An Examination of Reading Comprehension and Reading Rate in University Students

by

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Abstract

The following dissertation includes three studies investigating reading comprehension and reading rate in university students. The first study focused on measuring adult reading comprehension more effectively and efficiently by testing whether brief versions of standardized reading comprehension measures could provide a reasonable estimate of reading comprehension in less time. Results suggested that a computerized brief version of the *Scholastic Abilities Test for Adults* reading comprehension subtest (Bryant, Patton & Dunn, 1991) appears to be an adequate measure of reading comprehension and rate in studies where there is a need to measure reading comprehension quickly and reliably and that the Curriculum Based Measurement (CBM) appears to be an adequate brief screening measure of reading comprehension and rate that would be appropriate to use in situations where it is important to ensure adequate reading comprehension skills. The second study examined how different component skills of reading comprehension contribute to performance on four different reading comprehension tests. Consistent with studies examining children's reading comprehension, the tests were at best moderately correlated and the total amount of variance explained by word and nonword reading rate, text and sentence reading rate and working memory varied across four different reading comprehension measures. Overall, word and nonword reading rate explained between 6 and 15% of the variance, sentence and text reading rate explained between 10-29% of the variance and working memory explained between 5-22% of the variance. The third study compared university students with and without a history of reading difficulties on measures of word and nonword reading rate, text reading rate and comprehension, and question-answering times. Consistent with past studies, results indicated that students with a history of reading difficulties demonstrated slower word, nonword, and text reading rate than their typical reading peers, but had comparable reading comprehension scores. Results also found that students with a history of reading difficulties took longer to answer questions even when reading rate was controlled, suggesting that they require extra time to complete reading comprehension measures for reasons other than slow reading rate. These three studies examine reading comprehension and reading rate within the university population, and thus contribute to filling a current gap in understanding of these processes in adult reading research.

Preface

This thesis is an original work by Megan Hebert that was completed in collaboration with Dr. Rauno Parrila at the University of Alberta. The research project received research ethics approval from the University of Alberta Research Ethics Board, Project Name "Assessing Reading Comprehension in University Students", No. Pro00043086, Approved August 2013.

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Chapter I: General Introduction

Reading is a critical, life-long skill that presents itself in everyday tasks, such as reading road signs, the newspaper, or signing a consent form at a doctor's office. It is also critical for long-term learning. Despite its importance in everyday adult life, the majority of reading research has focused on children (Snowling, 2000). Although it is, undoubtedly, crucial research to further our understanding of how reading skills develop in the first place, reading research in adults, and specifically in high-functioning adults, is arguably just as important for understanding this complex process. High-functioning adults, such as university students, usually have advanced reading skills and studying reading within this population allows for insight at the end product of development. Researchers have also identified a subset of university students who have compensated for deficits in early reading skills or who continue to struggle with basic reading skills, but understand texts successfully, and further understanding their reading success can inform reading theories, research, and practice (Gallagher, Laxon, Armstrong, & Frith, 1996; Hatcher, Snowling, & Griffiths, 2002; Kemp, Parrila, & Kirby, 2009). Although this population may appear small, it is estimated that 1 in 10 Canadians have learning disabilities (Learning Disabilities Association of Canada, 2007) and approximately 80 % of learning disabilities are thought to be reading related (Bell, McCallum & Cox, 2003). Despite past and present difficulties in reading, more students with learning disabilities are currently pursuing and successfully completing post-secondary education than ever before (Vogel et al., 1998). In fact, a recent Canadian survey revealed that 2-5 % of university students with various learning difficulties were seeking supports through student disabilities services (Harrison & Wolforth, 2012); however, not all students who experience difficulties necessarily seek or qualify for the services (Stack-Cutler, Parrila, & Torppa, 2015), suggesting that this number likely underestimates the number of students who have disabilities and would benefit from support services.

The current dissertation consists of three studies that sought to examine two important skills in university students' skills in reading comprehension and reading rate. The dissertation begins with a general introduction presenting a review of theories of reading development and its processes, reading research in high-functioning adults, and measures of reading comprehension and reading rate. The first paper (Chapter II) focuses on developing more efficient ways to measure reading comprehension and reading rate in adults. The second paper (Chapter III) focuses on determining which underlying processes influence adult reading comprehension performance. The final paper (Chapter IV) examines performance times during text reading and question-answering of students with and without a history of reading difficulties. Finally, the dissertation concludes with a general discussion, including a summary of the main findings and their implications (Chapter V).

Definitions of Terms

The following terminology is used in the current research.

Reading Comprehension: a complex, multiple construct process that involves decoding text and understanding its meaning. Some component processes include word reading, vocabulary, inferencing and background knowledge (Plaut, 2005).

