UNDERLYING CHANGES IN REPEATED READING: AN EYE MOVEMENT STUDY

by

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(Under the Direction of Scott P. Ardoin)

ABSTRACT

Past research supports the use of repeated reading (RR) but does not provide conclusive evidence as to the mechanisms through which RR takes effect. Eye tracking allows for precise examination of intervention effects. The current study examined underlying changes in elementary students' (*N* = 43) reading behavior across four consecutive readings of the same passage. Passage-level analyses revealed that rereading yielded significant decreases in measures thought to reflect early processing (i.e., first fixation duration, gaze duration) and higher-level processing (i.e., total fixation time, number of regressions, average number of fixations per word). Analyses based on embedded high- and low-frequency target words suggested that RR mainly facilitates reading of low-frequency words, but that children remain sensitive to word frequency after rereading. Finally, results indicated that children who have completed RR continue to focus on word-level (versus passage-level processing) but devote less overall attention to individual words with repeated practice.

INDEX WORDS: Reading, Eye tracking, Eye movements, Repeated reading, Repetition, Rereading, Word frequency, Elementary students

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CHAPTER 1

INTRODUCTION

Repeated reading (RR) is the oldest and most frequently cited approach for assisting individual learners in becoming fluent readers (Kuhn, 2004; Meyer & Felton, 1999). Very simply, it consists of rereading short passages until fluency is achieved (LaBerge & Samuels, 1974). Although the RR technique was formally conceptualized by Dahl (1979) and Samuels (1979), RR methods can be traced as far back as the 17th century. Early reading instruction in America and Europe commonly revolved around texts based on familiar material like prayers and Bible stories and required students to practice repeatedly until they could read the material (Samuels, 1979). Similarly, reports from the turn of the 20th century described children in Asia and the United States who were learning to read simply by repeatedly reading texts until they could read them fluently (Huey, 1908/1968).

Despite the long-established nature of RR, the educational community has shown renewed interest in this simple approach due to increased emphasis on reading fluency as a major goal of reading instruction. Whereas past researchers labeled reading fluency a "missing ingredient" or overlooked goal in reading curricula (Allington, 1983; Anderson, 1981; Kuhn, 2004), the educational community now recognizes that fluency instruction is a necessary component of effective reading instruction in promoting literacy (Teigen, Malanga, & Sweeney, 2001). Despite a strong emphasis on reading in today's educational systems and settings, many students fail to attain reading fluency, or the ability to read with accuracy, automaticity, and proper expression (Kuhn & Stahl, 2003). In 2002, the U.S. Department of Education estimated that approximately 40% of fourth-graders were not fluent readers (Daane, Campbell, Grigg, Goodman, & Oranje, 2005). This bleak picture of reading instruction has understandably prompted the educational community to reevaluate instructional strategies for reading (Therrien, 2004). Furthermore, intervention research has suggested that educators must specifically target reading fluency as a distinct goal in classroom instruction (National Institute of Child Health and Human Development [NICHD], 2000), as instruction focused on other reading skills (e.g., phonemic awareness, phonics) is not sufficient to close gaps in the fluency of struggling readers as compared to average readers (Meyer & Felton, 1999; Torgesen, 2006).

Fluency instruction has also gained attention because of the relationship between reading fluency and comprehension (Meyer & Felton, 1999). Research suggests that reading fluency plays an important role in students' ability to construct meaning from text, which is the overall goal of reading instruction (Kuhn, 2004; Kuhn & Stahl, 2003). By influencing the development of skills like automatic word recognition and prosody, reading fluency enables students to attend to the meaning of text without attending to the mechanics of reading (Kuhn, 2004; Meyer & Felton, 1999; Samuels, 1979, 2006b).

Using LaBerge and Samuels's (1974) theory of automaticity, many researchers have conceptualized and more fully explained the connection between reading fluency and comprehension. Based on the idea that attention is selective and of limited capacity (Bos, 1982), LaBerge and Samuel's hierarchical reading model posits that complex skills (like reading) can only be performed when attention is not exhausted on the simple components of a complex skill. As complex skills require coordination of several smaller processes, they may be successfully performed only when those constituent processes are completed automatically (LaBerge & Samuels, 1974). In the context of reading, this means that decoding and thorough comprehension cannot be performed simultaneously if a reader must focus disproportionately on word recognition (Meyer & Felton, 1999; Samuels, 2006a; Samuels, 2006b). Nonfluent readers who labor through reading on a word-by-word basis use all of their cognitive resources on decoding, leaving little to no capacity for semantic-level processing (Bos, 1982) or comprehension (LaBerge & Samuels, 1974; Therrien, Gormley, & Kubina, 2006). As a result, not only do these students exhibit a reading style that is slow and effortful, but they also tend to struggle with comprehension due to their need for frequent repetitions of text and pauses between words that break their continuity of thought (Teigen et al., 2001). In contrast, fluent readers automatically process words at the visual and phonological levels, resulting in immediate word recognition, which frees attention for higher-level processing (e.g., focusing on meaning and integrating information from the text with previous knowledge; Bos, 1982). In short, because of the limited and hierarchical nature of information processing, difficulties with reading fluency virtually ensure that students will fail to comprehend reading material (Therrien, Gormley, et al., 2006), adversely impacting their achievement. Given these implications, researchers have extensively studied strategies designed specifically to promote reading fluency, including RR (Therrien, Gormley, et al., 2006).

The following review of the RR empirical literature will detail the basic methods of RR, current evidence supporting its effectiveness, and limitations associated with existing RR research. A discussion regarding how eye-tracking procedures can be used to overcome certain limitations will be provided along with a review of previous studies which examined the effects of multiple readings of the same text on eye-movement behavior.

Repeated Reading

Based on the theory of automaticity (LaBerge & Samuels, 1974), RR is designed to increase reading speed, facilitate the transfer of these improvements in speed to subsequent material, and improve comprehension with rereading (Meyer & Felton, 1999). RR follows the premise that one must repeatedly practice basic skills to develop speed and fluidity. In this manner, it equates fluent reading with other complex skills like playing an instrument or playing a sport; repetition gives individuals opportunities to master material before progressing further and provides them with the practice needed to develop automaticity (Samuels, 2006a; Samuels, 1979, 2006b).

Consistent with LaBerge and Samuels's (1974) theory, RR facilitates the development of word recognition skills that allow students to surmount the "decoding barrier," freeing attentional capacity for text comprehension. Word recognition development occurs in three stages: the nonaccurate stage, the accuracy stage, and the automatic stage. In the first two levels, students' attention is exhausted on decoding but to different degrees. Students in the nonaccurate stage have difficulty recognizing words even with ample time, whereas students in the accuracy stage can correctly recognize words with sufficient attention. However, students in both stages lack fluency and read in a slow and careful fashion, resulting in limited capacity for comprehension. In contrast, students in the third stage (i.e., the automatic stage) can recognize words without conscious attention and can comprehend text during oral reading if material is familiar (Samuels, 1979). Without automatic word recognition skills, readers must switch their attention between decoding and comprehension, rendering reading a slow and difficult process. However, with practice, readers can develop automatic word recognition and perform the two processes simultaneously (Samuels, 2006a; Samuels, 2006b). In addition, as opposed to beginning readers who focus on recognition of small units of words (e.g., individual letters), skilled readers can quickly recognize larger units of text (e.g., words, phrases), making processing more efficient (Samuels, 2006a). Development of automatic word recognition yields improvements in fluency and represents the change mechanism through which RR takes effect.

The methods of RR. Although specific procedures for RR vary across settings and contexts, they share a common goal: to increase students' fluency by having them reread meaningful text until their reading is fluid and automatic (Dowhower, 1987; Samuels, 2006a; Samuels, 1979, 2006b). Common across all RR methods, the student reads an appropriate-level passage multiple times until he or she achieves a set criterion (most commonly, a desired reading rate in words per min but sometimes a specified number of readings). Once this goal is met, the student moves on to other passages of the same level and rereads them in a similar fashion. In some cases, the student is given feedback on the number of errors made and the number of words read correctly, and performance is graphed (Meyer & Felton, 1999).

Several variations of RR expand on the simple framework described above. In unassisted RR, students silently repeat passages to themselves (without adult supervision), whereas students engaged in assisted RR orally repeat passages along with a fluent reader (Young, Bowers, & MacKinnon, 1996). Other versions of RR include questions aimed at building comprehension (Samuels, 1979) and/or involve reading with peers, reading poems and plays, and computer-based intervention (Samuels, 2006a; Samuels, 2006b).

