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# Reading Rate Acceleration: How fast is too fast?

Matthew D. Carter, Ph.D.
Valdosta State University
mdcarter@valdosta.edu

Marianna M. Walker, Ph.D.
East Carolina University

Monica S. Hough, Ph.D.
Florida International University

Kevin O'Brien, Ph.D.
East Carolina University

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Abstract

Studies show that individuals who read digital text approximately 12% faster than their typical reading rates improve oral literacy abilities. However, previous studies have failed to systematically vary the rate increases despite the fact that technology allows for such an investigation. The purpose of this study was to investigate the effects of increased oral reading rates on the literacy skills of high school students. Twenty students with typical reading abilities and sixteen students who presented with reading difficulties participated in this study. Participants completed four oral reading comprehension tasks in which digital text was scrolled across a computer screen at increasing rates followed by the answering of comprehension questions. Both word reading and comprehension accuracy improved during the accelerated conditions, although the most rapid acceleration conditions did not yield improvements in either skill. It is recommended that individualized accelerated reading tasks be considered for implementation into electronic oral reading tasks.

**Keywords**: reading disorders, acceleration phenomenon, dyslexia, reading comprehension

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Literacy is an extremely complex ability that is not served by a singular neural organizational network. Instead, it is subserved by a conglomerate of cognitive systems which must operate in conjunction with each other in order to achieve the ultimate purpose of reading: comprehension. In order to comprehend what is read, the reader must encounter and analyze words in their written form on the screen or page which eventually must lead to the activation of the semantic properties of both singular units (words) and larger units (connected text). Multiple stages of linguistic and non-linguistic processing must occur in fractions of seconds while the reader constantly updates all available levels of information. The fluent reader remarkably completes these complex mental gymnastics at a nearly subconscious level. Despite the high level of cognitive processing that literacy requires many children learn to engage in this process effortlessly in a relatively short amount of time. However, there are many children, and later on adults, who do not achieve this desired level of automaticity and struggle with the execution of this skill. Deficiencies in a singular component process can lead to cascading negative effects which can limit the effectiveness by which one reads (Kamhi & Catts, 2012). Accelerating the rate at which individuals read is an effective method of improving literacy abilities as revealed by both standardized and non-standardized reading assessments. However, the parameters of this remedial method have not been well established. The purpose of this study was to further investigate the utilization of reading rate acceleration and its effects on literacy abilities.

## Literature Review

Reading is an intricate process, which requires both bottom-up word recognition processes as well as top-down comprehension processes (Verhoeven & Perfetti, 2008). Successful word recognition occurs when the orthographic representation of a word activates the stored concept associated with that word within the individual's lexicon. Much research

has been devoted to the investigation of what information is actually represented in the lexicon and how that information is organized and accessed (see Carter, Hough, Rastatter, & Stuart, 2011 for a review). However, it is agreed upon that the efficiency by which the lexicon can be accessed can highly impact the ability to comprehend what has been read.

**Reading Comprehension**

Although it is difficult to articulate a singular powerful, yet parsimonious theoretical model of reading comprehension, many comprehension models place word reading at the center of their frameworks which expand outward toward higher level comprehension processes (Graesser & Britton, 1996; Kamhi & Catts, 2012; Perfetti & Stafura, 2014). In an additive fashion, each single word that is read must be incorporated into the larger body of the text. This word-by-word processing yields word-to-text integration, which forms the basis for comprehension. This cumulative process is highly reliant on different aspects of memory, attention, and prior knowledge as well as additional underlying skills such as single word reading. The mastery of the underlying skills such as word reading leads to automaticity, which allows more cognitive resources to be devoted toward comprehension (Carter, Rastatter, Walker, & O'Brien, 2009; Carter, Walker, & O'Brien, 2015; Fuchs, Fuchs, & Hosp, 2001; LaBerge & Samuels, 1974). When single word reading is effortful and slow, comprehension often suffers as well (Breznitz, 2012).

**Digital Reading Comprehension**

Just as in nearly every other facet of American life, technology has drastically impacted the means by which we engage in literacy tasks. As a result, interest in reading digital texts has increased tremendously (Ortlieb, Sargeant, & Moreland, 2014). School systems incorporate digital reading activities for their students at all grade levels, individuals continue to utilize e-readers to engage in numerous literacy activities, and the modern

individual continues to be inundated with digital literacy the moment they open their computers, tablets, or smart phones. The research that has been devoted to assessing differences in reading comprehension as a function of media type (commonly computer screens, tablets, iPADs, e-readers, etc.) often results in conflicting results (see Chen, Cheng, Chang, Zheng, & Huang, 2014 for review). An overview of the many studies in this area leads one to suspect the conflicting results to be an artifact of utilizing different aspects of literacy skills as dependent measures across the methodologies. The wide variance in the overall purposes of reading tasks falling under the umbrella term of "digital literacy" makes comparisons challenging as well. For example, an individual browsing a website or reading through the daily headlines on their smartphone has different intentions for engaging in reading than does a high school student who is preparing for a book report on their e-reader. However, there does seem to be enough compounding evidence to support that there are in fact distinct differences between the literacy skills demonstrated by individuals reading in digital versus print based formats (Chen & Chen, 2014) although at times the differences might be subtle.