Phonological Awareness: a broad skill that involves being sensitive to the sound structures of language, including phonemic awareness, alliteration, syllables and rhyming.

Phonemic Awareness: the ability to identify and manipulate individual sounds (phonemes) in spoken words (Adams, 1990).

Decoding: the ability to 'sound out' or decipher words by using letter-sound knowledge (Siegel, 1993).

Word Identification: the ability to recognize words correctly and effortlessly (Ehri, 2006).

Word and Nonword Reading Rate: the rate (speed) that someone reads individual, context-free words or nonwords.

Sentence Reading Rate: the rate (speed) that someone reads words within the context of a sentence.

Text Reading Rate: The rate (speed) that someone reads words within the context of a text or passage that has multiple sentences.

Working Memory: the ability to hold and manipulate/process information in short term memory and the use of attention to manage short term memory (Cowan, 2008).

Long Term Memory: an immeasurable mental storage of knowledge and record of prior events (Cowan, 2008).

Breadth of Vocabulary: the size or number of words that an individual has at least minimal knowledge of the meaning (Nation, 2001).

Depth of Vocabulary: how well an individual knows a word or the level of knowledge and semantic associations an individual has surrounding a word (Read, 1993).

Background knowledge: the prior content knowledge we have about a subject or theme, which includes vocabulary knowledge.

Inference Making: a process that involves integration of information within text or integration of general knowledge about text that is not explicitly stated but is necessary to make text coherent, to make predictions, to make connections or to conclude causes (Cain & Oakhill, 2009).

Comprehension Monitoring: actively thinking about and continuously monitoring understanding while reading text by asking questions whether the text makes sense and rereading words and the text if confused (Cain & Oakhill, 2009; Pressley, 2001).

University Students with a History of Reading Difficulties: individuals who self-report having a significant history of reading difficulties but do not necessarily have a formal diagnosis from a qualified professional (i.e., psychologist).

University Student with Reading Disorders: Individuals with a history of reading difficulties who have been identified by a professional (i.e., psychologist) and have received a formal diagnosis.

Open-Ended Cloze Task: A type of reading comprehension task that involves several short passages (1 to 3 sentences) with a missing word in a sentence. Individuals are required to vocalize a word that they think best fits within the sentence (e.g., *Please set the table. It is time for* ______;Woodcock, 1998).

Maze Cloze Task: A type of reading comprehension measure that involves a single passage with three-word choices every 7th word (except for the first sentence). Individuals are required to circle the word that they think best fits the sentence. (e.g., *The children are still street/fun/playing outside*; Fuchs & Fuchs, 1992).

Current Theories of Reading Comprehension

Reading is a complex task that involves a number of processes at multiple levels with the ultimate goal to understand text. To achieve understanding, readers go through a process that progresses from visual recognition of letters to phonological processing to comprehension of syntax to higher level discourse processes such as inferencing, which all underlie comprehension of meaning (Plaut, 2005). Word level processes include word identification – decoding print and retrieving word meaning. Sentence and discourse level processes form structures of specific ideas into sentences and then integrate meanings across them, resulting in a mental representation of what the text describes (Long, Johns & Morris, 2006). Different theories and models of reading comprehension, such as the Construction-Integration Model, have been developed to help understand the complexity of reading (Kintsch, 1994). The Construction-Integration Model has been influential in explaining the entire process of reading comprehension. The Construction-Integration Model focuses on two phases: the construction phase and the integration phase. During the construction phase, a reader decodes a word and the readers' mind activates all of the words' meanings (vocabulary) and semantic associates (background knowledge) to create a textbase. The textbase is a literal memory of what has been read but is not yet coherent to the reader. During the integration phase, a coherent mental representation of the text is created from text information being integrated through inferences, connections and interpretations being made from background knowledge (Kintsch, 1994). Another model, The Simple View of Reading, has been influential in explaining different reading ability profiles in the literature and focuses on two main components of reading comprehension: word recognition/word decoding and oral language comprehension (Gough & Tunmer, 1986). According to this model, successful reading comprehension is a product of decoding print and oral language comprehension, suggesting that reading comprehension cannot occur unless both decoding and language comprehension are well-developed.

One of the best predictors of decoding and reading acquisition is phonological awareness (Stahl & Murray, 2006; Stanovich, 1991). Phonological awareness refers to the awareness of individual sounds (phonemes) in spoken words. The relationship between reading acquisition and phonological awareness is well-established and researched (see Adams, 1990, for a review;

Stahl & Murray, 2006). Closely related to phonological awareness is the ability to map letters to sounds and knowing that letters represent sounds is the key to decoding when learning to read. Decoding has been referred to as the bottleneck of comprehension, meaning that poor decoders will also struggle with reading comprehension (Siegel, 1993; Perfetti, 1985). Beginner readers who are good decoders are able to 'sound out' a word when the word is new or unfamiliar (Stahl, Duffy-Hester & Dougherty Stahl, 2006). Once readers have been exposed to specific words multiple times they are able to recognize those words at a glance and read them "by sight" (Ehri, 2006).