Research has identified specific characteristics and components that maximize the effectiveness of RR. Between three and five readings is considered optimal, with most procedures typically employing three or four readings of a text (Dowhower, 1989; Samuels, 2006a; Samuels, 2006b; Therrien, Gormley, et al., 2006). Reading passages should be short, i.e., between 50 and 300 words, with the exact length depending on the skill level of the reader (Dowhower, 1989; Samuels, 1979). Passages should also be of an appropriate level of difficulty. Students should begin a passage with at least 85% accuracy or the passage is considered too difficult (Dowhower, 1989). However, passages should also be difficult enough to require students to reread them a sufficient number of times before achieving the fluency criterion (Therrien, Gormley, et al., 2006). Students reaching the desired rate of fluency on their first or second reading of a passage should progress to harder passages, whereas readers that have not yet demonstrated fluency should continue reading passages at the same level of difficulty (Dowhower, 1989). In addition to these stipulations, researchers have outlined specific procedural components that can optimize intervention effectiveness. Specifically, Therrien's (2004) meta-analysis suggests that the greatest gains from RR are achieved when students read aloud to an adult who can give effective feedback, receive corrective feedback on word errors, and read until they achieve a performance criterion. In particular, corrective feedback often results in improved performance because of its immediate nature (Teigen et al., 2001).

Empirical support. RR has been associated with improvements in fluency since its inception and is now supported by an extensive range of empirical evidence (e.g., Ardoin, Williams, Klubnik, & McCall, 2009; Therrien, Wickstrom, & Jones, 2006). Early studies by Samuels (1979) demonstrated that RR resulted in increased reading speed, decreased reading errors, and cumulative gains, such that students' initial speed of reading each passage was faster than that on the previous passage, and the number of readings necessary to reach the fluency criterion decreased. These cumulative improvements suggested transfer of effects and general increases in fluency. In addition, Samuels (1979) demonstrated significant gains in reading fluency and comprehension for students with learning and reading disabilities and students with intellectual disability. Other early efficacy studies revealed significant reading gains for elementary-age poor readers (Dahl, 1979), elementary students with difficulties with memory, attention, and auditory perception (Carbo, 1978) and intermediate-grade nonfluent readers (Herman, 1985). Since this early research, studies have continued to establish RR as an efficient method for improving reading performance (Teigen et al., 2001). In particular, three more recent meta-analyses (NICHD, 2000; Meyer & Felton, 1999; Therrien, 2004) linked RR with improved reading fluency on practiced passages and provided preliminary support for transfer of these improvements to untrained passages.

Meyer and Felton (1999) reviewed studies published between 1981 and 1999 and concluded that, overall, RR resulted in improved reading speed (in words read per min) for both average and poor readers in elementary school. A number of the reviewed studies also demonstrated improvements in word recognition accuracy, but findings were mixed regarding transfer of effects and changes in comprehension ability. Meyer and Felton also noted the influence of reader characteristics (e.g., naming speed, reliance on decoding) on reading rate and degree of improvement, finding that baseline reading levels moderated intervention effects. Consistent with the methods described above, RR in these studies typically involved three or four readings per passage and daily sessions approximately 15 min in duration. In general, teachers, paraprofessionals, and volunteers implemented these programs, but researchers also mentioned the possibility of effective implementation by higher functioning peers (Simmons, Fuchs, Fuchs, Mathes, & Hodge, 1995).

In another review of reading research literature, the National Reading Panel (NICHD, 2000) linked intervention procedures emphasizing repeated oral reading practice, including RR, with consistent positive effects on word recognition accuracy, reading fluency, and reading comprehension, as measured by a variety of test instruments (e.g., standardized tests, informal reading inventories, and other informal measures) and at a range of grade levels (i.e., Grades 2-9). This meta-analysis yielded an overall weighted effect size average of 0.41, suggesting a moderate impact, and gains were found to be highest for reading accuracy, smaller for fluency, and lowest (but still significant) for comprehension. Results also indicated that RR had a clear impact on nondisabled readers' reading ability through at least Grade 4, and on the performance of students with reading problems through high school. These findings suggested that instructional methods encouraging repeated oral reading led to meaningful improvements for good readers as well as struggling readers (NICHD, 2000).

In order to expand on and overcome some of the limitations of Meyers and Felton's (1999) and the National Reading Panel's (NICHD, 2000) reviews, Therrien (2004) conducted a meta-analysis of quantitative and experimental studies with school-age participants (aged 5-18 years) published between 1977 and 2001. In particular, Therrien sought to examine the effectiveness of RR in terms of fluency and comprehension (including with students with cognitive disabilities) and to identify the critical components of the intervention. As neither of the previously mentioned meta-analyses (NICHD, 2000; Meyer & Felton, 1999) took into account inconsistencies in intervention implementation across studies, neither could offer clear insight as to the relative importance of different components of RR variations. Therrien's review also overcame other limitations by considering sample size differences (unlike Meyer & Felton, 1999) and focusing on findings specific to RR (unlike NICHD, 2000). Overall, Therrien concluded that RR improved reading fluency and comprehension for students with and without learning disabilities (as indicated by a moderate mean increase in fluency and a somewhat smaller mean increase in comprehension). In addition, transfer results suggested that RR procedures might improve students' ability to read and comprehend untrained passages despite the time-limited nature of the intervention programs (with most involving 45 or fewer sessions). Expanding on past meta-analyses, Therrien also identified critical components of RR. In particular, Therrien recognized the importance of providing students with a reading cue and requiring three or four readings of a passage for promoting fluency and comprehension of a single passage (nontransfer effects). Specifically, he noted that RR procedures involving three or four readings of a single passage were associated with average fluency effect size increases (*ES* = .85

and .95, respectively) that were significantly larger than those associated with RR involving only two readings of a text (*ES* = .57). Therrien also noted that having students read aloud to an adult, providing corrective feedback, and using a performance criterion were essential to promote overall fluency and comprehension gains. Although Therrien's work closed gaps in the findings of prior meta-analyses, it remained subject to some limitations in the literature it reviewed. Many of these studies failed to provide information about students' reading levels and reading material (e.g., level of word overlap, level of passages), and some lacked comparison control groups, raising the possibility that gains could be associated with variables other than intervention.

Despite some acknowledged flaws, the three aforementioned meta-analyses (NICHD, 2000; Meyer & Felton, 1999; Therrien, 2004) and the larger pool of scientific literature on RR (e.g., Dowhower, 1989; Kuhn, 2004; Sindelar, Monda, & O'Shea, 1990; Teigen et al., 2001; Weinstein & Cooke, 1992) strongly support its robust nature as an effective intervention with broad ranges of students. Studies have indicated support for the use of RR with readers at all levels: developmental, transitional and less-skilled readers (Dowhower, 1989; Sindelar et al., 1990); students at the beginning stages of reading acquisition (Weinstein & Cooke, 1992); mastery-level readers (Sindelar et al., 1990); and even adults (Dowhower, 1989). RR has also resulted in improvements for students with emotional and behavioral disorders or severe oral language deficits (Teigen et al., 2001) and struggling students in a small group format (Kuhn, 2004). This impressive evidence base clearly supports the widespread use of RR in current educational systems. However, these studies do not provide evidence as to *why* RR results in improvements in students' rates of reading and comprehension skills.

Limitations of extant research. In addition to the study-specific limitations noted above, the literature on RR suffers from an added flaw; by employing inexact measures of fluency and focusing merely on effect sizes and overall gains, current studies do not thoroughly investigate the mechanisms through which RR takes effect. As no exact test of automaticity exists, researchers must rely on imprecise indicators of reading fluency (e.g., rate of response, accuracy of word recognition, reading speed; Samuels, 1979, 2006b). The most commonly used measure of fluency is oral reading rate per min (Meyer & Felton, 1999). Oral reading rates vary along a sliding scale based on age and skill level, such that expected reading rates increase incrementally over time. For example, second grade students at low risk for poor reading outcomes are expected to exhibit oral reading rates of at least 44 words per min, 68 words per min, and 90 words per min at the beginning, middle, and end of the school year, respectively (University of Oregon Center on Teaching and Learning, 2008).

Although commonly used measures of reading fluency allow researchers and practitioners to detect overall intervention effects, they fail to explain these effects fully. RR has repeatedly been associated with increases in reading speed (as discussed above), but little is known about the specific source of these increases. For example, an educator can clearly perceive quantifiable improvement in students' reading fluency simply by noting increases in the students' reading rates (in words per min). However, he or she cannot specifically attribute the students' changes in reading rate to certain factors. With repeated practice, some students may feel less of a need to go back and reread certain words or sections whereas other students may spend less time initially reading particular types of words (e.g., function words, low-frequency words, high-frequency words, etc.).

In this manner, a wide variety of changes in reading behavior may contribute to the same overall change in reading time/rate (Hyönä & Niemi, 1990; Raney & Rayner, 1995). Thus, global measures of reading fluency allow us to recognize the effects of interventions like RR but provide us with limited information about specific mechanisms of change.

Eye-Movement Research

Significance of eye tracking. Eye tracking is a unique technology that allows for precise examination of intervention effects. Eye-tracking techniques allow researchers to study natural reading directly without relying on secondary tasks that influence reading rate and might interrupt natural processing (Dussias, 2010; Rayner, 1998). Eye tracking also enables direct observation of silent reading and the otherwise unseen cognitive processes which underlie it (Rayner, 1998; Rayner, Chace, Slattery, & Ashby, 2006). Another advantage of eye tracking technology is the manner in which it allows researchers to examine reading processes separate from other characteristics like memory and articulation ability (Rayner et al., 2006). In addition, eye movement measures can be used to investigate multiple processes (e.g., surface-level word recognition, higher-level semantic processing) within a single sample of reading behavior (Just & Carpenter, 1980; Rayner, 1998). Eye tracking is also recognized as the best method available for inferring moment-to-moment cognitive processes and for pinpointing exactly when in a text a given variable has an effect (Dussias, 2010; Rayner, 1998; Rayner et al., 2006). This precise measurement has allowed researchers to demonstrate significant relationships between eye movements and characteristics of given words (Just & Carpenter, 1980; Rayner, 1983). For example, research suggests that readers spend more time fixating on difficult, important, and long words and are most likely to skip short, function words. These features distinguish eye tracking as a method that enables researchers to glimpse how rereading actually alters reading behavior (Raney & Rayner, 1995).

