do not comprehend while reading. They compared two teacher selected groups of students on
measures of reading fluency and comprehension. One group consisted of teacher identified word callers (i.e., students who teachers perceived to be fluent readers with comprehension difficulties). The other group consisted of students teachers selected as having similar levels of fluency but with good comprehension skills. Hamilton and Shinn found that the students identified as word callers did not actually read as fluently as the teacher selected similarly fluent peers. As such, it is not surprising that the “word callers” also performed worse on the three measures of reading comprehension administered.

Although results of Hamilton and Shinn (2003) may be limited by the use of teacher judgments of students’ reading abilities to select the samples, the strong correlation between passage reading fluency and reading comprehension holds true in other studies (Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003a, 2003b). Jenkins and colleagues (2003a, 2003b) found that oral reading fluency was a stronger predictor of comprehension than was word list reading, explaining twice as much variance in reading comprehension. In fact, Fuchs, Fuchs, and Maxwell (1988) found that oral reading fluency was a significantly better predictor of comprehension skills as measured by a standardized test than were other direct measures of comprehension such as question answering, recall, and cloze procedures. Although CBM-R may lack face validity in the eyes of many practitioners, a plethora of empirical evidence supports its use as an indicator of reading comprehension and general reading ability (e.g., Fuchs, Fuchs, Hosp, & Jenkins, 2001; Marston, 1989; Reschly et al., 2009).

Another criticism of CBM-R is that it has to be individually administered, thus is time consuming (Faykus & McCurdy, 1998; Shinn, Good, Knutson, & Tilly, 1992; Wesson, King, & Deno, 1984). Still others criticize it for being a measure of oral reading when most reading is done silently (Hiebert, Samuels, & Rasinski, 2012). The maze procedure is a reading assessment
that addresses these two limitations of CBM-R and has greater face validity as a measure of comprehension. The maze uses passages in which selected words are removed and replaced with three word choices. Students are typically given 3 min to read the passage silently and choose the correct word from the three choices to fill in the blank (Hosp & Hosp, 2003). Despite having greater face validity than CBM-R as a measure of comprehension, the extant literature on the topic does not support its use over CBM-R as a general outcome measure for reading ability. Ardoin et al. (2004) investigated the benefits of administering a maze passage in addition to CBM-R for identifying students in need of intensive intervention. Results indicated that CBM-R alone was a better indicator of both reading comprehension and overall reading achievement. The maze did not provide significantly more information beyond CBM-R. Furthermore, results from January and Ardoin (2012) suggested that completion of the maze task does not require comprehension beyond the sentence level. The difference between the CBM-R and the maze in their ability to predict comprehension may at least be partially due to the difference in the behaviors engaged in when students read passages aloud versus silently. Conflicting results from reading rate, comprehension, and eye-movement studies make it unclear whether or not these two modes of reading are the same process (e.g., Hale et al., 2007; Hasbrouck & Tindal, 2006; Jones & Lockhart, 1919; McCallum, Sharp, Bell, & George, 2004; Sovik, Arntzen, & Samuelstuen, 2000).

**Silent versus Oral Reading**

Rate data indicate that silent reading rate exceeds oral reading rate (Allen, 1988; Hasbrouck & Tindal, 2006; McCallum et al., 2004). Researchers suggest that this difference is likely due to the extra processing required for speech production in oral reading (e.g., Balota & Chumbley, 1985; Inhoff, Solomon, Radach, & Seymour, 2011). In addition to the additional
processing time for speech production, the overt vocalization that occurs during oral reading might also slow reading because individuals must at least attempt to pronounce each word, whereas when reading silently, individuals can skip words that are unfamiliar or difficult to pronounce and deduce the word’s meaning from context. The available reading rate research conducted with children suggest that silent and oral reading are distinct but related processes ($r = .79$ for skilled readers and $.44$ for average readers; Kim, Wagner, & Foster, 2011).

In contrast, research examining the difference in comprehension when reading aloud versus silently has provided conflicting results, with some studies suggesting that silent reading produced greater comprehension (e.g., Jones & Lockhart, 1919; Mead, 1915, 1917; Pintner, 1913), some suggest no differences (e.g., Jones, 1932; McCallum, et al., 2004), and still others suggest that aloud reading results in greater comprehension (e.g., Collins, 1961; Duffy & Durrell, 1935-36; Hale et al., 2007; Rowell, 1976). Early literature examining these differences found that comprehension was better following silent reading (e.g., Jones & Lockhart, 1919; Mead, 1915, 1917; Pintner, 1913). Using identical methodology, Pintner (1913) and Mead (1915) measured the reading comprehension of fourth and sixth grade students, respectively, following oral and silent reading by having them write everything they could remember following a 2 min reading of six passages. Results from both studies suggested that students were able to recall more details from the story following silent than aloud reading. Although these two studies provided a foundation from which further research could have been conducted, unfortunately, despite having adequate sample sizes (Mead $N = 112$, Pintner $N = 23$) neither study employed inferential statistics to evaluate differences. Furthermore, both studies used measures that required students to write answers to assess reading comprehension; therefore, the results of this study may be confounded by the student’s writing ability. Students with poor written expression
ability may not have been able to adequately demonstrate their comprehension of the passage since they were required to provide written responses.

Results from other studies examining comprehension following silent and oral reading suggest that comprehension is the same for the two types of reading (e.g., Jones, 1932; McCallum et al., 2004). McCallum et al. (2004) investigated differences in silent and oral reading comprehension using the Test of Dyslexia (McCallum & Bell, 2001) amongst 74 kindergarten through sixth grade students. The reading comprehension subtest of the Test of Dyslexia required students to read sentences or passages of increasing difficulty and then answer two to five comprehension questions after each reading. Half of the participants completed the reading comprehension subtest aloud with the remaining half reading the materials silently. Despite greater reading efficiency in the silent reading condition, results indicated no significant difference in comprehension between the two reading modes.

Results of more recent research are in contrast to earlier findings (Mead, 1915, 1917; Pintner, 1913) and suggest that oral reading leads to better comprehension than silent reading (e.g., Collins, 1961; Duffy & Durrell, 1935-36; Hale et al., 2007; Rowell, 1976). Hale et al. (2007) examined the silent and oral reading comprehension of 51 fourth and fifth grade students, and 42 tenth, eleventh, and twelfth grade students. Participants answered multiple choice comprehension questions after reading three passages aloud and three passages silently. Results indicated that across grade level and reading ability students’ comprehension was better when they read passages aloud.

Further complicating results of the extant literature, studies such as Miller and Smith (1990) found an interaction between reading mode and reading level in that poor readers demonstrated better comprehension following oral reading but skilled readers’ comprehension
did not differ based on mode. More recently, researchers (Prior et al., 2011) examined comprehension following oral and silent reading in a sample of first through seventh grade students by having them answer oral open-ended comprehension questions following oral and silent reading of grade level passages. Results also revealed an interaction between grade level and mode of reading. Elementary school students demonstrated better comprehension following oral reading, but the seventh grade students’ comprehension was better following silent reading. Comprehension was equivalent after both reading modes for the sixth-grade sample.

The mixed findings from the extant literature comparing silent and oral reading (e.g., Hale et al., 2007; Jones, 1932; McCallum et al., 2004; Mead, 1915; Pintner, 1913) are unclear in regard to whether the two types of reading result in the same level of comprehension let alone are the same process. The lack of clarity may at least partially be due to the measures used to quantify reading differences between oral and silent reading. By measuring reading fluency and comprehension, the extant literature measures the outcomes of reading rather than the actual behavior of reading. A measure of reading behavior (i.e., eye-movement behavior) may lend information that could allow researchers to gain a better understanding of similarities and differences between oral and silent reading. Recent advances in eye-tracking technology allow for the measurement of reading behavior in children while they read both orally and silently.

**Eye Movement Research**

To better understand the mixed results of the silent versus oral reading literature it may be beneficial to examine the differences in the underlying behaviors of reading (i.e., eye movements) which lead to the outcome of comprehending. Eye-tracking technology allows for the observation of eye movements during reading (i.e., underlying reading behaviors). Eye-movement studies in reading are based on the theory that eye movements reflect the cognitive
processes involved in reading (Rayner, 1986). There are two components of eye movements during reading that are typically measured in the eye-tracking literature: fixations and saccades. Fixations occur when eye movements are suppressed and vision is focused on one portion of the visual field. Researchers theorize that new information is extracted from the visual field during fixations. Saccades are the movements eyes make between one fixation and the next. Information is generally not extracted from the visual field during saccades due to the rapid movement of the eyes (Matin, 1974). Readers occasionally have to revisit text already fixated, which is accomplished through a regression or backwards saccade in the text. Regressions are thought to occur when additional processing is required or to correct for overshoots in forward saccades. These two components of eye-movement analysis result in several measures (e.g., frequency, duration, and length of fixations, saccades, and regressions) that when combined result in differences in reading rate and processing. Thus eye-tracking technology allows for the direct measure of the reading behaviors that impact reading rate and comprehension. Resultant data can, therefore, be used to examine and explain differences in students’ oral and silent reading.

Sovik, Arntzen, and Samuelstuen (2000) investigated the relationship between silent and oral reading by having 20 Norwegian sixth grade students read two expository passages silently and a third expository passage aloud. Researchers examined the relationship between (a) eye-movement parameters collected while students read the first passage silently (b) students’ time to read the second passage silently, and (c) an index of oral reading fluency obtained from the reading of the third passage. Eye movement parameters measured during the first silent reading included recognition span (average number of words in a fixation), average fixation time, number of forward saccades, and number of regressions. As a measure of oral reading fluency, a
composite score that was calculated based on the number of pauses, repetitions, and decoding errors made during students’ oral reading of the third passage was used. The frequency of these errors were summed and then placed on an ordinal scale from 1 (far above average) to 5 (far below average). Reading speed, defined as the number of words read in a minute, was measured on all three passages as well. Results revealed a strong relationship between silent and oral reading as evidenced by significant correlations between various eye-movement variables (e.g., recognition span, average fixation time, and number of regressive saccades) and oral reading rate, fluency, and errors in reading. Additionally, silent reading speed and oral reading speed were highly correlated.

Unfortunately results from Sovik et al. (2000) simply confirm that a relationship exist between silent and oral reading. The results do not provide any additional information regarding the extent to which the two modes of reading are similar or different. Results of the study are also limited in that students read different passages across conditions. Various passage characteristics such as reading difficulty can impact how stories are read in terms of fluency (Ardoin & Christ, 2009) as well as eye-movement behaviors (Rayner, 1998). Although the authors claim to have made efforts to choose passages that were similar in difficulty, they did not describe what those efforts entailed. Commonly used practices of determining passage difficulty (e.g., readability formulas) are not empirically supported for these purposes (Ardoin, Suldo, Witt, Aldrich, & McDonald, 2005; Ardoin, Williams, Christ, Klubnik, & Wellborn, 2010; Compton, Appleton, & Hosp, 2004; Poncy, Skinner, & Axtell, 2005). Without adequately controlling for passage difficulty, it is impossible to tease apart the effects of type of reading and the effects of passage characteristics on the results. Additional limitations of this study hinder its generalization. First, the study was conducted using passages written in Norwegian, thus
generalization of these results to English readers is unclear. Second, researchers used a small sample of 6th grade students. Whether these relationships are upheld in younger beginning readers is unknown. Third, the convoluted composite score representing reading fluency weakens the findings. Translating reading fluency into an ordinal scale introduced bias, as the criteria for determining the scaled score were not included. This takes away from the meaning of the measure since ordinal scales do not provide a direct measure of degree of change (Keppel & Wickens, 2004). Finally, eye-movement data were not collected during students’ oral reading of the third passage, leaving the question of whether reading behaviors during the two types of reading are similar unanswered.

Anderson and Swanson (1937), a study conducted over 70 years ago using technology with much less sophistication than currently available, is the only identified study that directly compared eye-movement behavior during oral and silent reading. They measured the mean duration per fixation, mean size of fixation, mean number of regressions per line, and rate of reading of university students’ while they read silently and aloud. Although the two modes of reading were highly correlated on all measures, results also revealed significant differences between silent and oral reading. Oral reading was characterized by significantly longer fixation durations and more regressions as well as smaller fixations and slower reading rate. These differences suggest that oral reading is slower than silent reading, which may be a reflection of the additional processing needed for speech production during oral reading. Anderson and Swanson also found that these differences were more pronounced in skilled readers than in poor readers.

Although results of Anderson and Swanson (1937) have important implications for the purpose of this study, it is important to recognize that (a) their technology was far less
sophisticated than that employed in the current study and (b) their participants included only adults. Current empirical evidence indicates that children’s eye movements during reading differ from those of adult readers (Rayner, Chace, Slattery, & Ashby, 2006). In fact, average fixation durations for children are nearly double the average fixation duration for adults. Children also make substantially more regressions than adults. Adult readers regress 10% to 15% of the time to previously read material, whereas with children, this number is as high as 30%. These differences highlight the importance of replicating and extending this study with a sample of children.