The rate or speed at which someone reads words or text accurately and effortlessly is called reading rate or reading fluency (Stahl & Heubach, 2006), and is thought to be reflective of efficient word decoding skills. Reading rate is generally measured by either contextual or context-free tasks. Contextual reading rate tasks involve timing the reading of paragraphs or sentences (words connected to text; e.g., Brown, Fishco & Hanna, 1993), whereas context-free reading rate tasks involve timing the reading of lists of unrelated words (e.g., Torgesen, Wagner & Rashotte, 1999). The relationship between reading rate and reading comprehension was established early in reading research (Traxler, 1932). Although the strength of correlations between these constructs have varied across studies, reading rate has been positively correlated with reading comprehension and has predicted unique variance in reading comprehension performance (Cutting & Scarborough, 2006; Keenan et al., 2008; Kendeou, Papadopoulos, & Spanoudis, 2012).

Having the ability to decode and read words by sight at an adequate rate does not ensure comprehension; however, it is argued that if these basic processes are mastered, then more capacity is available for language comprehension and other the higher order processes of reading comprehension. Conversely, when they are not mastered, there is limited cognitive capacity left for these higher order processes (Perfetti, 1985; Perfetti & Hart, 2002; Stanovich, 1988). Oral language comprehension, including vocabulary, inference making, comprehension monitoring, general knowledge, and working memory are all higher order processes that have been identified to contribute to comprehending a text and to account for individual differences in reading comprehension. Positive associations between these skills and reading comprehension have been observed in multiple studies, indicating that better comprehension is more likely if these higher order processes are functioning at high level (Cain & Oakhill, 2009; Perfetti, Landi & Oakhill, 2005).

Oral language comprehension and vocabulary knowledge have been repeatedly examined in reading comprehension studies, since understanding language is imperative to understanding text. Vocabulary knowledge has been identified as having two interdependent dimensions: breadth and depth. The breadth of vocabulary refers to the size or number of words for which an individual has at least minimal knowledge of the meaning (Nation, 2001). The depth of vocabulary refers to how well an individual knows a word or the level of knowledge and number of semantic associations or representations an individual has surrounding a word (Read, 1993). Reading a word without having at least minimal vocabulary knowledge (i.e., poor depth) may jeopardize understanding the meaning of the entire text. Consequently, reading comprehension is strongly correlated with both the breadth and depth of an individual's vocabulary knowledge, and vocabulary has been repeatedly shown to predict reading comprehension, especially in adults (Gough, Hoover & Peterson, 2008; Keenan et al., 2008; Landi, 2010; Williams, Ari & Santamaria, 2011). Although there is also a strong correlation between the depth and breadth of knowledge of an individual's vocabulary and reading comprehension, the depth of one's vocabulary has been shown to be a stronger predictor and has made larger unique contributions to reading comprehension performance (Quian, 1999). Furthermore, research has shown that the breadth of one's vocabulary is a better predictor of decoding and word recognition skills, whereas the depth of one's vocabulary is a better predictor of reading comprehension (Ouellette, 2006).

Background knowledge, the prior content knowledge we have about a subject or theme (including vocabulary knowledge), and memory skills have been identified as important components involved in comprehending text. When reading a text, readers must be able to rapidly access information such as general knowledge, relevant topic knowledge, and what they have already read. This requires access to prior knowledge stored in long term memory, but also the use of working memory. Working memory involves the storage and processing of information and is required to hold representations of words and sentences active while simultaneously processing other parts of the text and background knowledge (Cowan, 2008; Nation, 2005). Reading span is a commonly used measure of working memory originally developed by Daneman and Carpenter (1980). Daneman and Carpenter's reading span task requires individuals to read sets of unrelated sentences and later recall the last word of each sentence. Individuals are required to hold the final words of the sentences active while also engaging in a secondary task (e.g., reading sentences) that is interfering and requires executive control (Cowan, 2008). Measures of working memory have been found to be highly correlated with reading comprehension measures (Perfetti et al., 2005; Singer, Halldorsen, Lear, & Andrusiak, 1992). Individual differences in working memory contribute to differences in reading comprehension (Cain & Oakhill, 2009), and working memory has been shown to be a significant predictor of reading comprehension in children and adults (Cutting & Scarborough, 2006; Kendeou et al., 2012).