One finding of note regarding those engaged in digital reading tasks is a decreased tendency to engage in deep comprehension (Carr, 2010). Wolf and Barzillai (2009) define deep reading as the series of processes designed to propel the reader into more complex patterns of reasoning, abstraction, analysis, reflection, and insight (p. 32). The authors claim that the barrage of information that is readily available to the online reader can act as both a blessing and a curse. It can be a blessing if the reader utilizes the additional digital access and context to further solidify their current understanding of the topic. However, Wolf and Barzillai state that it can be a curse if the reader is not skilled in utilizing their executive, organizational, critical, and self-monitoring skills to maintain vigilance toward the original

text that is intended to be comprehended. The reader instead, becomes mired in the endless sea of information, much of which can be either irrelevant, false, or just merely distracting. Liu (2005) provided empirical support for Wolf and Barzillai's commentary regarding digital literacy when he reported that individuals who read in a digital environment exhibit a decrease in sustained attention. Deficits in attention can negatively affect memory, which has been demonstrated to have a tremendous impact on literacy abilities (see Breznitz, 2012 for a review). This could be quite troublesome for the student who decides to routinely select the digital copy of their textbooks over the print copy. However, reading at more rapid rates has been demonstrated to more effectively allocate attentional and memory resources. The remainder of this review will focus upon this finding as it pertains to literacy and digital text.

**Reading Rate**

Textual reading rate is becoming more important as the value of fluency continues to increase in reading instruction, assessment, and intervention (Breznitz, 2005). Reading fluency is an element of literacy and has been defined as the "ability to read text quickly, accurately, and with proper expression" (National Reading Panel, 2000, p. 5). The heightened awareness regarding reading fluency can, in part, be explained by the fact that much can be learned about the literacy capabilities of an individual by assessing their level of fluency. For example, if a reader reads at an appropriate pace, then that individual is most likely reliant upon sight word reading as opposed to phonological decoding. The utilization of sight word skills as the primary word reading mechanism allows for cognitive resources toward comprehension. A reader who continues to decode text in a phonological manner is more likely to struggle with comprehension since phonological decoding drains cognitive resources. Thus, fluency is reliant upon the successful integration of many lower-level skills and is frequently postulated as a by-product of appropriate literacy development.

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Previous research geared toward improving reading fluency in digital mediums tends to focus on providing appropriate adult-like models for the reader to imitate (Thoermer & Williams, 2012). This is commonly referred to as audio-assisted reading. These models are designed to provide appropriate examples of reading rate, reading accuracy, and reading prosody/expression. It is hoped that as the reader listens and reads along they will begin to generalize this more fluent pattern of reading to non-targeted texts. There is much debate regarding whether this generalizability ever occurs, however, that is not the focus of the current discussion. Regardless of the merits of this method as a remedial tool in terms of generalizability, this method still has severe limitations, namely in the form of availability. One must have access to an actual recording of the specific text that they are attempting to read. Although audio-visual libraries and student access to these libraries is expanding at increasingly rapid rates, there still remain a multitude of texts that do not have audio support that accompanies the text. This represents a problem for those who are reliant upon audio-assisted literature for comprehension.

**Reading Rate Acceleration**

One technologically advanced means by which digital, visual-only text can be manipulated to enhance fluent reading is by reading rate acceleration. Reading rate acceleration has often been used as a clinical tool to improve the oral reading comprehension of both proficient and struggling readers. Reading rate acceleration has been found to increase both word reading accuracy and comprehension in readers who present with a vast range of reading abilities (Breznitz, 1987; 1997a; 1997b; Breznitz & Norman, 1998; Breznitz & Share, 1992). This finding, deemed the "acceleration phenomenon", has been demonstrated in children (Breznitz, 1987; 1997a; 1997b; 1997c) and adults (Breznitz & Leikin, 2000; Karni et al., 2005; Leikin & Breznitz, 2001). The most consistently observed finding in these

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acceleration studies is that readers of various levels and abilities are able to decrease word reading errors and increase reading comprehension when forced to read at a faster pace. The basic experimental protocol used in these studies consists of using script presentation technology that automatically erases words off of a computer screen one by one at a predetermined rate as the reader reads the script aloud. A common thread among the reading acceleration studies is that the benefits have been most pronounced in "poor readers" (see Breznitz & Berman, 2003 for a review).

As previously mentioned, one of the problems associated with digital literacy is that it is associated with a decrease in sustained attention which decreases memory capabilities (Liu, 2005). However, it has been claimed that reading acceleration improves reading performance by extending attention span, reducing distractibility (Breznitz, 1988, 1997b), overcoming the capacity limitations of short-term memory while enhancing working memory processes (Breznitz, 1997a; Breznitz & Share, 1992), and increasing word retrieval abilities (Breznitz, 1987). Although numerous studies have been conducted in order to ascertain the neurocognitive processes that are affected in reading acceleration tasks, no studies exist which have manipulated the technological parameters of the task in order to operationally define the optimal task specifications to be utilized during accelerated reading tasks. The previously mentioned studies have typically elected to use the fastest reading rate that had been exhibited by the readers in the baseline tasks. As commonly reported, this "accelerated" rate has averaged to a 10 to 12% increase above the individual's average reading rate. However, this method excludes all reading rates not produced during pre-experimental testing from consideration and thus, does not allow for the full examination of the potential reading benefits that may occur with this technology if their reading rates were allowed to exceed those rates that the individual has already demonstrated. It is possible that an optimal reading

rate exists for each and every person and in order to procedurally identify the range in which an optimal reading rate exists, the selection of the experimental reading rates must not be limited merely to those reading rates that have already been demonstrated by the individual.