**Purpose**

Much of the extant literature on eye movements in reading examines behavior during silent reading; however, popular reading assessments used to determine reading achievement, such as CBM-R, assess oral reading. Based on the extant literature previously presented, the degree to which silent and oral reading are similar processes is unclear. Without this information, results from silent reading studies may be incorrectly generalized to oral reading behavior and vice versa. The purpose of the current study is to examine differences and similarities in the behaviors that underlie silent and oral reading.

Existing research on eye movements during oral reading is rather limited and outdated (e.g., Anderson & Swanson, 1937; Fairbanks, 1937). The only study found that compares eye movements when participants were reading aloud and silently was conducted over 75 years ago (Anderson & Swanson, 1937). As technology has improved drastically over the past 75 years, the research questions addressed by these studies should be revisited. Additionally the only study that directly measured eye movements during oral reading (Anderson & Swanson, 1937) was conducted with adult participants. The current study addressed these limitations by
examining the similarities and differences in eye movements during reading between silent and oral reading in an elementary school-aged population.

**Methods**

**Participants**

Participants were enrolled in elementary schools in one of two Southeastern school districts (two schools from District A and one school from District B). Forty four participants attended schools in District A, in which a large majority of the student body was Caucasian (82%). Other races represented in District A include African Americans (9%), Hispanics (6%), and Asians (1%). Approximately 56% of the student body in this district was eligible for free/reduced lunch. Thirteen participants attended a Title 1 charter school in District B that serves 530 students. This school was included in the sample in order to obtain a more diverse sample as a large majority of the student body was African American (87%), with other races represented as follows: Hispanic (6%), Caucasian (3%), and multi-racial (4%).

All third grade teachers in the participating schools were asked to send parental permission forms home with all below average to average readers in their classes. Approximately 90% of parents gave permission for their child to participate. Of the 78 permission forms that were returned allowing the student to participate, 11 of the students were not included in the sample due to inadequate reading fluency. Six students’ data were lost due to technical errors with the equipment, and three students’ data could not be analyzed due to extensive head movement during reading. The resulting sample consisted of 57 third grade students with a mean age of 8 years, 10 months (range = 7 years, 5 months to 10 years, 0 months). A majority of the students in the sample were Caucasian (65%) with the remaining
participants being identified as African American (25%), Hispanic (5%), and multi-racial (4%). One participant’s race was not identified.

**Apparatus**

Eye-movement data were collected using an SR Research EyeLink 1000 system with a sampling rate of 500 Hz, resolution of 0.05 degrees of visual angle, and a range of 32 degrees horizontally and 25 degrees vertically. The system provided real-time transfer of eye-movement data for the experimenter to review through an Ethernet connection between the eye tracker and the display computer. The experimenter used the display computer to evaluate the accuracy of tracking and determine when recalibration might be necessary as well as to give participants feedback about their performance.

The passage read by students was displayed on a 19” ViewSonic VG930m LCD monitor. The brightness and text size were set at a comfortable level before the commencement of data collection and remained the same within and across participants. All sessions were conducted in a dimly lit room at the participating schools.

Participants used a Microsoft Sidewinder Plug and Play game pad to notify experimenters when they had finished reading the passage and to answer comprehension questions. A chin and head rest was used to minimize movement during silent reading and as needed during the oral condition.

**Materials**

Four CBM-R passages drawn from FAIP-R (Christ, Ardoin, & Eckert, 2010) were used for this study. Three FAIP-R benchmarking probes were used to match students based on reading fluency and ensure that the reading fluency of both groups was equivalent. The fourth FAIP-R (Christ, Ardoin, & Eckert, 2010) probe was presented to students on the computer
screen and was used to assess differences in students’ eye movements while reading silently and aloud. Students read the passage while their eye movements were tracked, with half of the students reading the passage silently and the remaining half reading it aloud. The passage consisted of 194 words in 20 sentences and contained 5 low-frequency target words and 5 high-frequency target words that were matched in length. Low-frequency words had a frequency equal to or less than 10 per million running words. High-frequency words were defined as having a frequency equal to or greater than 50 per million running words. Frequencies were determined using *The American Heritage Word Frequency Book* (Carroll, Davies, & Richman, 1971).

Passages were presented in black text against a white background and in standard upper-case and lower-case letters. Text were presented in 20 point Times New Roman font. The entire passage was presented on the computer screen at once.

**Procedures**

Within one week prior to the experimental procedures, students who assented to participation were administered three FAIP-R (Christ, Adroin, & Eckert, 2010) passages using standard CBM-R administration and scoring procedures. Students were then matched based on the median WRCM score of the three passages and then randomly assigned to either the silent or oral reading condition.

Students were seated approximately 55 cm from a 19 in computer monitor. A self-adhesive black dot was placed on the participants’ forehead and served as a guide for the camera since students were likely to move around during oral reading. If students moved too much during the calibration procedure, the dot was removed and the chin and head rest were used to stabilize movement while reading. While the experimenter prepared the eye tracker, participants
were briefed on the experimental procedures. Students were also told how to use the gamepad to indicate when they had finished reading the passage. The eye tracker was calibrated for each individual participant before experimental procedures began. Calibration required participants to follow a dot on the computer screen with their eyes. A 13-point calibration grid that covered the entire display screen was used. Following a successful calibration, the experimenter repeated the same follow-the-dot procedure to validate the calibration. After validation, participants engaged in a practice trial in which they read a sentence either silently or aloud depending on their assigned condition and answered a comprehension question similar to the questions they would encounter during the experimental procedures

**Silent Reading Condition.** Following the practice trial, experimenters instructed students in the silent reading condition that after another “follow-the-dot game” they would be asked to read a story silently. Experimenters also told students that they would not receive assistance during reading, but that they should try to read each word and do their best reading as they would be asked a comprehension question after reading the passage. Calibration and validation were then conducted a second time. Before displaying the passage, a fixation dot appeared in the top left corner of the monitor where the first word of the text would be shown. Once students fixated on the dot, the experimenter prompted the computer to display the passage. As the student read silently, one of the experimenters watched their eye movements on the display computer. If a student appeared to get stuck on a word for more than 10 s, as evidenced by their eyes not moving past the word, the experimenters instructed the student to skip it and continue reading. Students indicated when they had finished reading by pressing a button on the gamepad. Then students were asked one true/false comprehension question to help ensure that
they were reading for meaning and not just speed. The comprehension question was displayed on the computer screen, and students provided their answer using the gamepad.

**Oral Reading Condition.** Experimenters instructed students in the oral reading condition to read the entire passage aloud. Experimenters also notified the students that they would not receive assistance on any of the words and instructed them to do their best reading. Students were told to attempt any unfamiliar words and continue reading without assistance. The eye tracker was calibrated once more following these instructions and then the experimental procedure began. A fixation dot was presented in the upper left corner of the screen in order to direct the students’ gaze to where the first word in the passage would appear. The experimenter determined when the student was adequately fixated on the dot and prompted the computer to present the passage. If a student struggled on a word for more than 10 s, experimenters prompted the student to skip it and continue reading. Students pushed a button on the gamepad when they finished reading to change the display to the comprehension question and then used the gamepad to submit their answer.

**Results**

Data analysis was conducted on two levels: global analyses and target-word analyses. The following dependent variables were included in both the global and target-word analyses: total time, first fixation duration, gaze duration, number of inter-word regressions, and number of fixations (for definitions of these variables see the Appendix). Global measures were based on students’ reading of the entire passage and derived by averaging the various measures across all words that were fixated on in the passage. Target-word analyses were used to determine differences between the two reading conditions on high- and low-frequency target words that were embedded within the passage. Target-word measures were derived by averaging the
various measures across the targeted low-frequency and high-frequency words that were fixated on in the passage. The percentage of words skipped across the entire passage was also measured and compared across the two groups.

Statistical analyses conducted to compare the silent and oral groups on various demographic variables and reading fluency (based on their median score on the three benchmark probes) indicate that the two groups were equally representative of the two school districts, \( X^2(1, N=57) = .113, p = .736 \), and various ethnicities, \( X^2(4, N=57) = 1.332, p = .856 \). Students in the two conditions also did not differ significantly in terms of reading fluency, \( t(55) = -.406, p = .686 \). Given this equivalency, it is reasonable to contribute significant differences between the two groups to their reading condition.

Differences between silent and oral reading on global and target-word measures were analyzed using independent samples t-tests. Statistical analyzes conducted to test the assumptions associated with using a t-test revealed that many variables deviated slightly from a normal distribution due to the presence of outliers. However, t-test analyses are generally robust to slight deviations from a normal distribution with an adequate sample size (\( n > 30 \); e.g., Box, 1953; Rasch, Teuscher, & Volker, 2007). Additionally, I believe the outlying data points were accurate measurements that are representative of the population. Analyses conducted with and without the outliers revealed similar results. Therefore, the outliers were retained when conducting global and target-word analyses. Furthermore, appropriate adjustments were made to the degrees of freedom on the analyses of the average total time measurement for low-frequency words and percentage of words skipped measurement given that these variables violated the homogeneity of variances assumption. Cohen's (1988) guidelines can be used to interpret effect
sizes according to values of Cohen’s $d$ (i.e., small – $d = .2$, medium – $d = .5$, and large – $d = .8$).

Means and test statistics for each global and target-word measure are presented in Table 1.

Results of the global analyses indicated that students in the oral reading condition required significantly more time to read the passage than did students in the silent reading condition based on average total fixation time, $t(55) = 2.98, p = .004; d = 0.80$. Students in the oral reading condition also fixated on words longer before making a saccade to another word as evidenced by significantly longer average gaze duration than the students in the silent reading condition, $t(55) = 2.36, p = .022; d = 0.64$. Finally, average fixation count was significantly higher for students in the oral reading condition, $t(55) = 2.36, p = .022; d = 0.64$. Significant differences were not observed between the two groups on measures of average first fixation duration, average number of inter-word regressions per word, or percentage of words skipped.

Target-word analyses indicated no differences between conditions across the dependent variables assessed on high-frequency target words. However, low-frequency word analyses revealed significant differences on average total fixation time and fixation count. Students in the oral condition were found to fixate longer on low-frequency words, $t(42.89) = 2.17, p = .036; d = 0.66$ and more often than students in the silent condition, $t(55) = 2.32, p = .024; d = 0.63$. All other measurements revealed no significant differences between the two groups.

**Discussion**

Given the widespread use of CBM-R across the country (e.g., Reschly et al., 2009), it is important to understand the implications of using a measure of oral reading fluency as a general outcome measure for reading when a majority of reading is done silently. Extensive research has been conducted to compare the two types of reading in terms of rate (e.g., Allen, 1988; Hasbrouck & Tindal, 2006; McCallum, Sharp, Bell, & George, 2004) and comprehension (e.g.,
Jones & Lockhart, 1919; Jones, 1932; McCallum, et al., 2004; Collins, 1961; Duffy & Durrell, 1935-36; Hale et al., 2007; Rowell, 1976). Few studies, however, have compared eye-movement behavior during silent versus oral reading (e.g., Anderson & Swanson, 1937; Fairbanks, 1937). The existing eye-movement studies comparing silent and oral reading are limited by the demographics of their sample, methodology, and primitive technology. Furthermore, they are outdated, having been conducted over 75 years ago. As such, the current study sought to clarify the relationship between oral and silent reading in children by directly comparing the eye-movement behaviors of third grade students during the two types of reading.

Global Analyses

Consistent with previous research comparing eye-movement behavior in oral and silent reading in adults (Anderson & Swanson, 1937), analyses of global measures from the current study suggest that students’ silent and oral reading behaviors differ. Much like the adults in Anderson and Swanson (1937), students in the oral reading condition spent significantly more time fixating on words before moving to another word in the text (average gaze duration), spent more time fixating on words overall (average total fixation time), and fixated on words more often (average fixation count) than the students in the silent reading condition. These results are also consistent with previous rate studies suggesting that reading rate is faster in silent reading than oral reading (e.g., Allen, 1988; Hasbrouck & Tindal, 2006; McCallum, Sharp, Bell, & George, 2004).

In contrast to Anderson and Swanson (1937), in which adults’ oral reading was characterized by more regressions than silent reading, students in the current study did not differ significantly in the number of inter-word regressions made as a function of condition. Interestingly, the difference in the number of regressions per line between silent and oral reading
in adults was more pronounced in poor readers than proficient readers. On all other measures, however, Anderson and Swanson found that the differences between silent and oral reading were more pronounced in skilled readers than poor readers. It may be that silent and oral reading are more similar, even in regards to regressions, in children who are not yet proficient readers. Future studies should utilize a more diverse sample in order to investigate how the relationship between eye movements during silent and oral reading differs as a function of reading proficiency in children.