Inferences are one type of higher level comprehension process required while reading because a text is never or rarely explicit. Readers are required to infer meanings throughout text by referring to and integrating information obtained from text with prior knowledge (Cain & Oakhill, 2009; Perfetti et al., 2005, Kintsch & Rawson, 2005). Inferences can be made to make text coherent, make predictions, make connections, or conclude causes (Perfetti et al., 2005). Kintsch and Rawson (2005) give the example, '*Fred parked the car. He locked the door'*. In this example, the reader must infer that '*door*' is referring to '*car door'*. The reader must use the information that was given in the first sentence and prior knowledge that cars have doors. Inference making is critical in text comprehension and failing to make inferences will compromise comprehension. Consequently, inference making is associated with individual differences in reading comprehension; the better a reader understands text, the better the reader is able to make inferences and vice versa (Cain & Oakhill, 2009).

Comprehension monitoring, the act of thinking about and continuously monitoring understanding, is also identified as an important higher-order process for reading comprehension. Comprehension monitoring enables the reader to integrate and infer information as well as to take remedial action if their understanding is impeded. The ability to identify inconsistencies in information helps readers to decide when to make inferences and connections to make text more clear (Cain & Oakhill, 2009). Therefore, readers who fail to monitor comprehension while reading text may also fail to infer and integrate pieces of information throughout it as well. In contrast, if a reader is successfully able to monitor comprehension while reading text, then the probability of making necessary inferences and integrating information throughout the passage is higher, resulting in better comprehension. Consequently, comprehension monitoring predicts individual differences in reading comprehension (Cain & Oakhill 2009; Oakhill & Yuill, 1996).

Therefore, theories of reading comprehension, such as the Simple View of Reading, assume that to comprehend text, one must be able to automatically map letters to sounds, and further, to decode printed words accurately and fluently (Stanovich, 1988). This leads to the assumption that students who struggle with word reading will consequently struggle to understand the meaning of what they are reading in texts. Difficulty with decoding may result in difficulty in sounding out unfamiliar words in text, resulting in inadequate development of sight words. Difficulty with recognizing words by sight may result in slower reading rate. This may ultimately affect comprehension because too much cognitive effort is used to decode and not on processing and remembering the meaning of what has been read. Finally, comprehension cannot be successful with failure to retrieve word meanings (Perfetti et al., 2005). Ultimately, it is argued that if these basic processes are mastered, then greater capacity is available for the higher level processes (e.g., comprehension monitoring and inferencing) of reading comprehension and, conversely, when they are not mastered, there is limited cognitive capacity for the higher order processes needed for reading comprehension (Perfetti, 1985; Perfetti & Hart, 2002; Stanovich, 1988).

Reading Comprehension in Adults

Although reading is a skill that most people acquire with relative ease well before adulthood, there are some adults who still struggle with reading. Their underlying cognitive processes supporting reading appear to be not as well developed. When there is a deficit in one or more of the processes involved in reading, reading comprehension can be compromised. Individuals who struggle with reading are typically labeled as having a specific reading disorder, or more specifically, dyslexia if their problems stem from deficits at the word level. As mentioned, a large proportion of reading research, especially on reading difficulties, has been with children, whose skills are in the process of developing (Snowling, 2000); however, studying reading in individuals whose reading skills should be fully developed, such as in highly skilled adult readers, can also give insight to this complex construct. University students are considered high-functioning adults, whose reading development is assumed to be advanced. Studying reading within this particular population, for the most part, gives researchers the opportunity to examine it without the presence of notable reading difficulties (Landi, 2010).

Although reading disorders are life-long, persistent, and, for many individuals, can have a significant negative impact throughout life (Kemp et al., 2009), recent studies have identified a group of university students who, despite having a history of reading difficulties, comprehend just as well as their student peers (Gallagher et al., 1996; Hatcher et al., 2002; Kemp et al., 2009). Surprisingly, while these students are able to comprehend text at the same level as other university students, they still have persistent difficulties with phonological awareness (Deacon, Cook & Parrila, 2012), decoding (Deacon et al., 2012; Parrila, Georgiou & Corkett, 2007; Pennington, van Orden, Smith, Green & Haith, 1990), word reading accuracy (Bruck, 1990; Deacon et al., 2012; Parrila et al., 2007), word reading rate (Deacon et al., 2012; Gallagher et al., 1996; Pennington et al., 1990), text reading rate (Parrila et al., 2007), and spelling (Gallagher et al., 1996; Kemp et al., 2009). Due to their academic success in the face of these deficits, these students have been termed as ‘compensated dyslexics’ (Lefly & Pennington, 1991), ‘college age resilient readers’ (Welcome, Chiarelle, Halderman, et al., 2009), ‘university students with a significant history of reading difficulties’ (Corkett, Parrila & Hein, 2006), and ‘high-functioning dyslexics’ (Kemp et al., 2009). These students are labeled as ‘high-functioning’, ‘compensated’ or ‘resilient’ since they are enrolled in post-secondary education and coping with the high literacy demands of postsecondary education (Deacon, Parrila, & Kirby, 2006). They are also increasingly enrolling in postsecondary education compared to the past (Vogel et al., 1998), with 2-5% of university students enrolling to receive assistance from student disability services (Harrison & Wolfort, 2012). These students’ difficulties at the word level of reading have not disappeared, yet they are able to achieve the same level of comprehension as their peers. For example, Parrila and colleagues (2007) examined reading, spelling and phonological skills of university students with a self-reported history of reading problems and compared their performance to that of university students with no history of reading difficulties. Findings indicated that the majority of students with a history of reading difficulties performed just as well as controls on reading comprehension when untimed. However, most students with a history of reading problems scored significantly worse than the controls on word reading, spelling, decoding, and reading rate measures.