It is possible that the best practices scenario for the utilization of reading acceleration is not being utilized due to the constraints that previous methodologies have employed upon the selection of the digital text presentation rates. As a result, those who wish to implement reading acceleration as part of a remedial program can have little certainty that what they are prescribing is in fact in the best interests of their clients. In addition, simple logic suggests that a reading rate ceiling must exist where increases in reading rate will surpass the cognitive, linguistic, and articulatory capabilities of readers and benefits of reading acceleration will no longer be present. However, to date, this ceiling has not been investigated in the research. Finally, if the literature and applied research findings reveal little consistency regarding which reading rate increases yield the highest literacy rewards for readers, doubt will be cast upon one-size-fits-all approaches to the utilization of reading acceleration as a technologically based reading intervention. If, in fact, reading acceleration is a beneficial tool in the remediation of reading difficulties (and the evidence supports that it is), then it is vital to investigate the optimal conditions by which it should be delivered. The purpose of this study was to investigate the effects of increased reading rates on the literacy abilities of high school students who exhibit reading difficulties. Independent variables for this study consisted of group (control vs. experimental) and text presentation rate (accelerated vs. non-accelerated). Dependent variables in this study consisted of word reading accuracy, comprehension accuracy, and optimal acceleration proportion. The first experimental question investigated in this study asked what are the effects of text presentation rate on the word reading accuracy of individuals who exhibit reading difficulties? The second experimental question investigated in

this study asked what are the effects of text presentation rate on the reading comprehension of individuals who exhibit reading difficulties? Finally, the third experimental question addressed in the current study asked if there are differences in optimal acceleration proportion (0, 10, 20, or 30% increases) as a function of group (control vs. experimental).

## Methods

### Participants

Twenty high school students (mean age = 16.90; median grade = 10th, 10 males) with typical reading abilities served as the control group and sixteen high school students (mean age = 16.65; median grade = 10th; 7 males) who presented with reading difficulties (experimental group) participated in this experiment. High school participants were sought for two reasons. The primary reason was based upon the belief that high school students have ample experience in engaging in digital literacy activities. Secondly, high school students are more likely to be able to choose between digital media and print media whereas grade school students are more likely to have that decision made for them. Therefore, it was thought that the current study would be of most benefit by seeking to provide additional information to high school students to assist in that decision making process. Participants were required to be younger than 19 years of age, enrolled in high school, and speak English as their primary language. No participants reported being considered an English language learner at any time in their academic history nor did they report that they considered themselves to be bilingual. Any participant with a self-reported history of brain injury was not eligible to participate in the study. Participation occurred in a quiet room and lasted approximately 1.5 to 2.0 hours. Of the 20 individuals who comprised the control group, 14 individuals were White, 5 individuals were African-American, and one individual was Asian. Of the 16 individuals who comprised the experimental group, 7 individuals were White and 9 individuals were African-American.

IRB approval was received through a university Institutional Review Board. Participants were recruited via various print media including flyers, newspaper ads, and university listservs. All participants were compensated monetarily for their time spent participating.

**Pre-Experimental Testing**

All participants passed a hearing screening administered at 20 dB HL at the following frequencies: 1000, 2000, and 4000 Hz (ASHA, 1997). In addition, a visual screening test was passed by all participants (http://www.sterlingoptical.com/eye_screening/2). This online screening test is designed to screen visual acuity and reading magnification level.

Group membership was defined based upon the results of the *Test of Word Reading Efficiency* (TOWRE) (Torgesen, Wagner, & Rashotte, 1999). The TOWRE was administered in order to provide a brief assessment of overall word reading accuracy and fluency and to aid in establishing the presence of reading difficulties. The TOWRE is a nationally standardized assessment tool which has two subtests. The Sight Word Efficiency subtest assesses an individual's ability to rapidly decode real words and the Phonemic Word Reading Efficiency subtest assesses an individual's ability to rapidly decode nonsense words (which assesses phonetic decoding abilities). The TOWRE provides standard scores (average 85-115) according to age-based norms.

The Word Identification subtest of the WRMT-R is designed to assess sight word reading abilities whereas the Word Attack subtest is designed to assess phonological decoding abilities. The WRMT-R provides standard scores according to age-based norms. A standard score of 90 or above on all subtests of the TOWRE and WRMT-R was required for placement into the control group. A standard score below 80 on either subtest of the TOWRE and either subtest of the WRMT-R was required for placement into the experimental group.