Commonly examined eye-movement parameters. Even though individuals generally feel like their eyes are moving smoothly across text while reading, reading actually consists of patterns of rapid movements (*saccades*) and pauses (*fixations*). While making saccades, the eyes move from one point to another and vision is suppressed. These movements are not involved in encoding textual information (Rayner et al., 2006). In contrast, fixations allow readers to extract information from fixated points and surrounding areas of visual acuity (Rayner et al., 2006). After processing on a particular word is complete, the eye is directed to land in a new location to get input for subsequent processing; this is typically manifested in rightward (forward) saccades or *return sweeps*, which carry the eye from the end of a line to the beginning of the next line (Just & Carpenter, 1980). However, readers also occasionally make backward saccadic movements, or *regressions* (Just & Carpenter, 1980; Rayner et al., 2006). These movements are not as well understood as forward saccades and fixations, but most regressions reflect additional processing of previously identified text or correction for "overshooting" eye movements. Although the durations and frequencies of fixations and saccades are influenced by factors like reading level and passage difficulty (e.g., word frequency, syntactical structure, etc.), it is generally accepted that difficulty with reading (as caused by any of these factors) is associated with longer fixations, shorter saccades, and more regressions (Rayner et al., 2006).

Eye tracking studies of reading are based on the idea that eye movement patterns (i.e., the number and durations of saccades, fixations, and regressions) reflect cognitive processes involved in reading (LaBerge & Samuels, 1974). Fixation durations are thought to reflect time spent executing comprehension processes, with longer fixations indicating longer processing times. Fixations allow for encoding and lexical access (the activation of words and their corresponding concepts from the visual characteristics of text), assignment of case roles (e.g., agent, recipient, location, time, action, state), and processing of words' semantic properties. In addition, they allow readers to integrate clauses and sentences and complete "wrap-up" processing, which occurs at the ends of phrases and sentences and allows readers to integrate information and reconcile any inconsistencies they have encountered. As a result, longer fixations suggest greater processing demands in these domains, which may be influenced by factors including word frequency, lexical ambiguity, and thematic importance. In this manner, eye movements are not the *source* of problems or skills in reading. Rather, they *reflect* readers' problems or skills in encoding and comprehending text (Rayner et al., 2006).

As fixation durations reflect processing demands, they can vary considerably across words in a passage. Readers do not simply fixate once per word; rather, they often skip short function words or predictable words and only fixate on approximately two thirds of the words they encounter. Furthermore, readers, particularly those who are less skilled, may fixate multiple times on a single word in order to allow for its processing, resulting in an uneven pattern of eye movements across a given passage. Thus, averaging time spent on fixations does not appropriately gauge processing time on single words. Instead, researchers commonly use measures of *first fixation duration* (the duration of the first fixation on a word, regardless of the number of fixations made on the word) and *gaze duration* (the sum of all of the fixations made on a word prior to movement to another word) to indicate lexical processing times. Researchers also examine probabilities of skipping or fixating words and the frequency of regressions out of a word to investigate the effects of textual variables (e.g., word frequency, predictability, etc.) on processing time. *Total fixation time* (the sum of all fixations, including regressions, on a word) is typically used to investigate higher-level text processing. In addition, by examining sums of these measures (aggregated across a given region of text), researchers can explore sentence- or discourse-level processing (Rayner et al., 2006).

Eye-tracking studies examining rereading. To date, no existing research has detailed changes in eye movements associated with RR intervention implementation. However, a number of researchers have examined differences in eye movements across multiple readings of the same passage. Given that this form of "rereading" underlies RR as an intervention method, previous eye-tracking studies of rereading provide fundamental information regarding the manner in which RR may impact reading behavior (i.e., eye movements). Considering the rather small number of studies that have examined eye movements during rereading of a text, this section will detail each of these studies individually.

Shebilske and Fisher (1980) were the first researchers to conduct a controlled study of eye movements during rereading. Although their work bears noting, more recent studies (e.g., Hyönä and Niemi, 1990) provide more conclusive, and sometimes contradictory, information regarding rereading, with differences possibly related to the small sample size employed by Shebilske and Fisher. In their study, Shebilske and Fisher asked 2 college graduates to read an excerpt from a tenth grade biology textbook twice in succession at a normal pace (i.e., as they would read an assigned reading). Results revealed that participants' reading rates were influenced by their familiarity with information in the passage as well as the importance of units of information in the passage. During the first reading, participants exhibited slower reading rates on important or unfamiliar ideas as compared to unimportant or familiar ideas. During the second reading, differences in reading rate on important versus unimportant meaning units became even greater. Specifically, participants spent increasingly more time reading important ideas and progressively less time reading unimportant ideas. Further analyses revealed that participants exhibited longer fixations and more regressions on important versus unimportant ideas, supporting the theory that the mechanics of reading (i.e., eye movements) reflect individuals' level of understanding (e.g., views of information, voluntary reading strategies) and cognitive processing of a given text. Shebilske and Fisher concluded that rereading primarily facilitates processing of unimportant or familiar ideas, as evidenced by readers' tendency to give progressively less visual attention to such units of text.

A later set of experiments by Hyönä and Niemi (1990) further supported the idea that eye movements reflect cognitive processing and demonstrated that rereading significantly impacts reading behavior and aids comprehension. Across the two experiments, undergraduate participants ($N = 11$ and $N = 18$, respectively) read a passage twice during one session and a third time one week later. Consistent with Shebilske and Fisher's (1980) findings, Hyönä and Niemi noted that important sentences were given slightly more visual attention (as evidenced by more fixations and longer fixation durations) than were unimportant sentences. However, in contrast with Shebilske and Fisher's findings, results from this study did not reveal a change in the ratio of visual attention given to important versus unimportant information as a result of rereading. Instead, Hyönä and Niemi determined that rereading mostly facilitates processing of difficult-to-comprehend sections of text. First pass analyses (analyses of eye movements on the "first pass" through each sentence, not taking into account any returns to earlier text locations) revealed that rereading led to increased familiarity with the surface features and content of the passage, reducing readers' need for fixation time (as indicated by decreases in average fixation duration per sentence and summed fixation time per sentence). In addition, analyses suggested that as comprehension was facilitated, increasing amounts of text were processed with each fixation, resulting in a decreased need for fixations in general (as indicated by a decrease in the number of fixations per sentence). Furthermore, results indicated that with repetition, regressions, which reflect cognitive processes, became less necessary due to facilitated comprehension. Finally, Hyönä and Niemi noted that the greatest facilitation (as indicated by decreased average fixation duration per sentence) occurred between the second and third readings of the passage. Overall, observed changes in eye movement parameters indicated that rereading increases familiarity with a given text, making processing more efficient and enhancing comprehension. Later research by Kaakinen and Hyönä (2007) replicated Hyönä and Niemi's results regarding fixation durations and regressions, supporting the conclusion that rereading facilitates textual processing, particularly integrative "wrap-up" processing at the ends of sentences.

Extending findings by Hyönä and Niemi (1990), Hyönä (1995) noted that, in addition to yielding increased familiarity with the surface features and content of texts, rereading impacts higher-level processing by allowing readers to construct and utilize mental representations of topical structures. Hyönä observed that, during their first reading of a passage, university students ($N = 18$) were sensitive to topic shifts, such that they spent more time reading and made more fixations on sentences that introduced new topics as compared to sentences that continued previously introduced topics (indicating increased processing time on topic-shift sentences). In contrast, this "topic-shift effect" was not manifested when participants read the passage a second or third time. Hyönä concluded that repetition allows readers to construct and use passage-level representations to enhance subsequent reading and processing of texts.