Theoretical models of reading development are unable to explain how these students achieve high levels of reading comprehension with poor basic processing skills (Deacon et al., 2012). Although The Simple View of Reading has been an influential model in the reading literature, it does not explain how university students with poor decoding skills are capable of adequate comprehension. Similarly, Perfetti (1985) emphasizes the importance of word level automaticity in reading comprehension. He would argue that an individual who struggles at the word reading level would struggle to comprehend text due to more cognitive/attentional resources focusing on the word level processes and fewer resources being available for high level reading comprehension processes. Ehri’s (1995) theory also seems to suggest that fully developed phonological awareness is crucial for the development of subsequent reading processes. However, the success that high-functioning individuals with dyslexia have accomplished with reading, challenges these theoretical models, leading to questions regarding how they are able to comprehend so well with their word level reading difficulties.

Assessing Reading Comprehension and Reading Rate

Clearly, reading comprehension is a complex process that involves many components, making it difficult to measure. Despite the many components involved, reading comprehension tasks commonly measure it as a unitary construct, leading to the assumption that they are all measuring the same skill; however, the contributions of the many components can be variable across reading comprehension measures. For example, studies have shown only modest correlations among children's reading comprehension tests, and that the unique contributions of different component skills, such as word reading, listening comprehension and reading rate, vary depending on the reading comprehension test (Cutting & Scarborough, 2006; Keenan et al., 2000; Nation & Snowling, 1997). Since this finding has been well-established with children's reading comprehension measures, it is likely that adult measures contain similar discrepancies. Having a better understanding of which processes contribute to different reading comprehension tasks will help researchers and clinicians to better identify and assist individuals with reading difficulties.

Commonly used tests of adult reading comprehension also have other short-comings. Most notably, there are not many tests designed for adults and the few available have long administration times (Williams et al., 2011). This is problematic in many situations, such as in research studies where reading comprehension is not of primary interest and in situations involving the general public in which a quick screening measure of reading comprehension would be beneficial (e.g., reading a consent form). One common type of reading comprehension measure involves individuals silently reading passages followed by answering various types of multiple choice questions. Examples include the *Nelson-Denny Reading Test* (ND; Brown, Fischo & Hanna, 1993), which has an administration time of 20 minutes, and *The Scholastic Abilities Test for Adults* reading comprehension subtest (SATA; Bryant, Patton & Dunn, 1991), which has an administration time of 15 minutes. Another common type of reading comprehension measure is the open-ended cloze task, such as in the *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1998), which involves the reader providing a word missing from a passage. These tasks can also take a significant amount of time to administer.

There are also few measures of text reading rate. The most popular are embedded in measures of reading comprehension, such as the ND reading rate measure, and consequently, they are also time-consuming (Lewandowski et al., 2003; Williams et al., 2011). Although the ND is one of the most commonly used measures of reading rate, it has been criticized for poor reliability and not being effective in measuring reading rate in adults, since it does not differentiate if readers are skimming or reading for comprehension (Perkins, 1984; Lewandowski et al., 2003). Not only is there a need to better understand current reading comprehension tasks in terms of the component skills involved, there is also a need for efficient, yet accurate measures of reading comprehension and reading rate within the adult population.

Current Dissertation

The current dissertation consists of three studies that examine reading comprehension and reading rate in university students. The first paper focuses on testing whether brief versions of standardized reading comprehension measures could provide a reasonable estimate of reading comprehension in less time. It also compares a newly created measure of reading rate to existing measures. Results suggest that a computerized brief version of the *Scholastic Abilities Test for*

Adults reading comprehension subtest (Bryant, Patton & Dunn, 1991) and a Curriculum Based Measurement (CBM) Maze task are quick and reliable estimates of reading comprehension and can also provide estimates of reading rate.