An oral reading comprehension baseline grade level and a reading rate baseline measure were needed for the experimental conditions. This comprehension baseline was established based upon the *Gray Oral Reading Tests-Fourth Edition* (GORT-4) (Wiederholt & Bryant, 2001). The GORT-4 is a normed-referenced test of oral reading rate, word reading accuracy, fluency, and comprehension. It consists of passages that increase in complexity as the test progresses. Accompanying each individual passage is a series of five multiple choice comprehension questions. Each individual who participated in this study obtained a reading comprehension grade equivalent between $4^{th}$ and $10^{th}$ grade on the GORT-4. In addition, baseline reading rates were obtained from the GORT-4. The reading rate measure was calculated by averaging the oral reading rate (words read correctly per second) of the two passages that occurred prior to the ceiling level. Ceiling level on the GORT-4 was established when the individual missed three out of the five comprehension questions that follow each text. Mean data for all pre-experimental measures are summarized in Table 1.

**Experimental Stimuli**

The stimuli used in this experiment consisted of twelve different 90 to 110 word narrative digital texts with varying topics that had been assigned a reading level based upon the Fry Readability Index (Fry, 1977) and subsequent comprehension questions.

The Fry Readability

Table 1.

*Means and Standard Deviations (SD) for Pre-Experimental Testing.*

| Measure | *Experimental* | *Control* |
|---|---|---|
| TOWRE Sight Word Efficiency* | 82.63 (2.39) | 101.67 (1.98) |
| TOWRE Phonemic Decoding Efficiency * | 79.94 (3.56) | 99.78 (1.68) |
| WRMT-R Word Identification* | 87.25 (3.03) | 100.67 (1.98) |
| WRMT-R Word Attack* | 85.19 (3.41) | 104.17 (2.10) |
| GORT-IV Comprehension+ | 7.19 (0.29) | 7.56 (0.34) |
| Baseline Reading Rate- | 2.10 (0.16) | 2.63 (0.08) |

* indicates standard scores (mean = 100, SD ± 15).

+ indicates scaled scores (mean = 10, SD ± 3).

- indicates words per second

Index assigns an approximate grade reading level to a passage of text. The formula depends on the vocabulary and sentence structure of the text, not the organization or content. The grade reading level is found by plotting the average number of sentences and syllables on the Fry Readability Graph, which assigns a text reading level from first grade to college level. Narrative texts were utilized for this study as it has been claimed that narrative processing tends to be focused more on the comprehension of the organization of events in a story, whereas expository processing has been shown to focus more on the activation and integration of relevant prior knowledge into discourse representation (Wolfe & Woodwyk, 2010). The narrative digital texts consisted of excerpts from short stories. By utilizing the Fry Readability Index (Fry, 1977), four texts were estimated to be written at the 6th grade level, four texts were estimated to be written at the 8th grade level, and four texts were estimated to be written at the 10th grade level. Each participant's stimuli set was closely matched in grade level with the grade reading level obtained by the participant on the pre-experimental administration of the GORT-4 (Wiederholt & Bryant, 2001). For the purposes of this study, if an individual read at a 4th through 6th grade level in pre-experimental testing, then the 6th grade digital passages were selected. If a participant read at a 7th or 8th grade level according to pre-experimental testing, then the 8th grade digital passages were selected. If an individual read at a 9th or 10th grade reading level, then the 10th grade digital passages were selected. If the GORT-4 reading grade equivalent consisted of an additional 6 or more months, that grade level was rounded up to the next year (ex: $4^{th}$ grade, $8^{th}$ month became $5^{th}$ grade).

The comprehension questions that were utilized in this study were developed by the authors. Open-ended questions were utilized because it has been claimed that cloze format questions tend to measure word recognition skills as opposed to comprehension and multiple choice formats can be more susceptible to passage independence effects (Fletcher, 2006;

Francis, Fletcher, Catts, & Tomblin, 2005; Keenan, Betjemann, & Olson, 2008; Nation & Snowling, 1997). Four factual questions and two inferential questions accompanied each text. Factual questions focused upon material which was explicitly stated in the body of the text which was read and included "who, what, where, and when" type questions. The answers to the inferential questions were not directly and explicitly stated in the body of the text, thus requiring the participants to surmise the answers based upon the information that was actually present in the body of the text.

In order to assess the validity and reliability of this self-developed measure, a series of analyses were performed on both the experimental data as well as on the questions themselves. Initially, the validity of the questions was analyzed in terms of their passage dependency. Passage dependency is the extent to which actually reading a text is necessary to answer comprehension questions (Keenan & Betjemann, 2006). Individuals often can rely upon previously gained knowledge to answer comprehension questions. Questions that are deemed higher in passage dependency are believed to limit this ability, thus improving content validity. To address this issue, the current study administered each of the comprehension questions to 57 graduate students without allowing the students to read the accompanying text. The students were required to answer the open-ended questions. Of the total 72 comprehension questions that were utilized, only three questions were answered correctly by more than 10% of the graduate students (5 or more students). Each of these three questions was replaced with an alternate question that was developed from the digital text. These questions were submitted to the same group of graduate students and satisfactory dependence levels were obtained. On average, the 72 questions that were utilized as part of the current study were answered in a passageless format with 1.47% accuracy.

Once data was collected, responses were scored as either correct or incorrect by the current authors. In addition, reliability data was collected on 20% of the total responses (173 out of 864 total responses). A trained research assistant read each of the passages and was given a key which included allowable responses. The research assistant scored each item as correct or incorrect. An independent samples *t*-test was utilized to examine mean accuracy proportions and it was found that no significant differences existed between raters, $t(172) = -.172$, $p = .898$. There was also a statistically significant positive Pearson correlation between the accuracy measures of each observer ($r = .94$, $p = < .000$).