Expanding on previous studies demonstrating how rereading impacts sentence- and passage-level processing (Hyönä and Niemi, 1990; Hyönä, 1995), Raney and Rayner (1995) examined the effects of rereading on word-level processing of high- and low-frequency words. Building on past eye-movement research investigating the effects of word frequency and repetition (i.e., rereading) on the reading of individual words during lexical decision tasks (Forster & Davis, 1984; Norris, 1984; Rugg, 1990; Scarborough, Cortese, & Scarborough, 1977), Raney and Rayner sought to determine whether reading similar words as part of connected text would produce similar effects. Specifically, they investigated whether or not reading embedded words of different frequencies would yield an interaction between frequency and rereading effects, such that repetition effects would be larger for low-frequency words versus high-frequency words. In this study, 28 university students read expository passages concerning a broad range of topics (e.g., beer, animals) twice in succession. In order to assess word frequency effects while controlling for contextual meaning, Raney and Rayner selected pairs of high- and low-frequency synonyms to embed in the passages. Each passage contained one high-/low-frequency target word, and target words from the first reading were either maintained or replaced with their opposite-frequency synonyms for the second reading. Eye movements were analyzed across four conditions: low-frequency targets during both readings, low-frequency targets replaced by high-frequency targets, high-frequency targets during both readings, and high-frequency targets replaced by low-frequency targets. Global analyses examining rereading effects at the passage level revealed that rereading facilitated processing and increased reading speed, as indicated by decreases in the number and duration of fixations, increases in saccade length, and decreases in the number of regressions. Target-word analyses examining comparative processing of high- and low-frequency words revealed that frequency and rereading independently influenced reading time such that, overall, fixations were shorter for high-frequency words, but decreases due to repetition were similar for both low- and high-frequency words. Overall, results not only replicated previous findings concerning rereading's effects on passage-level reading behavior, but they also suggested that rereading does not eliminate frequency effects in reading. More specifically, findings indicated that readers do not simply speed up during rereading, but rather remain sensitive to variables that affect processing difficulty.

A later study by Schnitzer and Kowler (2006) yielded further support for the significant impact that repetition has on reading behavior (i.e., eye movements) but differed from previous studies (e.g., Hyönä & Niemi, 1990; Raney & Rayner, 1995) in its explanation of rereading effects. In this study, 5 undergraduate students were required to read texts drawn from news sources and college textbooks. Participants completed 11 sessions, each consisting of 20 reading trials (four texts read four times each and four texts read once). Texts were randomly ordered with the constraint that they could not be repeated in consecutive trials. During 6 of the 11 sessions, 4 presentations of repeated texts were slightly modified such that syntax was altered, synonyms were introduced, or spelling was changed. In these cases, participants were asked to report whether they detected any changes after each presentation of repeated text. Analyses investigating the effects of rereading on reading behavior indicated that the most consistent behavioral change underlying rereading was a reduction in the proportion of regressions. In contrast, there seemed to be only modest changes in saccade size and fixation duration patterns. Schnitzer and Kowler concluded that memory for text content (a result of repetition) does not significantly improve word recognition or alter saccadic movements. Instead, with repetition of a passage, readers find it less necessary to revisit previously read material because of familiarity with the text, and changes in reading time are primarily related to this facilitation rather than improved accuracy or increased size of forward movements. Schnitzer and Kowler's conclusions differ from previous findings indicating significant decreases in fixation duration as a function of rereading (Hyönä & Niemi, 1990; Raney & Rayner, 1995), possibly due to differences in the rereading procedures employed in each experiment (i.e., number of readings per passage, interval between readings).

Limitations of extant research. Although eye-movement studies involving rereading (Hyönä & Niemi, 1990; Kaakinen & Hyönä, 2007; Raney & Rayner, 1995;

Schnitzer & Kowler, 2006) provide valuable information regarding the impact of rereading on underlying reading behaviors, the existing research base is fully comprised of studies conducted with university students. As a result, generalization to younger and less-skilled readers is limited.

As eye movement differences do not simply account for differences in reading rate but rather reflect differences in cognitive processing (Rayner, 1986), it would be difficult to generalize conclusions about fluent readers to nonfluent readers, who process text in distinct ways (Faulkner & Levy, 1999). Furthermore, consistent with differences in the cognitive processing of fluent and nonfluent readers, research clearly demonstrates that the eye movements of skilled adult readers and beginning readers differ (Rayner, 1978, 1986; Rayner et al., 2006).

In addition to differences in the reading behavior of adults and children, rereading typically serves different purposes for adults and children. Whereas adults read a text repeatedly in order to gain greater depth of knowledge, repetition is generally utilized as a fluency-based intervention for children who are still learning to read. Fluency instruction is most likely to benefit students with instructional reading levels between Grades 1 and 3 (Therrien, Gormley, et al., 2006), and RR appears most promising for beginning readers (Carver & Hoffman, 1981). As a result, previous eye movement studies investigating rereading yield limited findings as to RR's effects within the population for which it is particularly suited. Furthermore, the "repeated reading" procedures utilized in extant eye-tracking studies differ significantly from the manner in which RR is typically implemented with students learning to read. Unlike RR, which tends to involve three or four consecutive readings of the same text, the procedures employed within eye-movement studies with adults involved two readings (Raney & Rayner, 1995; Shebilske & Fisher, 1980), a delayed third reading (Hyönä & Niemi, 1990; Kaakinen & Hyönä, 2007), or four non-consecutive readings (Schnitzer & Kowler, 2006). Studies specifically examining the reading behavior of children during three or four consecutive repetitions of the same text have yet to be conducted and could provide researchers with greater insight regarding how RR improves the fluency of children learning to read.

Purpose and Hypotheses

The current study sought to extend the findings of existing eye-movement literature to children and to apply these findings to the practical use of RR as an intervention method. Accordingly, it examines changes in children's reading behavior (as measured by eye movement parameters) as a function of four rereadings of the same text. By utilizing a participant sample of elementary students rather than undergraduates or college graduates, this thesis yields findings that have greater relevance to the population of students with whom RR is typically implemented. In addition, because it involves four consecutive readings of the same text, this study corresponds to the practical implementation of RR more closely than previous eye-movement studies of rereading. The current study focuses on the following questions:

1) Does rereading facilitate children's processing of written material, as indicated by changes in eye movements across consecutive readings of a single passage? If so, when does the greatest facilitation occur, and do these findings support the traditional use of three or four readings in RR implementation?

2) What specific behavioral changes (i.e., patterns of change in eye movements) underlie children's increased reading fluency? Specifically, does rereading impact children's word recognition, higher-level text processing, or both?
3) Is the facilitation effect of rereading sufficient to overcome children's sensitivity to variables affecting processing difficulty? Specifically, after rereading the same text, do children continue to have difficulty processing low-frequency words as compared to high-frequency words? Do observed behavior changes differ across high- and low-frequency target words?

It was hypothesized that rereading would result in significant changes in eye movements indicating facilitation of word recognition and higher-level processing of text. More specifically, it was hypothesized that participants would exhibit significant behavioral changes indicating facilitated early processing (i.e., decreases in fixation durations) as well as facilitated comprehension (i.e., fewer regressions, fewer fixations). In addition, it was hypothesized that participants would remain sensitive to word frequency effects such that facilitation through rereading would be consistent across high- and low-frequency target words.

Table 1

Differences in Eye Movements of Skilled and Beginning Readers

Parameter	Skilled Adult Readers	Unskilled Readers/Children
Number of fixations	Skip short function/predictable words; fixate on approximately two thirds of words they encounter	Fixate on almost every word and make multiple fixations on some words
Fixation durations	200-250 ms	300 ms or longer
Length of forward saccades	7-9 character spaces	Considerably shorter saccades
Frequency of regressions	10-15% of time	Up to 30% of eye movements
Size of perceptual span	Larger; allows skilled readers to acquire information from words that they have not yet identified	Smaller; unskilled readers utilize information beyond the fovea (central area of high acuity) less effectively

(Rayner, 1978, 1986; Rayner et al., 2006)

CHAPTER 2

METHOD

Participants and Setting

Participants were 43 second-grade students with a mean age of 8 years, 2 months (range = 7 years, 4 months to 8 years, 11 months). Of these 43 children, 21 were female and 22 were male. The majority of students were Caucasian (90%), with the remaining students being identified as either Hispanic (5%) or multiracial (5%). All students were native English speakers drawn from two elementary schools serving K-5 students and one primary school serving K-2 students all located in the southeast. Across the school district, 22% of students were eligible to receive free or reduced-price meals. Students with learning disabilities were excluded from the study due to reasons associated with the larger study for which these data were collected.

All participants were administered four reading subtests from the Woodcock-Johnson Tests of Academic Achievement – Third Edition, Form A (WJ-III ACH; Woodcock, McGrew, & Mather, 2001). All participants' performance across subtests (as quantified by standard scores) fell within the Low Average-Very Superior range (range = 87-139). The average Letter-Word Identification standard score was 112, with a range of 99-130. The average Reading Fluency standard score was 111, with a range of 99-139. Passage Comprehension scores ranged from 87 to 124, with an average score of 104, whereas Word Attack scores ranged from 95 to 134, with an average score of 108. Thus, average standard scores for all subtests remained in the Average to High Average range.

Of note, one participant's scores were drawn from testing results about two months prior due to the fact that this student's scores at the time of data collection were not believed to accurately reflect her level of achievement based upon previous performance. The student's previous testing results (standard scores of 99, 102, 97, and 100 on the four WJ-III subtests) suggest that this student suitably resembles the other participants sampled in terms of reading achievement.

Apparatus

Eye movements were measured with an SR Research EyeLink 1000 system. The system uses an Ethernet connection between the eyetracker and a display computer (Toshiba Satellite A660 series laptop) for real-time transfer of eye movement data. The desktop-mounted EyeLink 1000 has a sampling rate of 1000 Hz, resolution of 0.01 degrees of visual angle, and a range of 32 degrees horizontally and 25 degrees vertically. By default, eye movements were recorded from the right eye, but tracking issues occasionally necessitated recording from the left eye. Although eye movements were recorded from one eye, viewing was binocular.