The second paper examines how different component skills of reading comprehension contribute to performance on different reading comprehension tests. Specifically, the study examines how four different reading comprehension tests are affected by word reading rate, sentence and text reading rate, and working memory skills. Across the four reading comprehension measures, the total amount of variance explained by the different components varied. Overall, word reading rate appears to account for minimal variance in adult reading comprehension performance, but sentence and text reading rate are better predictors of performance. Furthermore, working memory appears to be a significant predictor of reading comprehension.

The third study focuses on text reading rate and question-answering speed during reading comprehension tasks in students with and without a history of reading difficulties. Results indicate that the groups differ significantly on text reading time as well as the time they took to answer certain types of questions.

Overall, this dissertation provides information to researchers, clinicians, and other parties who may need to assess reading comprehension and rate in adults. It provides detailed information regarding commonly used measures of adult reading comprehension and rate so that practitioners carrying out reading assessments can make more informed decisions when choosing measures. It also offers suggestions for alternative, more efficient ways of measuring reading comprehension and rate. In addition, the findings contribute to the growing body of research focusing on high-functioning adults with a history of reading difficulties, and provide insight into their reading skills and processes.

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Chapter II: Assessing Reading Comprehension Effectively but Efficiently in University Students

Introduction

There are currently few standardized reading comprehension and reading rate measures for adults (Williams et al., 2011). Existing standardized reading comprehension measures for adults are time consuming and can take up to 30 minutes to administer, while existing reading rate measures for adults are often embedded within reading comprehension subtests, and therefore also require a significant amount of time (Lewandowski et al., 2003). This is problematic in situations where a quick screening measure of reading comprehension would be useful (e.g., before completing forms or signing documents at a physician's office) or when conducting reading research studies with adults (e.g., university students). Reading comprehension and reading rate tests take up a considerable amount of research study and clinical assessment time, which is not ideal, especially when reading comprehension is not the main focus. The goals of the current study were to examine if current reading comprehension measures can be modified to save time during testing while preserving reliability and validity, and to develop an efficient and accurate measure of reading rate.

Two commonly used reading comprehension measures for adults are the *Nelson-Denny Reading Test* (ND; Brown, Fischo & Hanna, 1993) and *The Scholastic Abilities Test for Adults* reading comprehension subtest (SATA; Bryant, Patton & Dunn, 1991). Both of these measures are traditional paper and pencil tests with time limits. They are valid and reliable measures of reading comprehension for adults, but they are also time consuming to administer, and not computerized. The SATA consists of passages that are followed by multiple-choice questions, including literal and inferential questions, as well as questions about the main idea, vocabulary and background knowledge. It does not include a measure of reading rate, but has a time limit of 15 minutes. Similarly, the ND also consists of passages followed by multiple-choice questions, but has a time limit of 20 minutes. The ND is also one of the few tests to include a reading rate measure embedded within the reading comprehension subtest. Although the ND is widely used as a measure of reading rate, it has been criticized for poor reliability and not being effective for measuring reading rate in adults (Perkins, 1984; Lewandowski et al., 2003). The format of the ND reading rate test does not differentiate if readers are skimming, scanning, memorizing, or reading for understanding, which may affect the speed of reading. However, since there are few other reading rate measures available for adults, the ND reading rate measure is commonly used both clinically and in research despite its shortcomings (Gordo & Flippo, 1983; Lewandowski et al., 2003).

The *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1998) passage comprehension subtest is another commonly used standardized adult reading comprehension test. It differs from the SATA and the ND as it involves open-ended cloze passages. Open-ended cloze tasks involve a missing word (blank) within a sentence of a passage and participants are required to provide a word that fills in the blank, whereas maze cloze tasks provide three-word choices within a sentence of a passage. It has been argued that cloze tests are efficient at measuring reading comprehension since a high number of items can be completed in a short amount of time (Gellert & Elbro, 2013); however, the WRMT-R does not have a time limit, but rather a suggested maximum time of 30 seconds per item, unless the examinee clearly requires more time, and a discontinue criterion (discontinue after 6 consecutive incorrect answers); as a result, it can also take a significant amount of time to administer with post-secondary students.

Another type of reading comprehension measure that uses the cloze design is the curriculum-based measurement (CBM) maze task. In contrast to the WRMT-R that omits words in sentences, the CBM Maze tasks provide word choices within the passage (Fuchs & Fuchs, 1992; see an example in Appendix A). In addition, CBM maze tasks are timed and the examiner stops the task after a certain amount of time, typically three minutes. Although they are more widely used in measuring reading comprehension in children (Fuchs & Fuchs, 1992) and have been criticized for only measuring low-level reading processes, these tasks have begun to be recognized for their efficiency and ability to measure reading comprehension effectively in adults. For example, Gellert and Elbro (2013) created a 10-minute Danish maze cloze task that correlated strongly (r = .84) with a standardized reading comprehension measure that typically took 30 minutes to complete, suggesting that an efficient maze cloze task can perform comparably to a time-consuming question-answering test. Similarly, Williams and colleagues (2011) compared struggling and non-struggling post-secondary students' performance on open-ended cloze and CBM maze tests. Participants were given 3-minute open-ended cloze and CBM tests in addition to the ND reading comprehension measure. Significant inter-correlations between the open-ended (r =.52) and CBM (r = .68) tasks and the ND reading comprehension subtest suggested that maze tasks are effective at measuring reading comprehension in adults.