In addition, after the experimental data was collected coefficient alphas were calculated for each of the 12 sets of questions in order to estimate internal consistency reliability with a Cronbach's alpha criterion level of .8 or higher (Crocker & Algina, 1986). Internal consistency ratings ranged from .835 to .871. The SPSS option of "Scale if item deleted" was utilized and it was found that no question items yielded an increase in the alpha coefficient if removed. These alpha levels are considered indicators of moderate to high reliability (Garcia-Barrera, Kamphaus, & Bandalos, 2011).

Finally, in order to assess the relative difficulty of the reading passages and their associated questions, the passages and their comprehension questions were individually administered to 42 undergraduate students (mean age = 20.65 years). The texts and questions were administered in a hard copy format by a trained research assistant over two sessions which occurred on separate days within the span of two weeks. The presentation order of the texts was counter-balanced. The comprehension accuracy proportions that were obtained from these administrations were arcsine transformed and submitted to a series of independent samples *t*-tests as a function of text grade level. Results indicated significant differences between the $10^{th}$ and $8^{th}$ grade texts, $t(56) = 15.73$, $p = .00$, with the $10^{th}$ grade texts being

answered less accurately (47%) than the 8th grade texts (58%). In addition, significant differences were obtained between the 8th grade texts and the 6th grade texts $t(56) = 13.92$, $p = .00$ with the 8th grade texts being answered less accurately than the 6th grade texts (71%).

**Experimental Instrumentation**

The digital stimuli were presented on a Hewlett Packard 18.5 inch LED backlit monitor. Adobe Premiere 6.0 was used to create .mov files of the digital text and to control for the speed of text presentation. Adobe Premiere enables the presentation of horizontally scrolling text across the computer screen at pre-determined rates (words per second). The .mov files were played for each participant using Windows Media Player. The texts were presented in Times New Roman, 72-point font and appeared in black on a white background.

**Experimental Procedure**

During the experimental conditions, the participant was seated in front of a computer screen with their chin resting and stabilized on a static head/chin rest to control for the distance and angle of vision. Each participant was required to read aloud a series of four digital passages at four different presentation rates. The text presentation rate for each digital passage was calculated to be proportional increases in reading rate (words per second) above their baseline oral reading rate that was obtained from the pre-experimental testing. The proportional accelerated reading rates were established for each of the participants as 0%, 10%, 20%, and 30% faster than their baseline reading rate. For example, if an individual exhibited an average reading rate of 2 words per second during the pre-experimental administration of the GORT-4, then their reading acceleration proportions would have been 2.0 words per second (0% increase), 2.2 words second (10 % increase), 2.4 words per second (20% increase), and 2.6 words per second (30% increase). The assignment of the different passages to the different presentation rates was counterbalanced among the four digital texts

within each grade level. The presentation order of the different acceleration rate conditions was also counter-balanced in order to control for any possible order effects.

The four digital passages were read aloud as they were presented on the computer monitor. Open-ended comprehension questions were immediately presented on a hard copy following the presentation of each of the texts. The participant was required to orally read each question and answer aloud. The participant was not allowed to refer to the text during the answering of the questions.

Word reading accuracy proportions and comprehension accuracy proportions were obtained for each digital passage. Both the word reading and comprehension accuracy percentages were transformed by SPSS (Version 21) in order to stabilize variance using the following formula: 2*arcsine [√(accuracy % / 100)] (Winer, 1971). Two separate two-way repeated measures ANOVAs were conducted on the transformed accuracy proportions with a between subjects factor of group and a within subjects factor of reading rate acceleration proportion.

Finally, optimal acceleration proportions were determined for each participant. The optimal acceleration proportion was defined as the rate (0, 10, 20, or 30% increase) at which the participant exhibited the highest comprehension accuracy proportion. If two or more percentage increases yielded identical comprehension accuracies, then the individual was considered unclassifiable. Three participants met this criteria. The reliability for this procedure as a means of providing discrete categorizations has not yet been established. However, this preliminary methodology could potentially assist in the process of customizing treatment protocols for individual readers. The optimal acceleration proportions were subjected to a series of 3 chi-square goodness of fit analyses in order to assess differences in distributions of results. One chi-square investigated the distribution of all participants' (control and

experimental) optimal acceleration proportions classifications. One chi-square investigated the distribution of the control group's optimal acceleration proportions classifications and one chi-square investigated the distribution of the experimental group's classifications.

## Results

The experimental task was designed to assess the effects of systematically increasing the reading rates of individuals who exhibit reading difficulties. Word reading accuracy and comprehension accuracy proportions were obtained as a function of presentation rate. In addition, optimal acceleration proportions were categorized based upon comprehension accuracy proportions.