Results of the current study illuminate not just differences in eye-movement behaviors in silent and oral reading, but also possible differences in cognitive processing as eye-movement behaviors are thought to reflect underlying cognitive processes (Rayner et al., 2006). One such relationship is that fixation time is considered to be a direct reflection of the time spent on comprehension processes during reading. Differences found in the current study suggest that students in the oral reading condition required more time for lexical processing and for higher-level text processing, such as comprehension than students in the silent reading condition. These results are commensurate with previous comprehension studies that suggest less proficient readers (i.e., elementary school students) comprehend better following oral reading than silent reading (Miller & Smith, 1990; Prior et al. 2011).

**Target-Word Analyses**

Although global analyses of eye-movement behavior revealed overall differences in silent and oral reading, it is important to conduct more detailed analyses to determine where in the text these differences occur or are more pronounced. One text characteristic that is well known to affect fixation time is word frequency (e.g., Joseph, Nation, & Liversedge, 2013; Just & Carpenter, 1980; Rayner & Raney, 1996). Analyses on high- and low-frequency target words
revealed that high-frequency words were read similarly during silent and oral reading as the two groups did not differ significantly on any of the variables measured. However, students in the oral reading condition fixated on low-frequency words longer overall and more frequently than students in the silent reading condition, suggesting that low-frequency words require more time for higher-level text processing when read orally. This difference may also reflect the fact that students in the silent reading condition could quickly move past unknown words since their reading of the passage was not being overtly monitored as in the oral condition. Students in the oral reading condition were aware of the researchers listening to their reading of the passage and following along as they read; therefore, they may have felt more pressure to attempt each word before continuing in the passage.

**Limitations**

Results of the current study are limited by the amount of lost data due to instrumentation difficulties during eye tracking. Three students’ data (oral n=2; silent n=1) had to be excluded from the data set due to substantial head movement during reading, making their data unreliable. The data from six other students’ were lost due to computer glitches (e.g., not saving data, freezing during the experiment). These lost participants decreased the sample size to 57.

Additional data were lost during some of the students’ reading of the passage due to the camera losing sight of their pupils. Consequently, it is unknown what happened during the time the pupils were lost as eye movements could not be recorded, and so those movements were not reflected in the data. Although no participants had to be completely excluded from the analyses due to excessive data loss, there were 10 students for which some reading behavior was lost; therefore, their data do not include reading behavior from all 194 words in the passage. Additionally, the number of students for which data were lost was not proportionate in the two
conditions. More data were lost in the oral condition (n=7) than in the silent condition (n=3), which is likely due to the increased head movement that occurs during oral reading when moving the mouth to articulate words.

**Implications and Future Directions**

The current study builds upon past research examining the relationship between eye-movement behaviors during oral and silent reading in adults by directly comparing the two types of reading in a sample of children and providing preliminary evidence to suggest that oral and silent reading are different processes in children as previously reported with adults (Anderson & Swanson, 1937). However, much remains unknown about these differences. For instance, despite observing significant differences on the global measures of eye-movement behaviors, few significant differences were found between the two groups on high- and low-frequency target words. As a result, it is unknown what aspect of the text differentially affects reading behavior in oral and silent reading. Because global analyses include all the words in the passage, the global results reflect processing time across various word characteristics, such as decodability, length, and position in a sentence. Future research examining these other text characteristics may clarify what variables differentially affect eye movements in the two reading conditions.

Understanding the differences between oral and silent reading is important when choosing how to assess reading achievement. Measuring reading ability using silent reading assessments may be more appealing to teachers since these measures typically require less teacher time to administer (Faykus & McCurdy, 1998). Furthermore, the ultimate goal of reading instruction is for students to be able to comprehend text that is read silently, again making a silent reading assessment a more desirable option as it may be more representative of
typical reading conditions. Although the maze measures silent reading and has greater face validity as a measure of reading comprehension (Faykus & McCurdy, 1998; Fuchs & Fuchs, 1999), it has not been shown to predict reading comprehension or total reading achievement as well as CBM-R does, which is an oral reading measure (Arodin et al., 2004). The differences between oral and silent reading revealed in this study may explain why CBM-R is a better predictor of reading comprehension than the maze, since longer fixation times are thought to reflect longer processing which may allow for better comprehension (Rayner et al., 2006). However, although together with previous research this study suggests the existence of a relationship between reading type (oral vs. silent), reading comprehension, and fixation lengths, the nature of this relationship remains unclear. Specifically the extant literature suggests that oral reading results in better comprehension in young readers (Miller & Smith, 1990; Prior et al. 2011), and the current study revealed that oral reading is characterized by longer and more fixations, which may be a reflection of the cognitive processes involved in comprehension (Rayner et al., 2006). Because comprehension was not measured in the current study, however, it is unknown whether the students in the oral reading condition did in fact comprehend the text better than the students in the silent reading condition. By measuring comprehension after silent and oral reading while measuring eye-movement behavior, future research could clarify how the eye movements in silent and oral reading affect comprehension. Results of the current study also do not clarify if comprehension is enhanced by the longer fixations that characterize oral reading or if oral reading is characterized by longer fixations because students are taking more time to read accurately and comprehend what they are reading.

Nonetheless, the differences in eye-movement behaviors found between the two conditions in the current study highlight the importance of taking reading mode into
consideration when choosing how to assess reading ability. Previous research supports the use of oral reading when evaluating reading achievement (e.g., Ardoin et al, 2004). In addition, analyzing oral reading provides information regarding the types of errors made during reading, which cannot be obtained through silent measures of reading. Together with extant literature, results of this study suggest that in young developing readers, oral reading may be a more accurate representation of global reading achievement.
References


Table 2.1

*Summary of Eye-Movement Measure Comparing Silent and Oral Reading*

<table>
<thead>
<tr>
<th>Measure</th>
<th>Silent M (SD)</th>
<th>Oral M (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First fixation duration (ms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(55) = 1.21, p = .226$</td>
<td>310.6 (64.16)</td>
</tr>
<tr>
<td>High Frequency</td>
<td>$t(55) = .19, p = .848$</td>
<td>316.1 (93.01)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>$t(55) = .48, p = .637$</td>
<td>366.9 (113.61)</td>
</tr>
<tr>
<td><strong>Gaze duration (ms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(55) = 2.36, p = .022$</td>
<td>363.7 (78.97)</td>
</tr>
<tr>
<td>High Frequency</td>
<td>$t(55) = .99, p = .328$</td>
<td>385.7 (115.44)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>$t(55) = 1.42, p = .160$</td>
<td>550.2 (209.51)</td>
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<tr>
<td><strong>Total fixation time (ms)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(55) = 2.61, p = .010$</td>
<td>469.9 (123.94)</td>
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<tr>
<td>High Frequency</td>
<td>$t(55) = 1.79, p = .079$</td>
<td>479.4 (178.49)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>$t(42) = 2.15, p = .038$</td>
<td>712.7 (284.15)</td>
</tr>
<tr>
<td><strong>Inter-word regressions (#)</strong></td>
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<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(55) = 1.20, p = .235$</td>
<td>.27 (.10)</td>
</tr>
<tr>
<td>High Frequency</td>
<td>$t(55) = .85, p = .400$</td>
<td>.31 (.24)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>$t(55) = .22, p = .828$</td>
<td>.32 (.22)</td>
</tr>
<tr>
<td><strong>Fixation count (#)</strong></td>
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<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(55) = 15.64, p = .022$</td>
<td>1.23 (.44)</td>
</tr>
<tr>
<td>High Frequency</td>
<td>$t(55) = 1.41, p = .188$</td>
<td>1.55 (.66)</td>
</tr>
<tr>
<td>Low Frequency</td>
<td>$t(55) = 2.32, p = .024$</td>
<td>1.86 (.94)</td>
</tr>
<tr>
<td><strong>Percentage of Words Skipped</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global</td>
<td>$t(29) = 1.84, p = .077$</td>
<td>22.2 (13.38)</td>
</tr>
</tbody>
</table>
CHAPTER 3

INVESTIGATING THE ADDED BENEFIT OF INCLUDING A LISTENING PASSAGE PREVIEW COMPONENT TO REPEATED READINGS USING EYE-TRACKING TECHNOLOGY
Abstract

Repeated Readings (RR) and Listening Passage Preview (LPP) are two common reading fluency interventions with extensive empirical evidence supporting their use. However, relatively little is known about the behavioral changes that occur in children’s reading in response to these interventions that in turn produce gains in oral reading fluency. As such, the current study measured the eye-movement behavior of 57 third grade students during RR or LPP+RR to compare intervention effects and determine how these interventions take effect. Results revealed similar outcomes in oral reading fluency and various eye-movement behaviors for students in both intervention conditions. Students in both conditions significantly increased their oral reading fluency and decreased the number of errors made in reading, total fixation time, frequency of fixations, and percentage of words fixated. Students’ reading improved particularly on low-frequency words due to a reduction in time spent on high-level text processing. Results have implications for the classroom as well as future eye-movement research.

Introduction

The importance of reading fluency was first highlighted by LaBerge and Samuels’ (1974) information processing model that proposed that fluent reading is necessary for comprehension, which is the ultimate goal of reading. Perfetti (1985) proposed a similar theory in his verbal efficiency model which suggests that non-automatic word recognition restricts a reader’s ability to hold a large amount of information in working memory, hindering comprehension. In 2004, the National Reading Panel’s evaluation of the literature surrounding comprehension further confirmed the importance of fluency for effective reading comprehension. Unfortunately, despite recognition of the importance of fluency, results from the National Assessment of
Education Progress continue to suggest that far too many fourth grade students lack sufficient reading fluency (National Center for Education Statistics, 2005, 2011). Given that classroom instruction in reading fluency seems to be insufficient for many elementary students, effective interventions aimed specifically at increasing reading fluency are needed. Two commonly employed and empirically based fluency interventions are repeated readings (RR) and passage preview (e.g., Begeny & Silber, 2006; Daly & Martens, 1994; Meyer & Felton, 1999; Skinner, Cooper, & Cole, 1997; Therrien, 2004).

Repeated Readings

RR is the most frequently cited method of improving reading fluency (Meyer & Felton, 1999). Samuels first introduced RR as an intervention in 1979. He described the procedure as the rereading of a short passage until the student achieves an acceptable level of fluency. Since that time, researchers have built a large base of empirical support for the effectiveness of RR as an intervention for increasing reading fluency (e.g., Ardoin, Eckert, & Cole, 2008; Dowhower, 1987; Herman, 1985; Rasinski, 1990). Results of multiple literature reviews and meta-analyses have concluded that RR is effective in increasing reading fluency across various populations and modes of implementation (Chard, Vaughn, & Tyler, 2002; Meyer & Felton, 1999; NICHD, 2000; Therrien, 2004). In a meta-analysis by Therrien (2004), results supported the use of RR for increasing the reading fluency and comprehension of both students with and without learning disabilities. Furthermore, these effects appear to hold true for students of varying reading abilities across the elementary school grades (Meyer & Felton, 1999; NICHD, 2000).

Arguably the most compelling evidence to support the use of RR is that it is not only effective in increasing fluency ($ES = .83$) and comprehension ($ES = .67$) on the passage read during the RR
procedure but also on transfer passages that are not read multiple times (fluency $ES = .5$; comprehension $ES = .25$; Therrien, 2004).

Therrien’s (2004) meta-analysis also identified characteristics of RR that result in greater student gains. First, during the RR procedure, students should read aloud to an adult rather than a peer. Second, the adult should provide the student with a cue regarding the purpose of reading prior to beginning the RR procedure (i.e., fluency, comprehension, or a combination of the two). Third, the passages should be read three or four times. Finally, a corrective feedback component should be included.

**Passage Preview**

Passage preview is a procedure commonly used in conjunction with RR; however, it can also be used in isolation. There are two general methods for implementing passage preview. The first method, independent passage preview, involves students previewing the passage on their own prior to instruction or testing on the passage. The second method of passage preview, and the method of interest within this study, is listening passage preview (LPP), which involves providing students with a fluent model of the passage prior to instruction or testing. Studies suggest that LPP is more effective in increasing reading fluency than the independent passage preview (Daly & Martens, 1994; Rose, 1984; Skinner, Cooper, & Cole, 1997). In fact, Rasinski (1990) found that repeated LPP, which involved students repeatedly listening to a fluent model of a test passage, produced similar gains in reading fluency as RR. These findings were not consistent with Young, Bowers, and MacKinnon (1996) who found that that repeated LPP did not produce significant gains in reading fluency or comprehension in poor readers, whereas RR did. A possible explanation for the mixed results is the difference in sample characteristics between the two studies. Rasinski primarily included above average and average readers in the
study sample (i.e., only 2 of 20 students were described as being poor readers) whereas the sample in Young et al. included 40 poor 5th grade readers. These mixed results suggest that repeated LPP may be sufficient for increasing the fluency of average to above average readers, but poor readers may require the more intensive practice as in RR. Unfortunately, these researchers failed to examine a more common practice, which is the combination of LPP and RR.