Text was displayed on a 19-inch (48.26 cm) ViewSonic VG930m LCD monitor. The monitor was adjusted to a comfortable level of brightness and remained constant throughout the experiment. The experiment was conducted in a dimly illuminated room in each participant's school. The brightness of the room was adjusted occasionally to minimize track losses.

A chin rest was used to minimize participants' head movement while reading. In addition, participants were provided with a Microsoft Sidewinder Plug and Play game pad, which allowed them to answer questions and to indicate when they were finished reading displayed text.

Materials

The text was an experimenter-developed narrative children's story consisting of 162 words in 16 sentences. The story was developed using examples from second- and third-grade-level reading textbooks and was designed to include a distinct beginning, middle, and end and a conflict or challenge. The reading level of the passage was 3.18, according to the Spache readability formula. An example of the text is provided in the Appendix. Embedded in the text were five target words of low frequency and five target words of high frequency. Low-frequency words had a frequency of U = 10 or less, and high-frequency words had a frequency of U = 50 or above, with U indicating the number of instances of that word per million running words, according to *The American Heritage Word Frequency Book* (Carroll, Davies, & Richman, 1971). The target words and their frequencies are presented in Table 2.

Text was seen as black against a white background and was formatted in standard upper- and lowercase letters and 20-point Times New Roman font. The reading passage was displayed as one page of 1.5-spaced text occupying 13 lines, with a maximum line width of 87 characters.

Procedure

The current experiment was part of a larger randomized controlled study in which participants received 9 weeks of one-to-one reading intervention. The current data were collected following completion of the intervention period along with a larger set of posttest measures. Given that all students completed similar pretest measures preceding the intervention period, all participants had prior experience with reading passages from a computer screen while having their eye movements recorded.

Eye tracking was conducted individually. Participants were seated in a chair approximately 50-55 cm from the computer monitor, and a chin rest was used to stabilize the head and minimize movement. As experimenters made slight adjustments to the chin rest and camera (e.g., changing the height of the chin rest, adjusting image thresholds), participants were informed that they would be reading stories from the display monitor while a camera recorded their eye movements. They were also instructed on how to use a game pad to indicate when they were finished reading and to answer comprehension questions. Before beginning the reading trials, the eye tracker was calibrated for each participant. Due to participants' young age, experimenters explained the calibration process as a "game" in which participants needed to follow dots with their eyes. Calibration was conducted using a nine-point calibration grid extending across the entire display screen. Upon successful calibration, another nine-point grid was used to validate the accuracy of tracking. After validation, participants completed a practice trial, which acquainted them with reading information from the monitor and using the game pad to communicate when they were finished and to answer comprehension questions. Following the practice trial, participants were reminded that they would next complete a series of trials requiring them to read passages silently from the display. They were instructed to do their "best reading" and to try to read each word. They were also told that they would not receive any help from experimenters and that they would be asked to answer comprehension questions after each reading.

After providing instructions, experimenters repeated the calibration process described above before proceeding with the reading trials. Before each reading trial, a fixation dot was displayed in the upper left corner of the display (where the first line of text would be shown). Experimenters asked the participants to fixate on the dot and presented a reading passage once fixation was satisfactory. After reading the passage, participants pressed a key on the game pad, which cleared the passage and presented a comprehension question. Participants pressed another key on the game pad to answer the question. Participants were not informed whether their answers to comprehension questions were correct. After each question was answered, another fixation dot appeared signaling the beginning of the next trial.

Although the current paper examines eye movement data collected during rereading, participants completed two reading trials prior to beginning the rereading trials. After completing these two trials, participants were given a separate set of instructions explaining that they would read the same story four times in succession, and that, after each reading, they would be presented with a different comprehension question and informed how long each trial took. They were instructed to read the entire story each time and to press a key when they were finished. Participants were not informed whether their answers to comprehension questions were correct.

Each session (including practice trials, two reading trials, and four rereading trials) took approximately 15-20 min. Head movement and other tracking issues occasionally necessitated repetition of the calibration process during the session.

Table 2

Target Word Frequencies

High-frequency		Low-frequency	
Word	U	Word	U
head	439.00	flecks	0.47
tail	109.64	supermarket	3.94
wings	83.27	cartons	3.70
ocean	134.14	incident	8.73
woods	99.19	refuge	6.00

CHAPTER 3

RESULTS

Two types of analyses were conducted: global analyses of reading behavior at the passage level (i.e., eye movements during reading of the entire passage) and target-word analyses based on reading of embedded high- and low-frequency target words. For both types of analyses, repeated measures analyses of variance (ANOVAs) were used to examine the effects of rereading on eye-movement parameters during all four readings of the passage. Statistically significant main effects of rereading were followed up with Bonferroni-corrected comparisons evaluating differences in eye movements between all pairs of consecutive readings (i.e., first and second readings, second and third readings, and third and fourth readings). Significant pairwise differences between readings are detailed below and indicated in Table 3 and Figures 1-4 by asterisks and patterned data points, respectively. Additional target-word analyses (described below) were used to investigate the impact of word frequency on changes in eye movements associated with rereading. For all analyses, fixations shorter than 120 ms or longer than 800 ms were omitted, as they are thought to reflect track losses; these cutoffs are generally consistent with prior research examining changes in reading behavior (e.g., Raney & Rayner, 1995). Effect sizes can be interpreted according to values of partial eta squared that correspond to Cohen's (1988) benchmark *f* values for small, medium, and large effects (i.e., η_p^2 = .0099, .0588, and .1379, respectively).

Due to track losses (loss of eye position recording, occasionally due to participant head movements) and technological issues (e.g., computer freezing), eye-movement data was excluded for 5 participants. As a result, the following analyses are based on a participant sample size of $N = 38$. Within this smaller sample, 1 participant completed only two trials that could be analyzed, and another participant completed only one trial that could be analyzed.

Global Analyses

Global measures averaging eye-movement parameters across all words in the passage included overall reading time (as indicated by summed fixation time), first fixation duration, gaze duration, total fixation time, number of inter-word regressions, and average number of fixations per word. Means and test statistics for each global measure are presented in Table 3.

Analysis of overall reading time (based on summed fixation time across the entire passage) indicated that, as expected, the amount of time required by participants to read the passage significantly decreased across rereadings ($\eta_p^2 = .61$). Pairwise comparisons revealed significant decreases in overall reading time between the first and second readings ($p < .001$) and the second and third readings ($p = .002$) of the passage, but indicated a nonsignificant decrease in reading time between the third and fourth readings ($p = 1.000$).

Analyses of all other global measures revealed that decreased reading time resulted from multiple underlying changes in reading behavior. Across all global measures, results indicated significant change in the expected direction across participants' four readings of the passage. First, measures thought to represent early lexical processing reflected facilitation due to rereading. That is, average first fixation duration ($\eta_p^2 = .12$) and gaze duration ($\eta_p^2 = .47$) both shortened as a function of rereading. Second, measures associated with higher-level textual processing also indicated significant rereading effects. Specifically, rereading yielded significant decreases in average total fixation time ($\eta_p^2 = .60$), number of inter-word regressions ($\eta_p^2 = .34$), and average number of fixations per word ($\eta_p^2 = .56$). Pairwise comparisons suggested that rereading had immediate significant effects on textual processing. That is, gaze duration ($p < .001$), total fixation time ($p < .001$), number of inter-word regressions ($p = .016$), and average number of fixations per word ($p < .001$) decreased significantly between the first and second readings. In addition, measures associated with higher-level textual processing displayed significant effects of continued rereading; average number of fixations per word decreased significantly between the second and third readings ($p = .032$), and total fixation time ($p = .016$) and number of inter-word regressions ($p = .011$) decreased significantly between the third and fourth readings.

Target-Word Analyses

Target-word measures included first fixation duration, gaze duration, and total fixation time on target words and the average number of fixations per target word. Means for each target-word measure are presented in Figures 1-4. Significant interactions between rereading and word frequency were followed up with analyses of rereading effects on high- and low-frequency targets (i.e., one-way ANOVAs and follow-up pairwise comparisons for significant effects) and simple analyses (i.e., *t*-tests) investigating frequency effects before and after rereading (i.e., during participants' first and fourth readings of the passage). Of note, alternative statistical tests (i.e., Welch's *F*) of frequency effects within the first reading and within the fourth reading were occasionally examined due to violation of the assumption of equal variances. Alternative tests yielded results similar to those reported with regard to statistical significance of findings.

First fixation duration. Analyses of first fixation duration on the target words revealed that there was no interaction between rereading and word frequency, $F(3, 102) = .81$, $p = .490$, $\eta_p^2 = .02$. Furthermore, there was no significant main effect of rereading; first fixation duration across high- and low-frequency target words decreased but did not significantly change across rereadings, $F(3, 102) = .96$, $p = .414$.