### Word Reading

In order to investigate word reading accuracy as a function of group and presentation rate, a two-way repeated measures ANOVA was conducted on the arcsine transformed word reading accuracy proportions with a between subjects factor of group and a within subjects factor of acceleration proportion. A significant main effect was found for acceleration proportion, ($F$ (3, 30) = 12.672, $p < .01$ $\eta^2 = 0.559$) (see Table 2). Post-hoc testing consisted of a series of six paired $t$-tests. This analysis revealed significant differences at the .05 level in word reading accuracy between the following proportional reading rate increases: 0% and 10%, 0% and 30%, 10% and 20%, 10% and 30%, 20% and 30%. The participants exhibited the highest word reading accuracy proportion when reading 10% faster than their baseline reading rate. The second highest mean proportion was demonstrated during the baseline reading rate while the third highest accuracy proportion was demonstrated when reading 20% faster. Mean word reading accuracy proportions were found to be the lowest when reading with a 30% increase in reading rate. No significant main effect of group was found and there were no significant interactions.

**Comprehension**

In order to investigate reading comprehension accuracy as a function of group and acceleration proportion, a two-way repeated measures ANOVA was conducted on the arcsine transformed comprehension accuracy proportions with a between subjects factor of group and a within subjects factor of acceleration proportion. A significant main effect was found for acceleration proportion, ($F$ (3, 30) 13.298, $p < .01$ $\eta^2 = 0.571$) (see Table 3). Post-hoc testing consisted of a series of six paired $t$-tests. This analysis revealed significant differences at the .05 level in comprehension accuracy between the following proportional reading rate increases: 0% and 10%, 0% and 30%, 10% and 30%, 20% and 30%. On average, the participants answered more comprehension questions correctly when reading 10% faster than their baseline rate. The second highest mean proportion was while reading with a 20% increase in reading rate while the third highest accuracy proportion was while reading with a 0% increase in reading rate. Comprehension accuracy proportions were lowest while reading with a 30% increase in reading rate. No significant main effect was found for group and no significant two-way interactions were found.

**Optimal Acceleration Proportion**

The current study also sought to establish potential optimal acceleration proportions for each of the participants. As previously stated, the reliability of this methodology has not yet been

Table 2.

*Means and Standard Deviations (SD) of Word Reading Accuracy Proportions as a Function of Group and Reading Rate Acceleration Proportion.*

| Group | Reading Rate Acceleration Proportion | | | |
|---|---|---|---|---|
| | 0% | 10% | 20% | 30% |
| Control | 91.28 (16.28) | 98.33 (2.00) | 92.17 (7.57) | 90.17 (7.59) |
| Experimental | 94.19 (6.07) | 95.97 (4.00) | 90.21 (8.78) | 86.46 (11.38) |
| Overall | 92.65 (12.47) | 97.22 (3.28) | 91.24 (8.10) | 88.42 (9.60) |

Table 3.

*Means and Standard Deviations (SD) of Comprehension Accuracy Proportions as a Function of Group and Reading Rate Acceleration Proportion.*

| Group | Reading Rate Acceleration Proportion | | | |
|---|---|---|---|---|
| | 0% | 10% | 20% | 30% |
| Control | 47.06 (5.58) | 59.28 (4.85) | 49.00 (5.42) | 38.89 (7.32) |
| Experimental | 50.00 (5.92) | 58.38 (5.15) | 53.19 (5.75) | 35.36 (7.77) |
| Overall | 48.44 (5.76) | 58.85 (5.01) | 50.97 (5.49) | 37.24 (7.50) |

established. However, this method could potentially assist in the process of customizing individual treatment plans for struggling readers. The optimal acceleration proportion was calculated by establishing the presentation rate which corresponded with the participant's highest comprehension accuracy proportion. Therefore, each participant could have obtained an optimal acceleration proportion of 0, 10, 20, or a 30 % increase. Frequency tables were calculated and the data were subjected to a series of chi-square goodness of fit analyses. Initially, all classifiable optimal acceleration proportions were subjected to a chi-square analysis. Results indicated that the classifications were not evenly distributed among the four potential classifications. Participants were classified with 10% as the optimal acceleration proportion more often than any of the other classifications ($X^2$ (3, $N$ = 33) = 18.51, $p$ = .000) (see Table 4). A subsequent chi-square analysis of the control group's classifications also revealed a significant tendency for 10% to be identified as the participants' optimal acceleration proportion $X^2$ (3, $N$ = 33) = 13.56, $p$ = .004. Finally, a final chi-square analysis was conducted on the experimental group's classifications. No significant differences were found in the distribution of the experimental group's classifications.

## Discussion

The purpose of this study was to investigate the effects of increased reading rates on the literacy abilities of high school students who exhibit reading difficulties. Previous research has indicated that oral reading abilities (word reading and comprehension) improve as reading rate increases in digital reading tasks. However, many of the studies which have utilized reading acceleration have determined experimental reading rates to be the fastest rate demonstrated by the individual in pre-experimental testing (Breznitz, 1987; 1997a; 1997b; 1997c; Breznitz & Share, 1992; Norman & Breznitz, 1992; Breznitz & Leikin, 2001; Karni et al., 2005; Leikin &

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Table 4.

*Contingency Table of Optimal Acceleration Proportion as a Function of Group.*

| Group | Optimal Acceleration Proportion | | | |
|---|---|---|---|---|
| | 0% | 10% | 20% | 30% |
| Control | 1 | 11 | 4 | 2 |
| Experimental | 0 | 7 | 4 | 4 |
| Total | 1 | 18 | 8 | 7 |

Breznitz, 2001). This procedure requires the individual to maintain a previously produced reading rate. This method excludes all reading rates not produced during pre-experimental testing and thus, does not allow for the full examination of potential reading benefits that may occur if reading rates exceed those rates that the individual has already demonstrated. It is possible that an optimal reading rate exists for each and every person. Technology allows for the investigation of this optimal reading rate. This study examined the effects of proportionately increasing oral reading rates above previously described levels.