Researchers and practitioners often use RR and LPP in conjunction without having adequate empirical evidence to support this practice (Daly, Martens, Dool, & Hintze, 1998; Daly, Murdoch, Lillenstein, Webber, & Lentz, 2002; Klubnik & Ardoin, 2010). For example, Daly et al. (2002) used brief experimental analysis to select intervention strategies (including RR and LPP) for struggling second grade readers. They provided students with increasingly more intensive interventions until the students made significant gains in reading fluency. For instance, if RR alone did not significantly increase fluency, they then added a LPP component to the RR procedure. Surprisingly, despite the modeling of fluent reading provided by LPP, it did not significantly increase the reading fluency of any of the five participants beyond RR alone. In contrast, results of Begeny and Silber (2006) suggest that LPP and RR together can produce greater gains in reading fluency when implemented together. Begeny and Silber investigated the effects of various combinations of LPP, RR, and word list training (WLT) on the number of words read correctly in a minute for four third grade students using an alternating treatments design. Results suggested that combining LPP with RR produced greater gains in reading fluency than LPP with WLT or RR with WLT. In addition, a combination of all three intervention components (LPP+RR+WLT) produced the greatest gains in reading fluency.
Based on these conflicting results and the small research base on the topic, the benefits of adding LPP to the implementation of RR are unclear and further research is warranted.

Although there is evidence to suggest that readers make significant improvements in reading fluency following the use of LPP and RR both separately and together (e.g., Ardoin et al., 2008; Dowhower, 1987; Therrien, 2004), the specific changes in behavior that occur to produce the resultant improvements in fluency remain unknown. Since most studies to date have used an indirect measure of reading behavior (i.e., oral reading rate or words read correctly in a minute; WRCM), the mechanism through which LPP and RR take effect has not been identified. Although increases in WRCM indicate quantifiable improvement in reading fluency, increases in WRCM alone do not inform what aspect of reading improved. This unknown can be answered by observing the changes in eye movements, the behaviors underlying reading, that occur when LPP and RR are employed. Recent advances in eye-tracking technology allow for the investigation of the behaviors that contribute to fluent reading in elementary students (e.g., Foster, Ardoin, & Binder, 2013).

By monitoring readers’ eye movements, researchers are able to observe multiple processes over time within a single reading of a passage (Rayner, 1998). During reading, the eyes make a series of discrete movements (i.e., saccades) separated by pauses (i.e., fixations). Readers extract information from texts during the fixations, and vision is suppressed during saccades such that readers do not extract information from the text during these eye movements. Saccades are typically forward movements of the eyes in text to gain new information. However, readers also make backward saccades in the text to words already read, called regressions. Although not well understood, it is believed that short regressions occur to correct for overshoots in forward saccades or to help identify a single word and longer regressions (i.e.,
more than 10 letter spaces back or to an entirely different line) are made to aid with comprehension (Rayner, 1998). These three major components of eye movements (saccades, regressions, and fixations) result in various measures used to evaluate reading behavior. A full list of these measures along with their definitions is provided in the Appendix.

Skilled and unskilled readers differ in their eye-movement patterns during reading (see Morris & Rayner, 1990 for review). The average fixation duration for skilled adult readers is approximately 200-250 milliseconds, and their forward saccades are generally 7-9 character spaces long. Adult readers make regressions about 10-20% of the time and skip over roughly one third of words. In contrast, beginning readers fixate on virtually every word, often making multiple consecutive fixations on a single word. As a result, their average saccade length is shorter than that of the skilled adult reader. Their average fixation durations are longer than those of skilled adults (300-400 ms), and up to 50% of their eye movements are regressive. These differences between the eye-movement patterns of unskilled and skilled readers are thought to reflect the difficulty that non-fluent readers face in recognizing the words in the text. As students become more proficient readers, their eye-movement patterns change systematically in that they make shorter fixations, longer and fewer saccades, and fewer regressions (Rayner, 1978). By examining changes in eye-movement behavior, researchers can determine the impact of interventions, such as RR and LPP, on students’ reading.

**Eye-Tracking and Rereading**

Few researchers have used eye-tracking technology to study the effect of rereading texts, as occurs in RR, on eye-movement behavior. Hyönä and Niemi (1990) conducted two similar studies that required university students to read a passage two times consecutively and then a third time approximately a week later. Results indicated a facilitation effect on all eye-
movement parameters included in the analysis. Specifically decreases in summed fixation time, average fixation duration, number of progressive fixations, and number of regressions as well as increases in saccade lengths were demonstrated across readings. Interestingly, these effects were greater for portions of the text that were more dense with information and likely more cumbersome to read during the initial reading of the text. Similarly, Hyönä (1995) had 18 university students read a passage twice during one session and a third time a week later in order to investigate the topic-shift effect of rereading. Hyönä found that facilitation effects across multiple readings of the same passage were greater for sentences introducing a new subtopic in a passage (i.e., topic shift sentences) than for sentences that were the continuation of a subtopic. It was hypothesized that this facilitative topic-shift effect occurred because comprehension of these topic-shift sentences required more higher order processing on the initial reading, thus requiring a greater number of regressions. However, when individuals reread the text, they already had a mental representation of the text’s structure; thus, topic-shift sentences required fewer regressive eye movements on subsequent readings than on the first encounter.

To further investigate the facilitation effects of rereading, Raney and Rayner (1995) studied differences in eye-movement behavior when participants reread high and low frequency words within passages. Twenty-eight university students read 16 passages twice, successively. Each passage contained target words that either stayed the same in the second reading or were changed to a synonym of the opposite frequency (i.e., low-frequency target words were changed to a high-frequency synonym, and high-frequency target words were changed to a low-frequency synonym). Overall facilitation effects were found in that reading times, fixation time, fixation frequency, and regression frequency decreased, while saccades lengths increased on the second reading as expected. In regards to word frequency effects, results indicated that readers spent
less time fixating on high frequency words during both readings. Additionally, Raney and Rayner found rereading facilitation effects to be similar for both word frequency types in that the decrease in fixation time was similar in degree for both high- and low-frequency words. This means that individuals were still sensitive to variables that affect processing efficiency (such as word frequency) even on the second reading.

In order to determine the effects of rereading on saccadic landing positions, Schnitzer and Kowler (2006) had 5 undergraduate students reread four texts over 40 times interspersed by an additional 44 texts, which were only read once. The only consistent change in eye-movement behavior found across all participants was a reduction in the number of regressions across rereadings. Rereading had a smaller effect on saccade length and fixation duration in that readers only read with slightly larger forward saccades and shorter fixation durations on subsequent readings. It was suggested that the number of regressions decreased across reading of the same text because readers became more familiar with the content of the passage across readings; therefore, it was unnecessary for them to revisit text for additional information.

Results from the adult literature consistently suggest that the number and duration of fixations and the number of regressions decreases across rereadings (Hyönä & Niemi, 1990; Raney & Rayner, 1995; Schnitzer & Kowler, 2006). Additionally, decreases in fixation duration across readings is demonstrated on both high- and low-frequency words to a similar degree (Raney & Rayner, 1995). However, the generalizability of these results to a child population participating in RR is limited. The studies discussed thus far examined the effects of reading a passage multiple times on the eye movements of adult readers rather than the effects of the specific RR intervention on the eye movements of young readers. This is problematic for two reasons. First, the purpose of rereading texts differs for adults and children. Adults typically
reread a text to enhance comprehension or learn new information (Raney & Rayner, 1995), whereas RR with children is a specific intervention aimed at increasing the reading fluency of students who are still developing reading skills. Furthermore, the methodology used in the adult literature is not consistent with the specific procedures utilized in RR. In the adult literature, participants read passages two, three, or 40 times, and the rereadings in the adult literature were often nonconsecutive. In contrast during RR, research suggests that students should read the passage three to four times consecutively to produce significant gains in reading fluency (Therrien, 2004). Due to differences in methodology and purpose of rereadings in the current adult literature, it may be inappropriate to generalize these results to beginning readers receiving RR. Thus, the effects of RR on the eye-movement behavior of children during reading are not well understood.

To date, only two studies have addressed the limitations of the previously discussed eye-tracking studies and examined immediate changes in eye-movement behavior across RR with beginning readers (Foster et al., 2013; Zawoyski, Oddone, Ardoin, & Binder, 2014), and only one study has examined the generalization of skills following RR using eye-tracking technology (Ardoin, Binder, Zawoyski, Foster, & Blevins, 2013). Foster et al. (2013) had 43 second grade students read a passage silently four consecutive times. After four consecutive readings of the text, participants read significantly quicker as evidenced by decreases in total fixation time, fixation frequency, and regression frequency. Target word analyses revealed that participants spent significantly more time fixating on low-frequency words as compared to high-frequency words even after four readings of the same text. These findings replicate those from the adult literature, suggesting that both adult and beginning readers continue to have relatively more difficulty reading low-frequency words as compared to high-frequency words after repeated
exposure to the text. Interestingly, results from Foster et al. also revealed differential effects on fixation times for high- and low-frequency words. Participants spent significantly less time fixated on low-frequency words in response to the RR intervention; however, fixation time did not decrease significantly on high-frequency words. This interaction between word frequency and fixation time suggests that RR with children facilitates reading of low-frequency words, which is contrary to what research found in the adult literature (Raney & Rayner, 1995).

Similarly, Zawoysk et al. (2014) investigated the effects of RR on 22 lower-performing and 22 higher-performing second grade students’ eye-movement behavior as a function of their reading ability prior to intervention. Like Foster et al. (2013), participants read the same passage four times silently and received performance feedback on their total reading time in between trials. Results support the use of RR with both samples of students as evidenced by increased efficiency of eye movements during reading. Significant decreases in students’ number of fixations, fixation durations, and number of regressions made during reading were revealed. However, even after intervention, higher-performing students consistently demonstrated more efficient eye movements than lower-performing students. Interestingly, the lower-performing students benefited from RR on both high- and low-frequency words, while facilitative effects for higher-performing students were only evident on their reading of low-frequency words. This suggests that RR may be more beneficial for lower-performing students.

Unfortunately, Foster et al. (2013) and Zawoyski et al. (2014) were limited by a number of factors with the primary limitation being that the procedures used during RR did not include all of the components of an effective RR procedure as outlined in Therrien (2004). Rather than reading the passage aloud to an adult, participants read the passage silently. Consequently, corrective feedback on errors could not be provided after each reading as is suggested (Therrien,
2004). Ardoin, Binder, Zawoyski, Foster, & Blevins (2013) addressed this limitation and investigated the generalization effects of oral RR on a high word overlap passage and compared those results to a control condition and a multiple exemplar condition in which students read four different high word overlap passages one time each during intervention. In order to assess generalization, students in each condition read the same passage silently while their eye movements were recorded. Results support the use of repeated practice of unfamiliar words, whether the repetition occurs through the repeated reading of the same passage four times or through four different passages containing the same unfamiliar words read one time each. Students in both conditions spent significantly less time processing low-frequency words on the generalization passage than students in a control condition who did not receive intervention prior to assessment. However, how students’ eye-movement behaviors change across four oral readings of a passage and how that compares to RR with a LPP component remains unknown.

**Purpose**

The existing research on eye movements during rereading is limited by a number of factors when considering its generalizability to elementary students who are learning to read. First, much of the extant literature was conducted with adults, and the extent to which these finding generalize to children is unclear. Now that the technology is more portable and user friendly, the same research questions investigated in the previously discussed adult literature can easily be answered using a sample of elementary school children. Second, a majority of the current literature examines eye movements during silent reading due to technological limitations. Previously, eye-movement data could only be collected when restricting the participants’ head movement using a bite plate (e.g., Tiffin & Fairbanks, 1937) or chin rest (e.g., Foster et al., 2013), making data collection on school children difficult, particularly with oral reading.
Advances in eye-tracking technology now allow for the collection of eye-movement data without restricting motion. In 2007, a remote tracking option was created that required neither a bite plate nor a chin rest (M. Johnson, personal communication, July 26, 2012), making it possible to collect oral reading data on children who tend to have more difficulty staying still than adults. Finally no known studies to date have investigated the changes in the underlying behaviors of reading during the RR intervention specifically while following the procedural suggestions for increasing the effectiveness RR outlined by Therrien (2004) or during RR with an LPP component.

The current study sought to determine the effects of RR with and without LPP on the eye movements of elementary aged students during reading, while addressing the limitations of the previous studies. A sample of third grade students was randomly assigned to one of two intervention conditions, RR alone or LPP with RR. Treatment effectiveness was determined based on traditional views of reading fluency (WRCM) and eye-movement data. Although results from Begeny and Silber (2006) suggests that the two interventions create the greatest gains in reading rate when used in conjunction, their effect on eye movements during reading is unknown.