Although rereading did not significantly impact first fixation duration on target words, there was a main effect of word frequency, $F(1, 34) = 5.28$, $p = .028$, $\eta_p^2 = .13$. Follow-up paired samples *t*-tests of frequency effects indicated that first fixation duration was significantly shorter for high-frequency targets as compared to low-frequency targets during the first reading, $t(37) = 2.20$, $p = .034$, but not during the final reading, $t(34) = .89$, $p = .381$. These results suggest that rereading allowed participants to overcome the effect of word frequency on first fixation duration.

Gaze duration. Analyses of gaze duration on the target words revealed a significant rereading × frequency interaction, Wilks' Lambda = .67, $F(3, 32) = 5.35$, $p = .004$, $\eta_p^2 = .33$. Follow-up one-way analyses of rereading effects indicated that gaze duration across high-frequency target words did not differ significantly across readings, $F(3, 102) = .38$, $p = .770$. In contrast, rereading yielded significant decreases in gaze duration across low-frequency target words, Wilks' Lambda = .64, $F(3, 33) = 6.17$, $p = .002$, $\eta_p^2 = .36$. In addition, pairwise comparisons revealed that gaze duration on low-frequency targets decreased significantly between the first and second readings (p = .020) and second and third readings (p = .025) as well. Thus, rereading appeared to continuously facilitate processing of low-frequency target words but had no significant effect on processing of high-frequency target words.

Additional follow-up analyses examining frequency effects during the first and fourth reading trials revealed that, although rereading yielded significant decreases in gaze duration on low-frequency target words, readers continued to fixate longer on low-frequency targets as compared to high-frequency targets following rereading. Specifically, word frequency significantly impacted gaze duration during the first reading, $t(37) = 5.24$, $p < .001$, and during the fourth reading, $t(34) = 3.03$, $p = .005$.

Total fixation time. Analyses of total fixation time on the target words revealed a significant rereading × frequency interaction, $F(3, 102) = 10.31$, $p < .001$, $\eta_p^2 = .23$. Follow-up one-way analyses of rereading effects indicated that, although total fixation time across high-frequency target words decreased by 81.05 ms across rereadings, this difference was not significant, $F(3, 102) = 1.80$, $p = .153$. In contrast, rereading yielded significant decreases in total fixation time across low-frequency target words, $F(3, 105) = 13.98$, $p < .001$, $\eta_p^2 = .29$. Pairwise comparisons revealed that decreases in total fixation time between the first and second readings approached statistical significance (p = .058), and total fixation time on low-frequency targets decreased significantly between the second and third readings (p < .001). Accordingly, rereading appeared to facilitate processing of low-frequency target words but had no significant effect on processing of high-frequency target words.

Additional follow-up analyses examining frequency effects during the first and fourth reading trials revealed that, although rereading yielded significant decreases in total fixation time on low-frequency target words, readers continued to fixate longer on low-frequency targets as compared to high-frequency targets following rereading. Specifically, word frequency significantly impacted total fixation time during the first reading, $t(37) = 5.96$, $p < .001$, and during the fourth reading, $t(34) = 2.88$, $p = .007$.

Average number of fixations per word. Analyses of the average number of fixations per target word revealed a significant rereading × frequency interaction, Wilks' Lambda = .65, $F(3, 33) = 5.90$, $p = .002$, $\eta_p^2 = .35$. Follow-up one-way analyses of rereading effects indicated that rereading yielded significant decreases in average number of fixations made on both high- and low-frequency targets. Although the average number of fixations per high-frequency target word decreased significantly across rereadings, $F(3, 105) = 3.21$, $p = .026$, $\eta_p^2 = .08$, pairwise comparisons revealed that it did not significantly change between any two consecutive reading trials (p-values = .215-.541). The average number of fixations per low-frequency target word also decreased significantly across rereadings, Wilks' Lambda = .54, $F(3, 33) = 9.49$, $p < .001$, $\eta_p^2 = .46$, as well as between the first and second readings ($p = .047$) and the second and third readings ($p = .004$). Thus, while rereading appeared to facilitate processing of both high- and low-frequency target words, its impact on the processing of low-frequency words seemed to be more immediate.

Additional follow-up analyses examining frequency effects during the first and fourth reading trials revealed that, although rereading yielded significant decreases in the average number of fixations per word on both high- and low-frequency target words, readers continued to fixate more times on low-frequency targets as compared to high-frequency targets following rereading. Specifically, word frequency significantly impacted the average number of fixations per word during the first reading, $t(37) = 5.58$, $p < .001$, and during the fourth reading, $t(35) = 2.79$, $p = .008$.

Table 3

Summary of Global Eye-Movement Parameters across Readings

Measure	Reading 1 *M (SD)*	Reading 2 *M (SD)*	Reading 3 *M (SD)*	Reading 4 *M (SD)*
Overall reading time in seconds				
$F(3, 34) = 17.44$, $p < .001$[a]	79.27 (25.05)	68.91 (24.02)*	59.69 (22.29)*	58.11 (20.13)
First fixation duration (ms)				
$F(3, 105) = 4.90$, $p = .003$	280.63 (35.91)	274.99 (34.54)	271.30 (31.31)	271.14 (33.29)
Gaze duration (ms)				
$F(3, 33) = 9.78$, $p < .001$[b]	411.84 (78.47)	382.56 (64.60)*	373.59 (63.62)	370.29 (53.19)
Total fixation time (ms)				
$F(3, 33) = 16.43$, $p < .001$[c]	583.72 (155.36)	521.08 (122.33)*	498.91 (108.59)	466.07 (88.76)*
Inter-word regressions (#)				
$F(3, 105) = 18.35$, $p < .001$	0.33 (0.16)	0.29 (0.13)*	0.27 (0.13)	0.24 (0.12)*
Average # of fixations per word				
$F(3, 33) = 13.85$, $p < .001$[d]	1.76 (0.47)	1.57 (0.42)*	1.40 (0.40)*	1.35(0.39)

[a]Wilks' Lambda = .39. [b]Wilks' Lambda = .53. [c]Wilks' Lambda = .40. [d]Wilks' Lambda = .44

*Significant pairwise differences between readings (i.e., between the indicated reading trial and the trial preceding it)

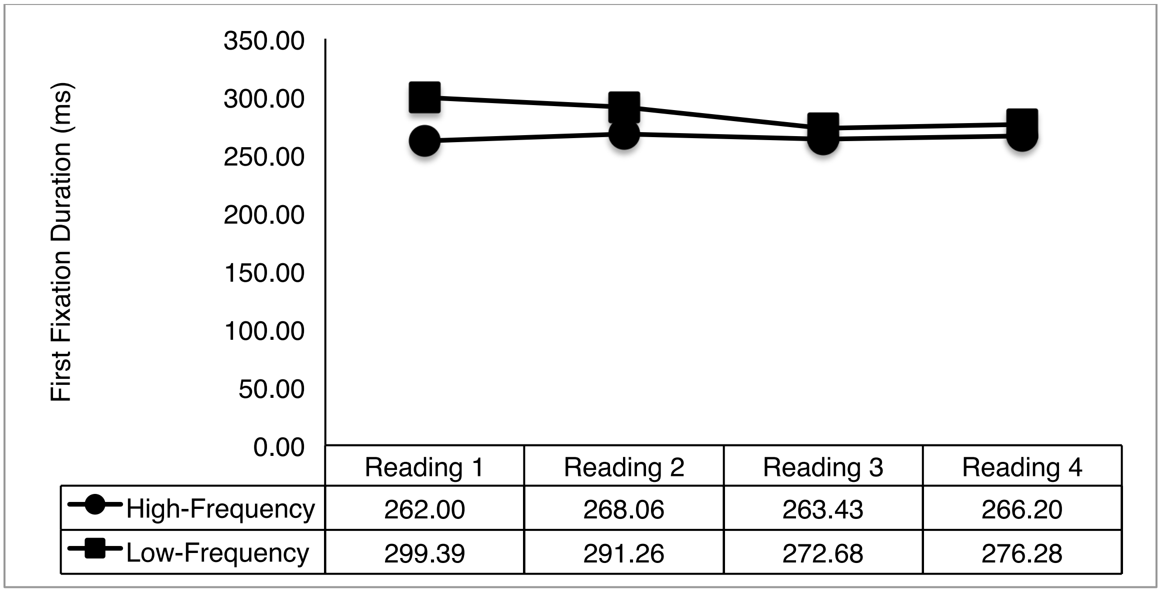


Figure 1. Average first fixation duration as a function of rereading and target word frequency.