**Word Reading**

Analysis of the word reading accuracy data revealed a significant main effect of acceleration proportion. Participants exhibited the highest mean word reading accuracy proportion with a 10% increase in reading rate above baseline. This finding is congruent with previous acceleration phenomenon studies which have indicated that word reading accuracy could significantly improve with approximately a 10 - 12% increase in reading rate in a digital literacy environment (Breznitz, DeMarco, Shammi, & Hakerem, 1994). The current data indicate that the optimal reading rate for word reading accuracy most likely exists between a 0% and a 20% increase above baseline reading rates, which would include the original range proposed by Breznitz et al. (1994). The current study also sought to investigate when oral word reading abilities would decrease as a function of reading rate. It was found that when reading rates were proportionally increased by more than 20%, word reading accuracy decreased below baseline levels. It is possible that proportionally increasing reading rates above 20% over baseline rates begins to exceed the resources necessary for the cognitive, linguistic, and motoric processes that must occur during oral reading tasks.

**Comprehension**

The second experimental question addressed whether or not significant differences existed in comprehension accuracy proportions as a function of group and acceleration proportion. Once again, analysis of the comprehension data revealed a significant main effect of acceleration proportion. It was found that the participants exhibited the highest comprehension proportions when reading digital texts with a ten percent increase and the lowest when reading with a thirty percent increase. These data suggest that individuals are most effective when reading between 10% and >30% faster than they typically read. The 30% increase condition is the only condition in which individuals, on average, read with lower comprehension levels than they did when compared to baseline levels. Both groups exhibited similar trends in reading comprehension as a function of acceleration proportion. These data provide further support regarding the potential benefits of reading acceleration as a short-term ameliorative reading technique with digital media.

**Optimal Acceleration Proportion**

The final experimental question addressed whether there were significant differences in optimal acceleration proportion classification results as a function of group. Overall, it was found that the majority of participants tended to read best with a ten percent increase in presentation rate, which is consistent with the previous analysis which was based upon overall comprehension accuracy proportions as well as the previously mentioned Breznitz et al. (1994) study. More precisely, 53% (19 out of 36) participants were classified as comprehending best with a ten percent increase in presentation rate. What the current study adds that previous studies have yet to demonstrate is the lack of a consistent distribution between the optimal acceleration proportions which were assigned to the group that displayed reading difficulties. The participants who obtained a 10% optimal acceleration proportion did

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not represent the significantly largest proportion of the group who exhibited reading difficulties. Over half of this group obtained optimal acceleration proportions that were not associated with reading at 10% increases. However, the control group did significantly tend to fall within the 10% category. The difference noted between the two groups that were utilized in this study could potentially be explained by ceiling effects which potentially existed for the control group. Intuitively, there must exist a proportional increase in reading rate that will overwhelm the capabilities of the reader, resulting in decreased literacy abilities. The capabilities of presentation technology are far greater than the motoric and cognitive capabilities of the reader when reading aloud. The simplest explanation is that it is possible that the control group was already reading at rates that were far closer to their own intrinsic optimal levels, and using technology to increase word reading rates above those levels began to be associated with diminishing returns in terms of comprehension. The proportional increases that were utilized in the current study might not have exacerbated the cognitive and motoric requirements of the experimental group in the same fashion. Quite simply, the experimental group had more room for improvement in terms of reading rate. Although this classification model which is based upon comprehension accuracy is exploratory in nature, it still might offer key insight into the manner in which reading acceleration might be delivered in order to provide the most appropriate, individualized plan of care to those utilizing reading acceleration.

**General Discussion**

Examining both the word reading and the comprehension results reveals that individuals can in fact continue to exhibit marked improvement in digital literacy abilities even when reading at rates that are 20% faster than their average reading rate. Previous research has tended to focus on a 10 - 12% increase in reading rate (Breznitz et al., 1994).

However, the current results indicate that a rigid adherence to this value might not be appropriate during digital reading tasks. If a clinician were to only utilize 10 to 12% increases in reading rate, then it is possible that the optimal acceleration proportion would not be utilized. These data suggest that investigating a larger range of acceleration values might prove to be beneficial to individualize this technological innovation for each reader.

Furthermore, it should be noted that 45% of the participants (7 control, 8 experimental) did not obtain an optimal acceleration proportion of 10%. Furthermore, 6 participants (4 experimental, 2 control) obtained the 30% condition as their optimal acceleration proportion for comprehension, which equaled 18% of the classifiable participants. The existence of this large proportion of the sample illuminates the necessity to consider individual variability when designing an acceleration program. This appears to be exceedingly important for those individuals who are already exhibiting reading difficulties considering the inconsistent nature of the optimal acceleration proportion classifications which they obtained. Therefore, although it seems likely that the beneficial acceleration range for most individuals exists below a 30% increase in reading rate, individual variability should always be taken into account. Future studies should continue to attempt to more accurately define the proportional acceleration range in which acceleration continues to benefit the reader during digital tasks and perhaps identify characteristics of individual readers that could predict optimal acceleration proportions.