**Methods**

**Participants**

A power analysis conducted using data from Foster et al. (2013) indicated a minimum of 36 students is needed to have power of 95.1% to yield a statistically significant result. To ensure sufficient power, given that the current study examined differences between two intervention groups, 57 third grade students were included in the sample for this study. The average age of participants was 8 years, 11 months (range = 7 years, 5 months to 10 years, 9 months). Students
were recruited from two suburban school districts in the southeastern region of the United States. Forty-four participants attended an elementary school in School District A, which serves primarily Caucasian students (80%), with other ethnicities represented as follows: African Americans (9%), Hispanics (6%), and Asians (1%). An additional thirteen participants were recruited from a charter school in District B in order to increase the diversity of the sample. This school serves approximately 530 students, a majority of which are African American (87%), with other races represented as follows: Hispanic (6%), Caucasian (3%), and multi-racial (4%).

All third grade teachers at the participating schools were asked to select below average to average readers to participate in the study. Consent forms were sent home with these students. Approximately 90% of parents whose child was selected by their teachers gave permission for their child to participate. Of the returned consent forms allowing participation, 11 students were not included in the study due to inadequate reading fluency (i.e., only students who were able to read at least 60 words correctly in a minute were included). Four students’ data were lost due to computer errors, three were lost because the eye tracker lost the students’ eyes too much during tracking, and two were lost because the student moved too much during eye tracking, resulting in a total of 57 usable participants.

**Apparatus**

SR Research EyeLink 1000 system was used to track eye movements during the experiment. It has a sampling rate of 500 Hz, resolution of 0.05 degrees of visual angle, and a range of 32 degrees horizontally and 25 degrees vertically. An Ethernet connection between the eye tracker and a display computer provided real-time transfer of eye movement data for the experimenter to review throughout the experimental procedures. The display allowed the
experimenter to evaluate the accuracy of tracking and determine when recalibration was necessary.

A 19” ViewSonic VG930m LCD monitor displayed the passage that was read by the students. The experimenter ensured that the brightness and text size was set at a comfortable level before beginning data collection. Those settings remained the same within and across participants. The experiment took place in a dimly lit room at the participating schools.

**Materials**

The passage read during intervention by all students was a progress monitoring passage from the FAIP-R passage set (Christ, Ardoin, & Eckert, 2010). It consisted of 190 words in 20 sentences. The passage included 5 high-frequency target words and 5 low-frequency target words that were equated by length. Word frequency was determined using the *The American Heritage Word Frequency Book* (Carroll, Davies, & Richman, 1971). Carroll, Davies, and Richman (1971) use a rating (U) that indicates the number of instances of a word per million running words. Low frequency words have a frequency a U rating of 10 or less. High frequency words have a U rating U of 50 or above. The passage was typed in black, 20-point Times New Roman font against a white background.

**Procedures**

After obtaining assent to participate, students were administered three FAIP-R benchmark probes (Christ, Adroin, & Eckert, 2010) to assess their reading fluency at the outset of the study. This data was used to match students based on their Median WRCM score. Matched pairs were then randomly assigned to either the RR condition or the LPP+RR condition. Students participated in the intervention portion of the study within one week of being administered the three FAIP-R probes. During intervention and eye tracking students were
seated approximately 55 cm from a 19 in computer screen that displayed the passage to be read. First, the eye tracker’s remote function was attempted to track the participants’ eye movements. A self-adhesive target was placed on the participants’ forehead to help the eye tracker locate the participants’ pupils during tracking. This allowed students to read aloud during the interventions without restricting movement. However, if the tracker had difficulty locating the participants’ pupils while using the remote function, the experimenters switched to a more sensitive, but restrictive setting in which a chinrest and head rest were used to stabilize movement during reading. While the experimenter prepared the apparatus, students were briefed on the experimental procedures, and then calibration was conducted using a 13-point calibration grid. For calibration, students were instructed to track a dot on the screen as it moved to 13 areas of the screen. The calibration procedure was repeated until a successful calibration was obtained and validated prior to beginning the intervention procedures.

Experimental procedures differed based on the condition to which each participant was randomly assigned prior to beginning the study. Students either received the Repeated Readings intervention (RR) or the RR intervention with a Listening Passage Preview component (LPP+RR). Students in the RR condition read the passage four times aloud while the eye tracker recorded their eye movements. Students in the LPP+RR condition first listened to a fluent reading of the passage by an adult while the eye tracker recorded their eye movements during the LPP phase. The fluent reading of the passage by the adult was pre-recorded and read at a rate of 110 WRCM. Each student in the LPP+RR condition listened to the exact same recording. Then the student read the passage three times aloud. Before each reading, the experimenter queued the students to do their best reading. During the reading of the story, experimenters only provided students with assistant if they hesitated for more than 3 s on a word.
In both conditions, the experimenter provided the students with feedback on their performance between each reading of the passage. This feedback included information regarding their reading rate and accuracy as measured by time taken to read the story and number of errors, respectively. The experimenter then reviewed any misread word by modeling how to correctly read the word, having the participant repeat the word correctly, and then having the participant re-read the phrase containing the missed word. After the last reading of the passage, students were thanked for their participation, given a prize, and returned to their classrooms.

**Inter-rater Reliability and Procedural Integrity**

All intervention sessions were conducted by experimenters with extensive experience conducting eye-tracking procedures and implementing similar intervention procedures as part of related research. Two experimenters were needed for each session, as one focused on the eye tracker while the other carried out the intervention protocol. All examiners were given a scripted protocol to follow during each session and were trained on the protocol prior to data collection. Inter-rater reliability and procedural integrity were evaluated by listening to the audio recording from 15% of the sessions selected randomly.

Inter-rater reliability on student’s WRCM was determined by comparing an independent scoring of each trial from the recordings to the protocol used during data collection. The total number of words agreed on as correct and incorrect was divided by the number of agreements plus disagreements to obtain the percentage of words on which the two raters agreed. Mean inter-rater reliability was 99.5% (range = 98% - 100%).

A procedural checklist developed based upon the scripted protocol was used to assess procedural integrity. The number of steps correctly completed during the session was divided by the total possible number of steps, which varied based on the condition and the number of errors
made during reading (ranging from 10 to 21). Procedural integrity was 100% for all of the assessed sessions.

**Data Analysis**

Students’ reading fluency was measured through oral reading data as well as through eye-movement behavior. Overall improvements in oral reading fluency were analyzed using students’ WRCM and number of errors made. A more detailed analysis using eye-movement data was conducted to determine what underlying changes in reading behavior may have affected students’ oral reading fluency. For all eye-movement variables, fixations shorter than 120 ms and longer than 3000 ms were omitted from analyses. Although typically fixations longer than 800 ms are removed when analyzing silent reading (e.g., Raney & Rayner, 1995), the upper limit was increased to 3000 ms in this study because the students read the passages orally. As frequently done within eye-tracking literature (e.g., Ashby, Rayner, & Clifton, 2005; Raney & Rayner, 1995) eye-movement data were analyzed on a global level by averaging the various measures across all words in the passage and also using target-word analyses to determine the effect of the interventions on the reading of high- and low-frequency words. Target-word measures were derived by averaging the various measures across the five low-frequency and five high-frequency words in the passage. The following dependent variables were included in both the global and target-word analyses: first fixation duration, gaze duration, total time, number of inter-word regressions, and number of fixations (for definitions of these variables see the Appendix). The percentage of words fixated on during reading across the entire passage was also included in the global analysis. Means and standard deviations for each measure are presented in Tables 2-4.
Prior to analysis, all sessions were examined for track losses (i.e., momentary loss of the eye’s position during recording). Track losses occurred during 31 trials across all 57 participants (14% of trials). A trial by trial analysis revealed that track losses were equally likely in the two conditions during Trial 1 (6 participants in each condition), Trial 2 (3 participants in LPP+RR and 2 in RR), and Trial 3 (2 participants in each condition). During Trial 4, track losses occurred more often for participants in the LPP+RR condition (n = 7) than in the RR condition (n = 3). The average duration of the track losses were similar in the two conditions (10.7 s in the LPP+RR condition and 11.8 seconds in the RR condition). Trials were excluded from the global analyses if data were recorded on fewer than three sentences and excluded from the target word analyses if data were recorded on fewer than 3 of the 5 target words. Based on these criteria, no trials were excluded from global analyses. Trial 4 for one participant in each condition was excluded from high-frequency word analyses, and Trial 4 for one participant in the LPP+RR condition was excluded from low-frequency word analyses.

Intervention effects on WRCM, number of reading errors, global measures, and target-word measures were analyzed using a repeated measures analyses of variance (ANOVA) with intervention (RR or LPP+RR) as the between-subjects factor and trial (first, second, third, and fourth exposure to the passage) as the within-subject factor. Significant main effects for trial and within group simple effects were further investigated through Bonferroni-adjusted comparisons between Trial 1 and 2, Trial 1 and 3, and Trial 1 and 4 to determine the number of trials needed to see significant changes in behavior. Significant pairwise comparisons are indicated in Tables 2-4 by asterisks. Additional analyses comparing Trial 2 in the LPP+RR condition to Trial 1 in the RR condition on all the eye-movement variables as well as WRCM and number of errors made during reading were conducted in order to determine the effects of listening to a fluent
model of the passage before having to read the passage independently. Cohen's (1988) guidelines can be used to interpret effect sizes according to values of eta squared (i.e., small - $\eta^2 = .01$, medium - $\eta^2 = .06$, and large - $\eta^2 = .14$). All analyses were evaluated at an alpha level of .05.

Statistical analyzes conducted to test the assumptions associated with using an ANOVA revealed that many variables deviated slightly from a normal distribution due to the presence of outliers. However, ANOVAs are generally robust to slight deviations from a normal distribution (Rasch, Teuscher, & Volker, 2007) particularly with an adequate sample size (n>30; Glass, Peckham, & Sanders, 1972). Additionally, the outliers were determined to be accurate measurements that were representative of the population; therefore, they remained in the data set for all analyses. Mauchly’s test indicated that the assumption of sphericity was violated on all global measures and all but one (number of inter-word regressions) low-frequency word measures. For these variables, degrees of freedom values were corrected using Greenhouse-Geisser estimates of sphericity when epsilon was less than .75 and Huynh-Feldt estimates when epsilon was greater than .75. Finally, Levene’s Test of Equality of Error Variances revealed unequal variances between the two conditions in Trial 1 and Trial 2 on low-frequency total fixation time, in Trial 1 on number errors made, global total fixation time, global fixation count, and percent of words fixated, and in LPP+RR Trial 2 and RR Trial 1 on low-frequency first fixation duration and low-frequency gaze duration. Welch’s F-test was used to analyze differences between the two conditions when the equality of error variances assumption was violated.

In order to confirm group equivalency at the outset of the study, the two groups were compared on various demographic data. These analyses indicate that two groups did not differ
significantly in regards to oral fluency rates as determined by the FAIP-R benchmark probes administered prior to the implementation of the interventions, $t(55) = -.289, p = .774$, district representation, $X^2(1, N=57) = .036, p = .850$, or race representation, $X^2(4, N=57) = 6.854, p = .144$.

**Results**

**Oral Reading Fluency and Accuracy**

Students’ oral reading fluency was measured by calculating WRCM based on the total number of words read correctly across the entire reading of the passage and the time required to read the passage. Reading accuracy was measured by recording the number of reading errors during each trial. Because students in the LPP+RR condition did not read aloud on the first trial, the analyses comparing the effects of the two conditions across readings only included Trials 2 through 4 for WRCM and number of errors.

The repeated measures ANOVA evaluating students’ WRCM revealed a significant interaction effect between condition and trial on students’ oral reading fluency, $F(1.787, 96.524) = 4.542, p = .016, \eta^2 = .070$. Follow up one-way analyses of trial effects indicated that students in the LPP+RR condition significantly increased their WRCM across the second through fourth trials, $F(2, 60) = 9.880, p = .000, \eta^2 = .248$, while the students in the RR condition did not, $F(1.580, 37.910) = .363, p = .648$. Trial 1 for the RR condition was then included on the one-way ANOVA, which revealed a significant increase in WRCM when considering their performance on the first reading $F(2.718, 65.225) = 6.148, p = .001, \eta^2 = .204$. Pairwise comparisons using the first independent reading of the passage as a reference group indicated that students in the LPP+RR group did not experience a significant immediate benefit from repeated exposures to the text (Trial 2 vs. Trial 3, $p = 1.000$) but rather, significantly improved
their oral reading fluency by the fourth exposure (Trial 2 vs. Trial 4, \( p = .002 \)). However, students in the RR condition demonstrated an immediate increase in WRCM (Trial 1 vs. Trial 2, \( p = .036 \)) that persisted through the third and fourth readings (Trial 1 vs. Trial 3, \( p = .006 \); Trial 1 vs. Trial 4, \( p = .009 \)). Between group comparisons revealed no significant differences in WRCM between students in the two conditions on Trial 2, \( t(54) = -.679, p = .500 \), Trial 3, \( t(54) = -.665, p = .509 \), or Trial 4, \( t(54) = -.243, p = .809 \). Therefore, the two interventions appear to produce similar levels of reading fluency; however, RR appears to produce a more immediate increase in oral reading fluency, while the increase occurred more gradually with LPP+RR.