Present Study

The first goal of the current study was to test whether brief reading comprehension measures can provide a reasonable estimate of reading comprehension in less time than standardized reading comprehension measures require. To create a variety of brief tests, shorter versions of the SATA reading comprehension subtest and the ND reading comprehension subtest were created by eliminating some of the passages. Both SATA versions were computerized:

participants read passages and questions one at a time on a computer screen and were unable to review text or their previous answers. Since this task was completed on the computer, it also provided a reading rate measure of participants' passage reading times. The third brief measure was a CBM Maze task that had a 3-minute time limit to read the whole passage.

The second goal of the study was to compare participants' performance on a newly created experimental sentence level reading rate task to the ND reading rate and the SATA passage reading rate estimates. There are few reading rate measures for adults but given its significance in different theories of reading comprehension (see e.g., Ehri, 1995; Gough & Tunmer, 1986; Perfetti, 1985), it would be highly beneficial to have alternative and possibly more efficient ways to measure it as well (Lewandowski et al., 2003).

All participants completed the standardized WRMT-R passage comprehension subtest, the CBM Maze test, the ND reading rate measure, the experimental sentence reading rate measure and either the brief or full versions of the ND and computerized SATA. The primary purpose of the study is to explore associations among the different reading comprehension estimates and reading rate estimates by examining inter-correlations between them. This battery of tests allows for comparisons between the full and brief versions of the reading comprehension measures, in addition to a traditional standardized reading comprehension measure. It also allows for a comparison between reading comprehension and rate measures, including the experimental sentence reading rate measure, the ND reading rate measure, and the SATA passage reading times.

Method

Participants

Participants were 237 university students recruited from a large Canadian University. All participants reported normal or corrected-to-normal hearing and vision and English as their first language. The mean age of the participants was 22.22 years (*SD* = 3.36). There were 181 female students and 56 male students. Eligible students were recruited through announcements in undergraduate classes and word-of-mouth. Students who were eligible received educational psychology course credit as compensation for their participation.

Measures

From a larger battery of administered tests, a subset of measures was selected for the analyses of this study. These included three standardized reading comprehension measures, two experimental brief reading comprehension measures, the CBM Maze reading comprehension measure, a commonly used reading rate measure and an experimental reading rate measure.

Nelson-Denny Reading Test: Reading Comprehension and Reading Rate Measures. Participants completed the reading comprehension subtest from the *Nelson-Denny Reading Test*-Form G (ND; Brown et al., 1993), which also includes a reading rate measure. The ND is a standardized reading comprehension measure that has seven passages with 38 comprehension questions. It has a 20-minute time limit to complete, making it partially a power test (i.e., a reading comprehension test influenced by performance speed). Participants who completed the full version of the ND were administered the ND reading comprehension subtest in the standardized format. It has a reported reliability coefficient of .81.

To create a brief version of the ND, three passages were removed. The passages of the ND increase in difficulty, therefore the easiest and most challenging passages were included in the brief version. The brief version included the first, third, fifth and seventh passages from the full version. There were 23 comprehension questions in total. The first passage was included in both versions and the number of words read on the first passage in 1 minute determined the reading rate score. Similar to the full version, participants were given a 20-minute time limit.

Participants either completed the brief or full version of the ND. Raw scores were used for analyses.

Scholastic Abilities Test for Adults Reading: Reading Comprehension Measure. The standardized full paper-and-pencil version of the SATA involves passage readings with multiple-choice questions (SATA; Bryant et al., 1991). The SATA has reported internal consistency coefficients between .90 and .94 for adults between the ages of 18 and 39 years old, and a test-retest reliability coefficient of .71. The SATA consists of ten passages, ranging from 59-179 words, that are each followed by six multiple-choice questions. The first question involves choosing the main idea, the second question involves vocabulary, the third and fourth questions are literal (explicit information), the fifth question is inferential (infer and integrate information), and the sixth question involves background knowledge. The SATA was administered on a computer using the reaction time software program Direct RT ©. In contrast to the standardized paper and pencil version, the computerized version did not allow participants to go back and review text or answers. Passages were presented individually on the screen. Once participants finished reading the passage, they were instructed to press the space bar to continue with questions about the passage. Multiple-choice questions were presented one at a time and participants pressed the number key corresponding to the answer they thought was correct. The next question was presented immediately after the key press. As per standardized instructions, participants were given a time limit of 15 minutes. The number of questions participants answered correctly within the 15- minute time limit determined their reading comprehension score. Raw scores were used for analyses.