The increases in reading abilities associated with reading acceleration have been hypothesized to decrease the effects of the asynchronous processing of auditory and visual information which is common in individuals with below average reading abilities. It has been claimed that reading acceleration reduces these deleterious effects by extending attention span, reducing distractibility (Breznitz, 1988, 1997b), overcoming the capacity limitations of short-

term memory while enhancing working memory processes (Breznitz, 1997a; Breznitz & Share, 1992), and increasing word retrieval abilities (Breznitz, 1987). Although previous research has been primarily designed to account for the reading abilities of those who exhibit difficulties with reading, the current results indicate that the basic premises behind the theory can potentially be extended to those with typical reading abilities as well. A more efficient and well organized attentional, memory, and lexical system would be a desirous trait for readers of all abilities.

These results indicate that overall reading proficiency, regardless of baseline abilities, can often be improved. The lack of a significant main effect of group in the current experiment further supports the potential universality of this remedial approach. This approach does not require the presence of disordered reading abilities to yield beneficial results. A profitable reading tool that improves reading ability in nearly all individuals while decreasing the amount of time needed to read in a rapid paced society can become quite a powerful clinical tool. By the same token, it seems that although reading acceleration provides universal benefits for typical and struggling readers alike, the means by which this strategy is implemented might vary depending upon reading abilities. The rate at which reading acceleration is utilized should therefore be individualized and this seems to be most important for those readers who exhibit the most difficulties. Those who stand the most to gain from this approach, might also require the most thorough investigation in order to identify optimal reading levels. This is an important issue which requires more investigation.

In addition to being suitable for readers of various abilities, reading acceleration represents a technological innovation that can easily be utilized with readily available software. The current study utilized Adobe Premiere as the means by which the digital texts were created and scrolled across the screen. However, there are numerous movie editing

softwares that allow for this to occur. The process was rather simple to copy and paste electronic text into the software. Movie editing software generally contains an ever-present timeline and the user simply dictates how long they would like for the text to be displayed. The entire process of preparing the texts for each reader took approximately 3 minutes. This allowed the researcher to calculate the reading speed increases, paste the texts, save the files, and begin reading. Any text that one has access to digitally could be subjected to this process in a manner of moments. Optical character recognition software could also assist in transforming non-digital texts into readily accessible digital texts for this process as well. Although this method lacks the benefit of audio-assistance, it far improves upon the issue of access that is associated with acquiring and utilizing audio-assisted literature.

**Limitations and Future Directions**

In the current study, the constraints of time, energy, and available resources affected not only the results that were found, but also the questions that were asked. One constraint on this study was the number of incremental increases that were utilized. As such, this study does not address the effects of increasing reading rates any higher than 30% above average reading rates. However, both comprehension and accuracy were on average lower at 30% than they were with a 20% increase, which indicates that the upper limits most likely do not extend far above 30%.

Furthermore, by increasing the reading rates proportionally, those who were more proficient readers were presented with greater increases in reading rate than those who read slower. For example, the average control participant who read at 2.61 words per second increased their rate by 0.26 words per second at each experimental interval whereas the average experimental participant who read at 2.15 words per second increased their rate by 0.22 words per second. With a 30% increase in reading rate, the control group would be

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reading at an average rate of 3.39 words per second (203.4 words per minute) whereas the experimental group would be reading at an average rate of 2.80 words per second (168 words per minute). This represents 0.78 words per second increase for the control group and 0.65 words per second increase for the experimental group. Thus, it is possible that by basing each person's proportional acceleration level according to their average reading rate, some individuals did not attempt what may potentially be their optimal reading rate. This limitation could also be addressed in future studies by pre-determining the reading rates.

Finally, increasing linguistic diversity within the sample groups could yield valuable information as well. The current study rather narrowly focused upon individuals in high school who spoke English as their sole language. Future studies could find value in investigating the effects of reading acceleration on the literacy profiles of bilingual individuals or even individuals with clinical diagnoses such as attention deficit hyperactive disorder. In addition, it would be of benefit to investigate if younger readers tend to follow the same patterns that the older participants in the current study exhibited.

**Conclusions**

Reading acceleration has a long history of proving to be a beneficial means of improving digital reading abilities. However, previous research had only focused on a narrow range of acceleration proportions, thus not truly exploring the potential benefits of this technology-based ameliorative technique. The current study found that individual variation in optimal accelerated reading rates can be great, especially for those who exhibit difficulties with reading tasks. Therefore, the clinical implementation of this method must co-exist with a thorough investigation of each individual's performance within a wide range of presentation rates. Individuals who frequently engage in digital literacy activities, especially those for which comprehension is at a premium, should consider the pace at which they read.

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Finally, the authors would like to stress that they are not advocating a read-fast-at-all-costs approach to reading remediation. The current results do not support such an approach. Instead, the current results indicate that reading acceleration of varying degrees might be beneficial for many readers who exhibit varying literacy strengths and weaknesses. By no means are the current authors recommending that a systematic, language and literacy based approach be tabled in favor of having someone read quickly. If anything, these results stress the need to acknowledge uniqueness when considering individual treatment plans.

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