Results of the repeated measure ANOVA comparing students reading accuracy (i.e., number of errors in reading) did not reveal a significant interaction between trial and condition, \( F(1.680, 92.374) = 1.675, p = .197 \), or a main effect for condition, \( F(1, 54.98) = 1.928, p = .171 \). Students did, however, significantly decrease the number of errors they made during reading across the second through fourth trials, \( F(1.680, 92.374) = 10.659, p = .000, \eta^2 = .158 \). Post-hoc pairwise comparisons revealed a significant decrease in reading errors made from Trial 2 to Trial 3 \( (p = .003) \) that persisted in Trial 4 \( (p = .000) \).

**Global Analyses**

Results of the analyses on eye-movement behavior revealed that increases in oral reading fluency across trials resulted from several underlying changes in behavior. Specifically, students’ average total fixation time, \( F(1.644, 90.413) = 6.791, p = .003, \eta^2 = .108 \), average fixation count, \( F(1.666, 91.656) = 6.822, p = .003, \eta^2 = .110 \), and percentage of words fixated, \( F(1.765,97.062)=3.962, p=.027, \eta^2 = .067 \), decreased across the four trials similarly in the two conditions in that no interactions between condition and trial or main effect for condition were found on any of these variables. Pairwise comparisons revealed that students’ average total
fixation time during Trial 2 ($p = .030$) and Trial 4 ($p = .010$) were significantly shorter than in Trial 1. Additionally, students’ average fixation count per word ($p = .003$) and percentage of words fixated ($p = .045$) decreased significantly between Trial 1 and Trial 4.

Students’ number of inter-word regressions in the two conditions differed in regards to the degree of change across trials as evidenced by a significant interaction, $F(2.410, 132.556) = 3.720, p = .020, \eta^2 = .045$. Main effects for trial, $F(2.410, 132.556) = 24.945, p = .000, \eta^2 = .298$ and condition, $F(1, 55) = 8.230, p = .006, \eta^2 = .012$, were also revealed. Analyses of within group simple effects revealed that students in the LPP+RR significantly decreased the number of inter-word regressions made during reading from Trial 1 to Trial 2 ($p < .001$), and this difference persisted through Trial 3 ($p < .001$) and Trial 4 ($p < .001$). In contrast, students in the RR condition did not decrease their number of inter-word regressions from Trial 1 to Trial 2 ($p = .191$). Their inter-word regressions decreased on Trial 3 as compared to Trial 1 ($p = .002$), and this decrease persisted on Trial 4 ($p < .001$). The more immediate decrease found in the LPP+RR condition can likely be attributed to the high number of inter-word regressions made during LPP. Follow up analyses of between groups simple effects indicate that students made more inter-word regressions while listening to a story being read (LPP+RR Trial 1) than when they read the story on their own (RR Trial 1), $F(1, 55) = 12.111, p = .001, \eta^2 = .180$. Students’ number of inter-word regressions did not differ significantly on Trial 2 ($p = .083$). However, students in the LPP+RR again made more inter-word regressions during Trial 3 than students in the RR condition, $F(1, 55) = 6.596, p = .013, \eta^2 = .107$. This difference did not persist in Trial 4 ($p = .067$).

Analyses of first fixation duration on a global level revealed that there was not a significant interaction effect between condition and trial, $F(2.345, 128.966) = .651, p = .547$, and
no main effects for condition, $F(1, 55) = .464, p = .498$, or trial, $F(2, 345, 128.966) = 1.140, p = .329$. Similarly, no interaction, $F(2.345, 128.966) = .267, p = .802$, or main effect for condition, $F(1.55) = .413, p = .514$, or trial, $F(2.368, 130.214) = 1.248, p = .293$, were found for students’ average gaze duration. These analyses suggest that students’ average first fixation time and gaze duration did not change across readings or differ between groups when examining their behavior across all words within the passage (global analyses).

**High-Frequency Word Analyses**

Results of high-frequency target-word analyses revealed no significant interactions between trial and condition on any of the measured eye-movement behaviors. Additionally, the main effect for condition was not significant for any of the measures when considering students’ reading of high-frequency words. A main effect for trial indicating a significant increase in gaze duration on high-frequency words was found, $F(3, 159) = 2.706, p = .047, \eta^2 = .048$. Although no significant pairwise comparisons were revealed between Trial 1 and all other trials, average gaze durations on high-frequency words increased between Trials 1 and 3 to a degree that approached significance ($p = .054$). A main effect for trial was also evident on the average number of inter-word regressions made to high-frequency words, $F(3, 159) = 5.805, p = .001, \eta^2 = .097$. Post hoc analyses indicate that students made significantly fewer inter-word regressions to high-frequency words in Trial 4 than Trial 1 ($p = .001$). Students’ eye-movement behavior did not change significantly on high-frequency words in terms of first fixation time, total fixation time, and fixation count.

**Low-Frequency Word Analyses**

Results of low-frequency target-word analyses indicated similar degree and level of effect across the two condition in that interaction and condition main effects were not significant
for any of the dependent variables. Significant decreases across trials in gaze duration, $F(2.69, 145.12) = 4.730, p = .005, \eta^2 = .079$, total time, $F(2.53, 136.49) = 8.97, p = .000, \eta^2 = .141$, and fixation count, $F(2.68, 144.94) = 3.542, p = .020, \eta^2 = .061$ were found. Post hoc analyses indicated that the average gaze duration on low-frequency words were significantly shorter in Trial 2 than in Trial 1 ($p = .009$); however, this decrease did not persist through Trial 3 ($p = .369$) and Trial 4 ($p = .063$). Students’ average total fixation time on low-frequency words decreased significantly on Trial 2 ($p = .001$) and continued to be significantly shorter on Trial 3 ($p = .021$) and Trial 4 ($p = .000$) as compared to Trial 1. Finally, students made significantly fewer fixations on low-frequency words on Trial 4 than they did on Trial 1 ($p = .021$).

**Comparison of the First Independent Reading**

Additional analyses on WRCM, number of errors during reading, and all eye-movement variables comparing Trial 1 in the RR condition to Trial 2 in the RR+LLP condition sought to determine differences in reading behavior on students’ first independent reading of the passage. Results revealed that students reading behavior differed significantly on low-frequency words during their first independent reading of the text. Specifically, students who were provided with a fluent model of the passage before reading the passage independently spent significantly less time fixating on low-frequency words than students who did not listen to a fluent reading of the story as evidenced by significantly shorter first fixation durations, $F(1, 34.78) = 8.337, p = .007, \eta^2 = .148$, gaze durations, $F(1, 38.50) = 9.235, p = .004, \eta^2 = .157$, and total fixation times $F(1, 55) = 6.651, p = .013, \eta^2 = .108$. Students’ reading in the two conditions did not differ in terms of the number of words read correctly, number of reading errors, eye movements on all words in the passage (global analysis), or eye movements on high-frequency words.
Discussion

Interventions focused on increasing reading fluency have been a topic of great interest in the school psychology literature for decades (e.g., Daly & Martens, 1994; Klubnik & Arodin, 2010; NICHD, 2000; Smith, 1979). Two common reading fluency interventions, RR and LPP, have extensive empirical evidence to support their use to increase students’ reading as measured by WRCM (e.g., Daly & Martens, 1994; Skinner, Cooper, & Cole, 1997, Therrien, 2004). However, a more direct measure of reading behavior, such as eye movements, can provide a more detailed understanding of the mechanism through which these interventions take effect. A majority of the existing eye-tracking studies investigating the effects of rereadings have been conducted with adults and do not follow the procedures typically associated with the RR intervention (Hyönä, 1995; Hyönä & Niemi, 1990; Raney & Rayner, 1995; Schnitzer & Kowler, 2006). The three known studies that directly investigated the effect of the RR intervention on the eye-movement behavior of children suggest that the intervention has a facilitative effect on word-level processing and higher-level processing particularly on low-frequency words (Foster et al., 2013) and with less fluent readers (Zawoyski et al., 2014). However, these studies measured intervention effects on eye movements during silent reading when typical intervention and assessment procedures are conducted while students read aloud. In addition, the benefit of using LPP in conjunction with RR is unclear based on previous studies utilizing WRCM as a measure of fluency (Begeny & Silber, 2006; Daly et al., 2002). As such, the current study measured students’ eye-movement behavior during oral RR with and without LPP. The two main goals of this study were to determine if the two interventions differentially affect students’ reading and how the interventions affect reading behavior across the four exposures.
Analyses of overall intervention effects indicate that RR and LPP+RR appear to produce similar reading behavior across the four trials given that students’ reading in the two conditions only differed on the number of inter-word regressions made across the entire reading of the passage. Participants in the LPP+RR condition made more inter-word regressions than the participants in the RR condition on Trial 1 and Trial 3. Inter-word regressions are thought to be made due to comprehension failures or to remedy oculomotor errors (i.e., an ill-placed fixation), both of which occur more during labored reading (Rayner, 1998). Therefore, the increased number of inter-word regressions made by students in the LPP+RR condition may be an indication of poorer reading by those students in Trial 1 and 3. Additional differences in eye movements during students’ first independent reading of the passage in each condition were noted. Specifically, results suggest that LPP is particularly facilitative for students’ reading of low-frequency words, both in terms of lexical processing and higher-level processing, indicating a direct effect of being provided a fluent model of the passage before reading. However, the eye movement improvements demonstrated in response to being provided with LPP were not reflected in students’ oral reading fluency as students’ WRCM and number of errors made on the first independent reading of the passage did not differ significantly between conditions. In addition, neither the difference in average number of inter-word regressions made during the two conditions nor the direct effect of LPP persisted through Trial 4.

The similarity in outcomes for students in the two intervention conditions contradict the expected results based on previous research (e.g., Begeny & Silber, 2006; Chard, Vaughn, & Tyler, 2002). LPP+RR was expected to produce greater gains in reading than RR alone due to the hypothesized facilitative effects of modeling on students’ decoding and comprehension processes. Assuming participants were paying adequate attention, students in the LPP+RR
condition had the correct reading of all words in the passage modeled for them prior to independently reading the passage in Trial 2. The vast resemblances in students’ eye movements between the two conditions provide preliminary evidence to suggest that students were in fact reading along as they listened to the model. Therefore, LPP should have aided students’ decoding by preventing the unfamiliarity with text that often causes labored reading. Furthermore, students provided with LPP had the opportunity to gain information about the context of the passage during the first exposure to the passage without having to focus excessively on decoding. Based on LaBerge and Samuels’s theory of automatic information processing (1974), LPP should facilitate comprehension more than independent reading because LPP reduces the cognitive demands of decoding, allowing students to allocate their attentional resources to comprehension. In the current study, decoding processes during Trial 1 in the LPP+RR condition should have required less attentional resources than Trial 1 of RR, freeing more resources for comprehension thus facilitating subsequent readings of the passage. In addition results of previous research suggest that students benefit most from intervention packages that include both LPP and RR (Begeny & Silber, 2006).

Differences between the current study and the expected results, as seen in Begeny and Silber (2006), are possibly due to differences in the participants’ fluency skills prior to receiving intervention. Students in the current sample were more fluent than the four students who participated in Begeny and Silber, whose fluency ranged from 22 to 74 WRCM on a third grade passage. As RR has been shown to produce greater gains in lower performing readers (Levy, Nicholls, & Kohen, 1993; Zawoyski et al., 2014), LPP+RR might also differentially facilitate fluency as a function of reading ability.
Several procedural differences between Begeny and Silber (2006) and the current study may have also resulted in different outcomes. Procedural variations used in Begeny and Silber may have reduced the efficacy of the RR component and increased the efficacy of the LPP component. First, RR as conducted in Begeny and Silber may not have produced the optimal results because intervention occurred in pairs of students in which they alternately read the passage two times each to each other rather than reading the passage four times to an adult. Additionally, although students helped each other with unknown words during RR, error correction procedures and feedback on rate were not provided to the students between readings as in the current study. In contrast, the effect of the LPP component may have been enhanced because experimenters paused periodically while modeling the passage to have students read the next word. This may have increased students’ engagement during the LPP component. In addition, the time needed to implement intervention packages was not equated in Begeny and Silber; therefore, it is unknown whether enhanced treatment outcomes in the LPP+RR+WLT condition were due to the intervention components or due to the increased time needed to implement all three components. Although the hypothesized results were not supported in the current study, students’ reading improved in response to both intervention conditions.