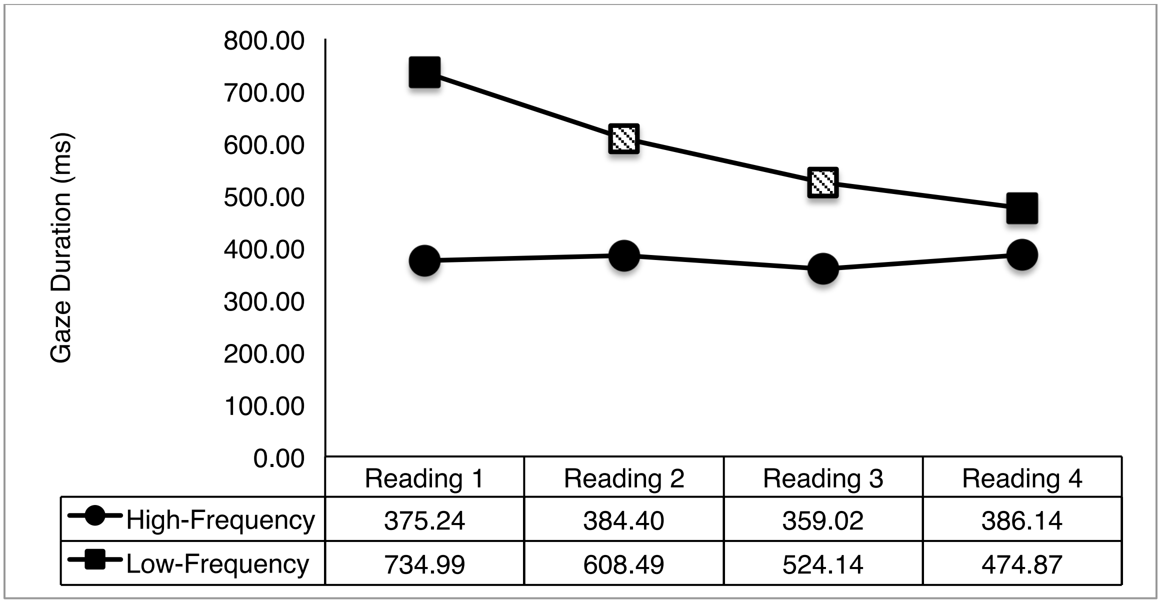


Figure 2. Average gaze duration as a function of rereading and target word frequency. Patterned data points indicate significant pairwise differences between readings (i.e., between the indicated reading trial and the trial preceding it), $p < .05$.

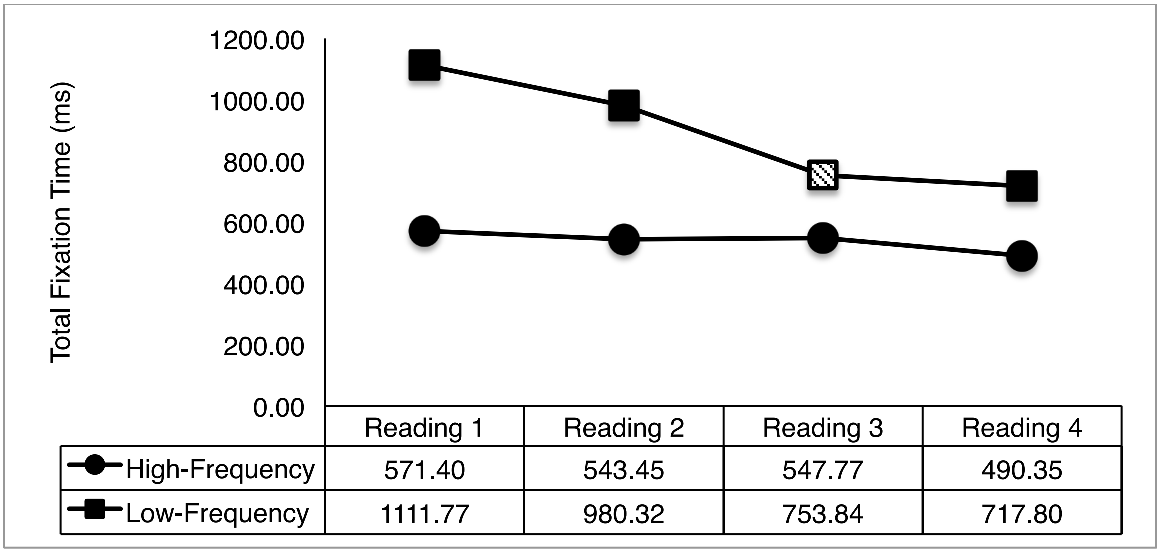
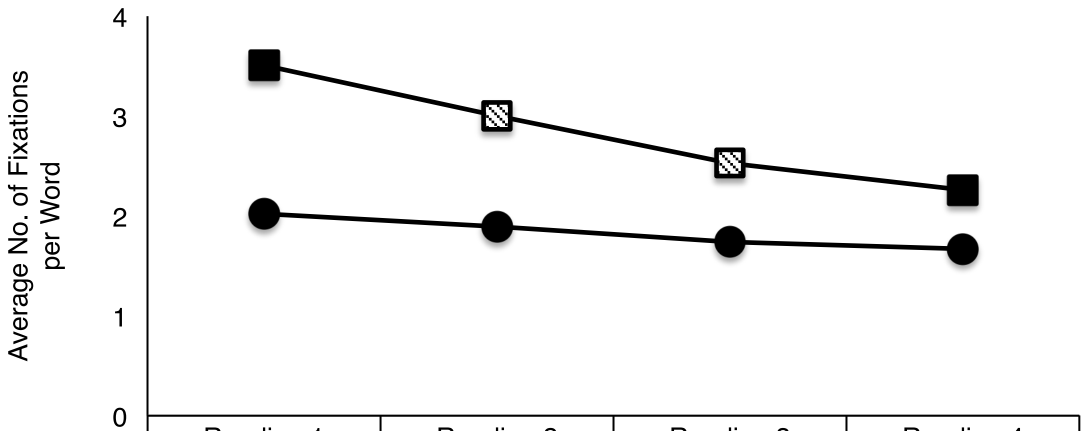


Figure 3. Average total fixation time as a function of rereading and target word frequency. Patterned data points indicate significant pairwise differences between readings (i.e., between the indicated reading trial and the trial preceding it), $p < .05$.



	Reading 1	Reading 2	Reading 3	Reading 4
High	2.02	1.89	1.74	1.67
Low	3.51	3.00	2.53	2.26

Figure 4. Average number of fixations per word as a function of rereading and target word frequency. Patterned data points indicate significant pairwise differences between readings (i.e., between the indicated reading trial and the trial preceding it), $p < .05$.

CHAPTER 4

DISCUSSION

Numerous empirical studies support implementation of RR as an effective reading fluency intervention (e.g., Kuhn, 2004; Teigen et al., 2001; Weinstein & Cooke, 1992) but do not identify or explain the specific mechanisms of change that underlie RR. Although research suggests that RR results in improvement as measured by global indicators of reading fluency (e.g., WRCM), commonly used measured of fluency fail to explain *how* RR facilitates improved fluency (i.e., how it impacts specific reading behaviors). Previous eye-movement studies with adults (Hyönä & Niemi, 1990; Kaakinen & Hyönä, 2007; Raney & Rayner, 1995; Schnitzer & Kowler, 2006) provide valuable information regarding changes in reading behavior associated with rereading, but findings from these studies have limited generalizability to elementary students. Furthermore, rereading methods in extant studies differed significantly from typical implementation of RR with elementary students. Thus, the primary purpose of the current study was to examine changes in elementary students' reading behavior as a function of four consecutive readings of the same text.

Consistent with previous research demonstrating that rereading results in increased reading rates (e.g., Ardoin, McCall, & Klubnik, 2007; Martens et al., 2007), analyses of overall reading time (based on summed fixation time across the entire text) indicated that participants required progressively less time to read the passage after each rereading. The greatest facilitation occurred between the first and second readings, but a statistically significant decrease in reading time also occurred between the second and third readings. Together, these findings suggest that RR has an immediate significant impact on reading rate but, in line with past research on RR (Dowhower, 1989; Samuels, 2006a; Samuels, 2006b; Therrien, Gormley, et al., 2006), may require three readings to produce optimal results. Finally, in light of a nonsignificant decrease in reading time between the third and fourth readings, additional readings may yield further improvement but may be unnecessary for providing readers with the full benefits of RR.

Additional global analyses of eye movements across the entire text suggested that rereading impacts multiple reading behaviors. Specifically, measures associated with early lexical processing (i.e., first fixation duration and gaze duration) and higher-level textual processing (i.e., total fixation time, number of inter-word regressions, and average number of fixations per word) reflected facilitation due to rereading. Consistent with previous eye-movement studies linking rereading to decreases in average fixation duration, fixation count, and number of regressions (Hyönä & Niemi, 1990; Kaakinen & Hyönä, 2007; Raney & Rayner, 1995; Schnitzer & Kowler, 2006), participants in the current study spent significantly less time actively fixating on words (on average), made significantly fewer fixations per word, and revisited previously fixated material significantly fewer times after four consecutive readings of the same passage. Taken together, these results suggest that RR improves the fluency of beginning readers by decreasing the amount of time they spend actively focusing on words *and* by reducing their need to reconsider previously read content. Consistent with analyses of overall reading time, pairwise comparisons across readings revealed that, although rereading appears to have immediate effects on reading behavior (i.e., significant effects after a single rereading), reading text a third and fourth time (as is typical in RR) results in further facilitation.

Contrary to previous findings indicating similar rereading effects for high- and low-frequency words (Raney & Rayner, 1995), target-word analyses revealed significant interactions between rereading and word frequency on two measures of reading behavior (i.e., gaze duration and total fixation time). Specifically, participants' fixation time on low-frequency target words decreased significantly over time, whereas fixation time on high-frequency words did not change significantly. In addition, although rereading resulted in a decreased need for fixations on both types of target words (as evidenced by fewer fixations per word on low- *and* high-frequency targets), significant effects were more immediate on low-frequency words. Thus, when implemented with beginning readers, RR may improve reading fluency by primarily facilitating reading of low-frequency words.