Even though RR appears to be equally effective with and without an LPP component in improving oral reading fluency after four repeated exposures to the same text, the immediacy of the effect differs in the two interventions. Students in the RR condition significantly improved their WRCM on the second trial whereas the students in the LPP+RR condition did not significantly improve their reading fluency until the fourth trial. In consideration of Therrien’s (2004) recommendation to use a performance criterion to determine how many repetitions to use
during RR procedures, RR alone may be a more efficient option given the immediacy of the effects as compared to LPP+RR.

In looking at changes in reading behavior across trials in the two conditions, the current study found that repeated exposure to text (either four readings of the text or a listening preview followed by three readings of the text) affects multiple reading behaviors associated with higher level processing, which is consistent with previous findings (Foster et al., 2013; Zawoyski et al., 2014). Specifically, participants spent less total time fixating on words, revisited text fewer times, and fixated on words fewer times on average after four consecutive exposures to the passage. Students also fixated on a smaller percentage of words on the fourth exposure to the text, which often characterizes more skilled reading and indicates an increase in efficiency in the acquisition of information during each fixation (Blythe, Häikiö, Bertam, Liversedge, & Hyönä, 2011; McConkie et al., 1991). Since familiar words are more likely to be skipped (Radach & Kempe, 1993; Rayner, Sereno, & Raney, 1996), these findings suggest that repeated exposure to text does in fact increase students’ familiarity with the practiced words.

Similar to Foster et al. (2013) and Zawoyski et al. (2014), the facilitative effects of these interventions were greater for low-frequency words than for high-frequency words. Participants spent less time actively fixating and fixated significantly fewer times on low-frequency words during Trial 4 than Trial 1. In addition, students’ gaze durations were shorter on low-frequency words during the second trial as compared to the first; however, this effect did not persist into the fourth trial. In contrast the only facilitative effect produced on high-frequency words was on the number of inter-word regressions in that there was a significant decrease from Trial 1 to Trial 4.

Contrary to previous findings suggesting quicker lexical processing as a result of RR particularly across all words in the passage and on low-frequency words (Foster et al., 2013;
Zawoyski et al., 2014), the fixation times associated with lexical processing (i.e., first fixation and gaze duration) did not decrease significantly for participants in the current study across the four exposures. This difference is likely attributable to the feedback and error correction procedures employed during the current study that were not used in Foster et al. (2013) or Zawoyski et al. (2014). Previous studies have shown that the content of directions and performance feedback provided during intervention and assessment affects students’ reading performance in terms of reading rate (Ardoin, Morena, Binder, & Foster, 2013; Christ, White, Ardoin, Eckert, & VanDerHeyden, 2013; O’Shea, Sindelar, O’Shea, 1985, 1987), comprehension (O’Shea et al., 1985, 1987), and prosody (Ardoin, Morena, Binder, & Foster, 2013). Although participants in Foster et al., Zawoyski et al., and the current study all received feedback on their reading rate after each trial, only students in the current study received feedback regarding the errors they made during reading. Given that, during the current study, error correction procedures were implemented at the end of each trial rather than as the errors occurred during the reading, the performance feedback provided on errors in between each trial required more time and attention to address than the performance feedback provided on reading rate. This likely had a punishing effect on inaccurate reading and increased students’ awareness of their mistakes, which could have caused students to shift their focus from reading quickly to reading accurately. The changes in reading behavior seen during the current study suggest that such a shift in attention may have occurred. Results revealed that students did in fact significantly decrease the number of reading errors they made by the fourth exposure to the passage; however, the increases in WRCM during the current study were weaker than those found in previous studies (e.g., an increase of 32 WRCM in response to RR in Ardoin, Morena, Binder, & Foster, 2013, and an increase of 22–48 WRCM in response to LPP+RR in Begeny and
Silber, 2006). In contrast to students in the current sample, students in Foster et al. and Zawoyski et al. may have focused on improving their reading rate but not accuracy across exposures because they only received performance feedback on their total reading time after each trial.

Another possible cause of the discrepant results between the current study and previous studies is the difference in mode of reading used during RR procedures. Since students in previous studies (Foster et al., 2013; Zawoyski et al., 2014) read silently, they may not have been as concerned about accuracy in reading knowing that the interventionists could not directly evaluate their reading errors. Furthermore, previous studies have shown that oral reading is slower than silent reading (e.g., Allen, 1988; Hasbrouck & Tindal, 2006; McCallum, Sharp, Bell, & George, 2004), and this difference is reflected in eye-movement behaviors during oral and silent reading (Anderson & Swanson, 1937). It is possible that oral reading rate has a lower ceiling than silent reading given the extra processing and time required for speech production in oral reading (Balota & Chumbley, 185; Inhoff, Solomon, Radach, & Seymour, 2011), which would limit the amount of change possible across repeated readings during oral reading but not silent reading.

**Limitations and Future Directions**

Results of the current study should be interpreted with the following limitations in mind. Due to technological difficulties, some eye-movement behaviors were not recorded during some of the participants’ readings. On occasion, the eye-tracking camera lost sight of the participant’s pupil, usually due to excessive head movements. Eye movements made during that time were not recorded and, therefore, were not included in the analysis. These track loses occurred during
30 trials across 20 participants. On average, data were collected on 187 of the 190 words (range = 67 – 190).

In addition, given the variability in the data, a larger sample size may be needed to detect subtle differences between the two interventions. Although the sample size of the current study (n=57) approached the predetermined number necessary for adequate power (n=60), the power analysis conducted prior to the experiment was based on the results of Foster et al. (2013) and evaluated the sample size needed to detect changes across trials, which the current study was able to do. However, this number may not have been adequate enough to detect difference between the two groups. Of note, several interaction terms and between group differences in the current analysis approached significance (i.e., p-values between .05 and 1).

Finally, results are also limited by some sample characteristics such as students’ reading fluency prior to intervention. Based on the fluency data from the CBM-R probes administered prior to collecting eye-movement data, the average reading fluency for the sample was 128 WRCM, ranging from 66 to 199 WRCM. The participants’ high reading fluency at the outset of the intervention may be problematic for three reasons. First, a higher rate of fluency prior to intervention may have caused a ceiling effect to weaken the effects of the intervention, again increasing the need for more participants for sufficient power to detect between group differences. Second, the results of this study may not generalize to the low achieving students who typically receive interventions such as RR and LPP. Third, the pre-recorded fluent model of the passage used during LPP was read at a slower rate (110 WRCM) than the average fluency of the LPP group ($M=126.5$, range = 66 - 191 WRCM). Although not well understood, studies have shown that a relationship between the reading rate of the model used during LPP and intervention outcomes exists (Skinner, Cooper, & Cole, 1997; Skinner et al., 1993). The same
recording was used for all participants in the current study for better experimental control between subjects; however, this could have affected the efficacy of the intervention based on each individual student’s reading fluency.

Nonetheless, the participants in this study still fall within the population for which reading fluency instruction has been identified as a necessary component of a comprehensive reading curriculum as outlined by the National Reading Panel (NICHD, 2000). Moreover, the National Reading Panel concluded that RR procedures improve reading in non-impaired readers through fourth grade. Notably, the average reading fluency of the sample (i.e., 128 WRCM) was below end-of-year grade expectations (129 WRCM; Christ et al., 2014). Thus, the sample consisted of at-risk to above average readers, all of whom should, and did, benefit from fluency intervention. However, the results may have been less pronounced because of the inclusion of higher functioning readers in the sample. Given that previous research has shown RR to be more effective with lower-performing students (Levy, Nicholls, & Kohen, 1993; Zawosky et al., 2014), it is likely that lower-performing students would demonstrate at least as much growth as the students in this sample if not more. However, little is known regarding the effect of LPP+RR on low performing students’ reading fluency and eye movements during reading.

Future studies conducted with a larger and more diverse sample will be needed to clarify the effects RR and LPP+RR. Specifically, replicating this study using a larger age and reading ability range may provide valuable information regarding intervention effects with beginning and struggling readers. Knowing more about how different samples respond to these interventions will help teachers choose appropriate instructional strategies for their students. Additionally, future eye-tracking studies investigating the effect of different rates of presentation
during LPP may help clarify the optimal rate of presentation to produce the greatest gains in reading fluency.

Conclusions and Implications for Practice

When choosing instructional strategies for developing reading fluency, it is important to know not only what works but also how it works. Knowing how an intervention affects reading can help determine the situations in which the intervention are most likely to be effective.

Despite the aforementioned limitations, findings from this study provide strong support for the use of RR and LPP+RR to improve students’ oral reading fluency. The two conditions produced similar improvement in reading fluency as measured by WRCM and eye-movement behavior. These similarities have two implications. First, both interventions appear to be equally effective in improving the reading fluency of third grade students who are at-risk to above average readers when four exposures to the text are used. However, RR alone appeared to have more immediate effects than LPP+RR, which is important if utilizing a performance criterion to determine the number of trials needed during intervention. Due to the immediacy of the effects in RR, students may reach the performance goal in fewer repetitions with RR, making it more time efficient in practice. Additionally, students in the RR condition made fewer inter-word regressions on two trials than students in the LPP+RR condition. Although this difference was not evident in the fourth trial, RR may be deemed more desirable since students in this condition practiced a better approximation of fluent reading more often than students in the LPP+RR condition.

Nonetheless, given the vast similarities in outcomes between the two intervention conditions, practitioners may wish look to other variables such as ease of implementation or acceptability from the students’ perspective in choosing which one to use.
The second implication of the similar results between the two conditions is that it can be reasonably assumed that students were generally reading during the LPP component. Their eye-movement behaviors were comparable to the eye movements made by their peers in the RR condition, who were reading the passage aloud. Thus it appears as though students were following along and reading to themselves as they listened to the fluent model. Further investigation is needed to determine if this generalizes to the classroom (i.e., a large group setting in which students’ eye movements are not being tracked). Results also support the use of a LPP procedure before students are required to read a passage independently given the facilitative effects of LPP on low-frequency words found during students’ first independent reading of the passage. Providing students with a fluent model of a passage may be especially beneficial when students are required to read passages that contain several unknown words.

Beyond showing that RR and LPP+RR are effective, the current study was able to provide further support for how reading fluency improved by measuring eye-movement behavior during intervention. Results indicate that RR with and without LPP produces gains in reading fluency by reducing the amount of time spent re-visiting and processing individual words (i.e., eye-movement behaviors associated with higher level text processing). Therefore, the gains in oral reading fluency as measured by WRCM in previous studies may be attributed to a reduction in time spent comprehending more so than to a reduction in time required for lexical processing. Measuring eye-movement behaviors also allows for the examination of which text characteristics affect the overall improvement in WRCM. By comparing reading behavior or high- and low-frequency words, the current study revealed that repeated exposure to the same text particularly facilitates students’ reading of low-frequency words. Therefore, RR with and without LPP may be more beneficial when used with passages containing several unfamiliar words.
Finally, the current study provides information regarding students’ reading fluency and eye-movement behavior during RR and LPP+RR procedures as they are typically implemented in the classroom. Intervention procedures used during this study incorporated the effective components identified by Therrien (2004). Students in the current study read the passages aloud to an adult, which allowed for the provision of corrective feedback on rate and accuracy. Additionally, students were cued to do their “best reading” prior to each trial, and each student was exposed to the passage four times. Therefore the results of the current study may generalize better to the results seen during typical classroom implementation of RR procedures.
References


Retrieved from www.fast.cehd.umn.edu


Table 3.1  
*Summary of Global Variables across Readings by Condition*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>WRCM</strong></td>
<td>--</td>
<td>126.3 (32.25)</td>
<td>127.8 (35.66)</td>
<td>132.3 (35.92)</td>
</tr>
<tr>
<td>RR (n=25)</td>
<td>122.3 (33.63)</td>
<td>129.6 (34.95)*</td>
<td>131.4 (36.0)*</td>
<td>131.0 (34.04)*</td>
</tr>
<tr>
<td>LPP+RR (n=31)</td>
<td>--</td>
<td>123.7 (30.21)</td>
<td>125.0 (35.73)</td>
<td>133.4 (37.89)*</td>
</tr>
<tr>
<td><strong>Errors</strong></td>
<td>--</td>
<td>3.9 (4.31)</td>
<td>2.2 (2.63)*</td>
<td>2.1 (2.51)*</td>
</tr>
<tr>
<td>RR (n=25)</td>
<td>4.7 (6.04)</td>
<td>2.9 (3.35)</td>
<td>2.0 (2.03)</td>
<td>1.8 (2.33)</td>
</tr>
<tr>
<td>LPP+RR (n=32)</td>
<td>--</td>
<td>4.7 (4.83)</td>
<td>2.4 (3.03)</td>
<td>2.4 (2.66)</td>
</tr>
<tr>
<td><strong>First fixation</strong></td>
<td>342.9 (63.66)</td>
<td>335.0 (64.32)</td>
<td>337.7 (65.68)</td>
<td>336.8 (65.81)</td>
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<tr>
<td>RR (n=25)</td>
<td>346.5 (74.49)</td>
<td>343.3 (57.74)</td>
<td>342.3 (61.66)</td>
<td>345.7 (61.29)</td>
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<tr>
<td>LPP+RR (n=32)</td>
<td>340.2 (54.82)</td>
<td>328.4 (69.21)</td>
<td>334.1 (69.42)</td>
<td>329.8 (69.28)</td>
</tr>
<tr>
<td><strong>Gaze duration</strong></td>
<td>416.3 (62.95)</td>
<td>405.8 (69.79)</td>
<td>414.8 (73.25)</td>
<td>412.6 (72.03)</td>
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<tr>
<td>RR (n=25)</td>
<td>422.2 (71.86)</td>
<td>412.5 (60.96)</td>
<td>418.3 (66.02)</td>
<td>421.9 (62.07)</td>
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<td>LPP+RR (n=32)</td>
<td>411.7 (55.77)</td>
<td>400.5 (76.53)</td>
<td>412.0 (79.38)</td>
<td>405.4 (79.15)</td>
</tr>
<tr>
<td><strong>Total fixation time</strong></td>
<td>565.2 (83.13)</td>
<td>530.1 (108.32)*</td>
<td>533.8 (116.09)</td>
<td>519.4 (112.60)*</td>
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<tr>
<td>RR (n=25)</td>
<td>550.0 (115.92)</td>
<td>529.7 (105.82)</td>
<td>526.3 (109.24)</td>
<td>521.8 (97.66)</td>
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<td>LPP+RR (n=32)</td>
<td>577.1 (41.80)</td>
<td>530.4 (111.92)</td>
<td>539.7 (122.58)</td>
<td>517.5 (124.55)</td>
</tr>
<tr>
<td><strong>Inter-word regressions</strong></td>
<td>.32 (.120)</td>
<td>.28 (.096)</td>
<td>.25 (.091)</td>
<td>.23 (.080)</td>
</tr>
<tr>
<td>RR (n=25)</td>
<td>.26 (.093)</td>
<td>.25 (.099)</td>
<td>.22 (.080)*</td>
<td>.21 (.071)*</td>
</tr>
<tr>
<td>LPP+RR (n=32)</td>
<td>.36 (.120)</td>
<td>.30 (.091)*</td>
<td>.28 (.091)*</td>
<td>.25 (.084)*</td>
</tr>
<tr>
<td><strong>Fixation count</strong></td>
<td>1.5 (.29)</td>
<td>1.4 (.36)</td>
<td>1.4 (.35)</td>
<td>1.3 (.32)*</td>
</tr>
<tr>
<td>RR (n=25)</td>
<td>1.4 (.35)</td>
<td>1.3 (.32)</td>
<td>1.3 (.30)</td>
<td>1.3 (.28)</td>
</tr>
<tr>
<td>LPP+RR (n=32)</td>
<td>1.5 (.22)</td>
<td>1.4 (.38)</td>
<td>1.4 (.38)</td>
<td>1.4 (.36)</td>
</tr>
<tr>
<td><strong>Percent fixated</strong></td>
<td>84.6 (6.55)</td>
<td>83.8 (6.97)</td>
<td>84.0 (6.98)</td>
<td>82.3 (6.97)*</td>
</tr>
<tr>
<td>RR (n=25)</td>
<td>84.0 (7.74)</td>
<td>83.0 (7.83)</td>
<td>82.8 (7.66)</td>
<td>81.9 (7.58)</td>
</tr>
<tr>
<td>LPP+RR (n=32)</td>
<td>85.1 (5.54)</td>
<td>84.5 (6.27)</td>
<td>84.9 (6.35)</td>
<td>82.7 (6.57)</td>
</tr>
</tbody>
</table>

*a* Significant Condition x Trial interaction, *p* < .05  
*b* Significant Main Effect for Condition, *p* < .05  
*c* Significant Main Effect for Trial, *p* < .05  
*Significant pairwise difference between the denoted reading and first trial, *p* < .05
Table 3.2
*Summary of High-Frequency Word Variables across Readings by Condition*

<table>
<thead>
<tr>
<th></th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$ ($SD$)</td>
<td>$M$ ($SD$)</td>
<td>$M$ ($SD$)</td>
<td>$M$ ($SD$)</td>
</tr>
<tr>
<td><strong>First fixation duration</strong></td>
<td>343.4 (97.06)</td>
<td>352.2 (104.89)</td>
<td>358.6 (102.11)</td>
<td>360.3 (110.68)</td>
</tr>
<tr>
<td>RR ($n=24$)</td>
<td>362.9 (99.35)</td>
<td>341.0 (105.17)</td>
<td>345.3 (108.02)</td>
<td>363.8 (100.38)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>328.3 (94.09)</td>
<td>360.9 (105.57)</td>
<td>369.0 (97.82)</td>
<td>357.5 (119.62)</td>
</tr>
<tr>
<td><strong>Gaze duration</strong></td>
<td>423.9 (115.68)</td>
<td>440.1 (147.11)</td>
<td>488.1 (179.16)</td>
<td>461.1 (139.15)</td>
</tr>
<tr>
<td>RR ($n=24$)</td>
<td>431.1 (108.78)</td>
<td>416.2 (135.00)</td>
<td>476.4 (203.35)</td>
<td>444.1 (137.46)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>418.4 (122.23)</td>
<td>458.6 (155.46)</td>
<td>497.2 (160.87)</td>
<td>474.2 (141.27)</td>
</tr>
<tr>
<td><strong>Total fixation time</strong></td>
<td>602.3 (155.94)</td>
<td>590.1 (198.29)</td>
<td>606.3 (236.88)</td>
<td>545.6 (180.96)</td>
</tr>
<tr>
<td>RR ($n=24$)</td>
<td>614.3 (172.58)</td>
<td>568.8 (226.39)</td>
<td>605.9 (277.92)</td>
<td>494.8 (159.76)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>592.9 (143.97)</td>
<td>606.6 (175.60)</td>
<td>606.6 (204.41)</td>
<td>584.9 (188.99)</td>
</tr>
<tr>
<td><strong>Inter-word regressions</strong></td>
<td>.24 (.195)</td>
<td>.23 (.197)</td>
<td>.19 (.207)</td>
<td>.10 (.203)*</td>
</tr>
<tr>
<td>RR ($n=24$)</td>
<td>.27 (.208)</td>
<td>.18 (.188)</td>
<td>.18 (.215)</td>
<td>.09 (.120)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>.22 (.184)</td>
<td>.27 (.199)</td>
<td>.20 (.204)</td>
<td>.11 (.251)</td>
</tr>
<tr>
<td><strong>Fixation count</strong></td>
<td>1.7 (.49)</td>
<td>1.7 (.51)</td>
<td>1.7 (.59)</td>
<td>1.6 (.61)</td>
</tr>
<tr>
<td>RR ($n=24$)</td>
<td>1.7 (.52)</td>
<td>1.6 (.57)</td>
<td>1.7 (.59)</td>
<td>1.3 (.44)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>1.8 (.46)</td>
<td>1.8 (.47)</td>
<td>1.7 (.60)</td>
<td>1.8 (.66)</td>
</tr>
</tbody>
</table>

*a* Significant Condition x Trial interaction, $p < .05$

*b* Significant Main Effect for Condition, $p < .05$

*c* Significant Main Effect for Trial, $p < .05$

*Significant pairwise difference between the denoted reading and first trial, $p < .05$
Table 3.3
Summary of Low-Frequency Word Variables across Readings by Condition

<table>
<thead>
<tr>
<th>Variable</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
<th>Trial 4</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td><strong>First fixation duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR ($n=25$)</td>
<td>351.1 (131.82)</td>
<td>307.0 (87.35)</td>
<td>327.0 (127.02)</td>
<td>311.6 (134.12)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>372.4 (144.83)</td>
<td>341.2 (86.01)</td>
<td>337.2 (136.58)</td>
<td>330.8 (149.44)</td>
</tr>
<tr>
<td><strong>Gaze duration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR ($n=25$)</td>
<td>499.4 (192.14)</td>
<td>414.0 (129.43)*</td>
<td>463.3 (167.85)</td>
<td>434.1 (163.82)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>538.9 (219.56)</td>
<td>446.8 (106.86)</td>
<td>453.8 (189.43)</td>
<td>448.0 (200.1)</td>
</tr>
<tr>
<td><strong>Total fixation time</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR ($n=25$)</td>
<td>656.7 (246.93)</td>
<td>523.7 (189.63)*</td>
<td>556.9 (207.34)*</td>
<td>515.4 (224.81)*</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>691.4 (298.18)</td>
<td>538.6 (149)</td>
<td>556.4 (229.45)</td>
<td>545 (268.59)</td>
</tr>
<tr>
<td><strong>Inter-word regressions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR ($n=25$)</td>
<td>0.43 (0.292)</td>
<td>0.33 (0.249)</td>
<td>0.33 (0.301)</td>
<td>0.33 (0.241)</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>0.34 (0.249)</td>
<td>0.32 (0.257)</td>
<td>0.34 (0.359)</td>
<td>0.34 (0.288)</td>
</tr>
<tr>
<td><strong>Fixation count</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR ($n=25$)</td>
<td>1.9 (0.79)</td>
<td>1.6 (0.65)</td>
<td>1.7 (0.53)</td>
<td>1.6 (0.58)*</td>
</tr>
<tr>
<td>LPP+RR ($n=31$)</td>
<td>1.9 (0.93)</td>
<td>1.6 (0.59)</td>
<td>1.7 (0.50)</td>
<td>1.6 (0.53)</td>
</tr>
</tbody>
</table>

*Significant Condition x Trial interaction, $p < .05$

bSignificant Main Effect for Condition, $p < .05$

*Significant Main Effect for Trial, $p < .05$

*Significant pairwise difference between the denoted reading and first trial, $p < .05$
CHAPTER 4

DISSERTATION CONCLUSION

The overarching aim of this two-study dissertation was to utilize eye-tracking technology to better understand common assessment and intervention practices. The purpose of Study 1 was to determine the similarities and differences between eye movements during silent and oral reading in children. Results suggest that third grade students’ eye-movement behaviors differ during silent and oral reading. Study 2 evaluated the effects of providing students with listening passage preview (LPP) in conjunction with repeated reading (RR). Results suggest that RR with and without LPP improve students reading fluency to a similar degree. Repeated exposure to text appears to improve students’ reading of low-frequency words more than that of high-frequency words.

Taken together with previous research, results suggest that reading type (silent vs. oral) is an important factor to consider when choosing assessments and generalizing results of intervention studies to classroom practices since significant differences were found between the two types of reading in terms of eye-movement behavior. Oral reading is favored given the additional information that can be gleaned from listening to a student read as well as its superior ability to predict overall reading achievement. Results also support the use of interventions that provide repeated exposure to text. Although both intervention conditions produced similar improvements on most measures, RR appeared to have a more immediate effect on students WRCM. As such, RR may be more desirable because it may lead to shorter intervention implementation times. Another interesting finding indicates that listening to a fluent model of a
passage facilitates students’ reading of low-frequency words on their first independent reading of the text. Although this effect was no longer evident after four exposures to the passage, this finding has important implications for the classroom setting outside the practice of RR. Teachers can use LPP in their classrooms as a quick method of facilitating independent reading when time or resource constraints do not allow for the use of the RR intervention.

Future research is needed to clarify the relationship between reading type, eye-movement behaviors, and reading comprehension as this information would be valuable for informing assessment practices. In addition, using a wider range of participants to replicate the results of both studies would broaden the generalization of the results to a larger population. In addition, differential effects of reading type and intervention type may be revealed in higher and lower performing students.
**APPENDIX**

**Operational definitions of eye movement measures**

<table>
<thead>
<tr>
<th>Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Fixation Duration</td>
<td>Includes only the duration of the initial fixation on a word, regardless of how many fixations there were in total on that word.</td>
</tr>
<tr>
<td>Gaze Duration</td>
<td>The sum of all consecutive fixations on the initial viewing of a word, before the reader moves on to another word</td>
</tr>
<tr>
<td>Total Time</td>
<td>The sum of all fixations on a word, which include time spent on the word during re-reading</td>
</tr>
<tr>
<td>Inter-word Regressions</td>
<td>The number of times a reader looks back to an earlier section of the passage</td>
</tr>
</tbody>
</table>

*Global measures for each of these variables are calculated by averaging across all words in the passage, while local processing is measured by averaging across the identified target words (i.e., high- and low-frequency words).*