Although rereading primarily facilitated processing of low-frequency target words, analyses revealed that, consistent with earlier findings by Raney and Rayner (1995), participants seemed to remain sensitive to the frequency of target words after reading the passage four times. Specifically, although rereading yielded significant decreases in gaze duration, total fixation time, and average number of fixations per word on low-frequency target words, readers continued to make more fixations per word and fixate longer on these words as compared to high-frequency targets. These results support Raney and Rayner's conclusion that rereading does not eliminate frequency effects in reading. Thus, like adult readers, beginning readers may continue to have relative difficulty reading low-frequency and unfamiliar words as compared to high-frequency and familiar words despite improvements related to RR.

Whereas participants' gaze duration, total fixation time, and average number of fixations per word on low-frequency target words significantly decreased across rereadings, decreases in first fixation duration on these same words were not statistically significant. These results differ from earlier findings by Raney and Rayner (1995), potentially suggesting another means by which rereading may facilitate the processing of beginning and adult readers in distinct ways. Specifically, whereas adult participants in Raney and Rayner's study made shorter first fixations on target words during their second reading of a text (as compared to their first reading), participants in the current study devoted a consistent amount of time to initial fixations on target words even after rereading.

Differences in the manner in which adults and children approach rereading may help explain inconsistencies between the current results and Raney and Rayner's (1995) findings. Whereas adults typically employ rereading as a method for gaining greater depth of knowledge, beginning readers practice RR as a means for developing automaticity with basic reading skills. Accordingly, repeated practice appears to impact the reading behavior of these groups in different ways. Reading fluency allows readers to recognize individual words and phrases without conscious attention and to focus on semantic processing (i.e., understanding the meaning) of a text (Bos, 1982; Samuels, 1979, 2006a). Thus, as already fluent adult readers reread material, increased familiarity with passage content allows them to devote less attention to the processing of individual words (Hyönä and Niemi, 1990) in a top-down manner. In contrast, unskilled readers who lack fluency (including children) employ a bottom-up approach to reading and concentrate on word-level processing rather than higher-level processing of textual meaning (Bos, 1982; LaBerge & Samuels, 1972; Therrien, Gormley, et al., 2006). Thus, although rereading reduces the amount of conscious attention that these readers must allocate to word recognition (Samuels, 1979, 2006a, 2006b), they remain focused on reading at the individual word level.

Current results and earlier findings by Raney and Rayner (1995) are consistent with aforementioned differences in the rereading behavior of skilled and unskilled readers. Changes in eye movements among adult participants in Raney and Rayner's study (i.e., significant decreases in first fixation duration, gaze duration, and total fixation time on target words) reflect the manner in which rereading facilitates automatic word recognition and allows adult readers to devote less initial and overall visual attention to individual words. In contrast, results from current target-word analyses (i.e., a lack of significant changes in first fixation duration but significant decreases in gaze duration and total fixation time on target words) suggest that unskilled readers continue to focus on word recognition (i.e., continue to dedicate initial attention to individual words) but spend less additional time processing individual words following rereading. Overall, results from both studies suggest that RR improves the fluency of skilled and unskilled readers but via different mechanisms; in line with LaBerge and Samuels's (1974) theory of automaticity, RR allows beginning readers to recognize words more efficiently (i.e., execute basic reading skills more competently) and enables already skilled readers to focus on passage-level meaning rather than word recognition (i.e., devote less cognitive resources to basic reading skills altogether).

Skilled and beginning readers' tendencies to focus on different aspects of reading may also explain differences between Raney and Rayner's (1995) findings and current results regarding interactions between effects of rereading and word frequency. Research suggests that RR primarily facilitates passage-level transfer (versus word-level transfer) for fluent readers (Faulkner & Levy, 1999), supporting the idea that RR increases skilled readers' familiarity with passage-level meaning and thus reduces their need to focus on conscious recognition of individual words. This may explain Raney and Rayner's findings, which revealed a lack of interactions between rereading and word frequency. Specifically, skilled adult readers' focus on context and meaning during RR may lead to significant decreases in the amount of visual attention they devote to individual words, regardless of frequency. In contrast, in line with research showing that RR primarily facilitates word-level transfer for nonfluent readers (Faulkner & Levy, 1999), current findings indicate that RR significantly reduces the amount of *additional* (as opposed to initial) processing time required by individual words. Accordingly, greater facilitation due to RR would be expected for words that typically require greater processing time (e.g., longer and multiple fixations), such as unfamiliar and low-frequency words. Thus, current findings of interactions between rereading and word frequency seem to relate directly to beginning readers' focus on word recognition rather than passage-level meaning. Interestingly, this focus on word-level processing corresponds to that employed by adult participants in lexical decision studies (e.g., Rugg, 1990) and may explain similarities between their results and current findings (i.e., the common finding of significant interactions between rereading and word frequency).

Limitations

Current findings should be considered with caution in light of several limitations. Most significantly, rereading procedures utilized in the current study differed from typical implementation of RR in multiple ways. First, as the current study involved silent reading, participants' reading accuracy was not monitored. In addition, although rereading procedures in the current study closely corresponded to typical implementation of RR by involving four consecutive readings of the same text, they did not include other integral components of RR including immediate error correction and feedback.

A second limitation of the current study is the high-achieving nature of the participant sample. Specifically, generalizability of current findings to school-age children may be limited by the fact that participants in the current study exhibited higher levels of reading achievement than would be expected for students receiving RR in an educational setting. However, given that participants were young students capable of developing greater reading fluency, current findings have greater relevance to implementation of RR than previous research with skilled adult readers.

Third, results regarding word frequency should be interpreted with caution due to the fact that high- and low-frequency target words were not matched in word length. As word length has been shown to impact probability of fixation (Just & Carpenter, 1980; Rayner, 1983), current findings associated with word frequency may reflect effects of word length. However, independent analyses of reading behavior on high-frequency words and on low-frequency words are not limited by this possibility. In addition, target words utilized in the current study are consistent with the well-recognized fact that high-frequency words tend to be shorter on average than low-frequency words (Zipf, 1949).

Summary and Implications

Results of the current study provide further support for the benefits of RR and indicate that RR facilitates improved fluency for beginning readers by decreasing the amount of time they spend processing individual words and by reducing their need to reconsider previously read content. This suggests that RR not only improves word recognition and sight word acquisition but also potentially impacts higher-level comprehension processes. In addition, the current study provides insight as to how to implement RR interventions most effectively; specifically, in line with past research on RR (Dowhower, 1989; Samuels, 2006a; Samuels, 2006b; Therrien, Gormley, et al., 2006), results demonstrate optimal facilitation after three or four consecutive readings of a passage. Most importantly, results of the current study differ from previous findings with regard to two key conclusions. First, they indicate that RR improves the fluency of beginning readers by primarily facilitating their reading of low-frequency words. Second, RR does not obviate beginning readers' need to devote visual attention to words they encounter but does significantly reduce the amount of *additional* processing time that those words require. That is, beginning readers who have completed RR continue to focus on word-level processing (i.e., continue to devote considerable visual attention to words they encounter) but can devote less overall attention to each individual word with repeated practice. These results suggest that perceived improvements in students' reading fluency (typically indicated by increased WRCM) may stem primarily from improved recognition of low-frequency or unfamiliar words and thus may differ across passages consisting of different content and vocabulary. In addition, RR may be most beneficial to readers when implemented using passages involving low-frequency or unfamiliar words rather than familiar vocabulary.

Despite aforementioned limitations, the current study provides valuable information regarding the manner in which RR improves the fluency of beginning readers. By examining the eye movements of school-age children during four consecutive readings of the same text, this study builds on past research from multiple fields (e.g., cognitive literature, eye-movement studies, and reading research) and reveals key differences between the reading behaviors of adults and unskilled readers. Furthermore, results of this study highlight the benefits of using eye-tracking procedures when examining the impact of intervention on students' reading. By simply assessing the outcome of changes in reading behavior as a function of intervention (e.g., WRCM) researchers may attribute changes in student performance to a broad set of behaviors when improvements are actually specific to certain words or behaviors.

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APPENDIX

Experimenter-Developed Reading Passage

Emma is the most colorful dragon you will ever see. She has yellow flecks on her pink body. Her head is deep purple but her tail is green. Her wings are fire red with ocean blue spots.

Emma's best buddy is Queen Kathy. They met a long time ago when Queen Kathy helped Emma.

It began, years ago, when Emma flew to Dee's. Dee's is the only supermarket that sells cartons of Emma's favorite food, Dragon Pops. Dee's new owner did not like dragons. He would not order the Dragon Pops for her. This made her feel sad. She went to the woods for refuge and cried.

When Queen Kathy saw Emma crying she asked what incident happened, and Emma told her. Queen Kathy told Emma that because she is Queen, she is the boss of all the stores. She told the new owner to order Dragon Pops and he did. Ever since then Queen Kathy and Emma have been best buddies.