To create the brief version of the SATA, half of the passages and questions were removed. The second, fourth, sixth, eighth, and tenth passages were included in the brief version, leaving a total of 30 questions (six for each passage). The passages of the SATA increase in difficulty, therefore the easiest and most challenging passages were included in the brief version. Similar to the full version, participants were given a 15-minute time limit. The time it took participants to read each passage and read and answer each question was recorded separately. Both brief and full versions of the SATA included the fourth passage and the time to read this passage was recorded in milliseconds. To allow for comparisons between reading rate measures, times were converted to words read per minute (Table 1), but raw scores (multiplied by -1) were used in the correlation analyses.

Woodcock Reading Mastery Test-Revised: Passage Comprehension Subtest. The passage comprehension subtest from the *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1998) was administered to all participants to obtain a standardized measure of reading comprehension. The test consists of short passages (two or three sentences) and the goal is to identify the key word missing from one sentence within the passage. Participants are instructed to read the passages silently and then orally state a word that belongs in the blank space, that makes the passage make sense. Testing was administered in the recommended standardized format and was stopped after six consecutive errors, as recommended in the manual. Participants were also given as much time as needed to complete the items, as recommended in the manual, and were only instructed to attempt the following question if they provided an answer or indicated that they did not know the answer. The reported split-half reliability coefficient for this age level is .82. The participant's score was the number of correct missing words named. Raw scores were used in all analyses.

Curriculum Based Measurement Maze Test. A Curriculum Based Measurement Maze test (CBM Maze) was administered to all participants. Participants read a modified newspaper article (Pfister, 2001) that had a three-word choice for every 7th word that was left blank in each sentence, after the first sentence in the passage, which was intact. There were 75 word-choice items in the passage. Not including the three-word choices, the passage was 478 words in length. The three-word choice items were designed so that the correct words were considered to be 'obvious' in the context of the sentence (e.g., "*The children are still street/fun/playing outside*."). The CBM Maze tests are considered to be strong measures of both reading comprehension and word recognition (Fuchs & Fuchs, 1992). There was a 3-minute time limit and the number of correct choices was recorded and used in analysis. None of the participants completed reading the entire passage within the 3-minute time limit. See Appendix A for a copy of the test.

Experimental Yes/No Decision Reading Rate Measure. A brief experimental reading rate measure was created and administered to all participants, using sentences adapted from an adult reading span task (Daneman & Carpenter, 1980). Participants were presented with 20 sentences one at a time that they had to judge as either reasonable (e.g., *The lumbermen worked long hours in order to obtain the necessary amount of wood)* or unreasonable (e.g., *The intensity of the fire was starting to dwindle so he removed another log to keep warm*). Sentences were presented individually on the computer using Direct RT ©. If participants judged the sentence as reasonable, they would press the Y key and if they judged the sentence as unreasonable, they would press the N key. Total reaction times (ms) for sentence reading and yes/no decision-making were recorded for each item. To allow for comparisons between reading rate measures, times were converted to words per minute (Table 1), but raw scores (multiplied by -1) were used in the correlation analyses.

Procedure

All sessions were completed in a reading research laboratory. Since data collected were being used for other research purposes, participants completed other tasks not reported in this paper. Participants completed measures in a randomly assigned order. Unless participants were unable to due to time constraints, all participants were administered WRMT-R, CBM Maze, ND reading rate and the experimental reading rate measure. Participants were randomly assigned to complete either the full or the half versions of the ND and SATA reading comprehension measures. All tasks were administered individually and sessions lasted approximately two hours.

Results

General descriptive statistics for all measures are presented in Table 2.1. The few outlying scores were adjusted so that they were one unit above or below the next highest or lowest score in the sample, which was not an extreme score (Tabachnick & Fidell, 2007).

As shown in Table 2.1, skewness and kurtosis values of all reading comprehension and reading rate measures fell between -1.0 and 1.0, which is considered an acceptable range (Tabachnick & Fidell, 2007), indicating that the distribution was approximately symmetric and not overly peaked or flat. Cronbach alpha reliabilities of the reading comprehension measures ranged from .56 (Brief ND) to .95 (CBM Maze), and were in acceptable range with the exception of Brief ND whose reliability estimate is possibly compromised by the relatively small number of participants who completed this measure. Cronbach's alphas calculated for the two tests presented in standardized format, WRMT-R and Full ND, were .76 and .84, respectively. These estimates are comparable to the reliability coefficients reported in their respective manuals.

The mean times in minutes for participants to complete the full and brief versions of the ND and SATA are presented in Table 2.2 together with the completion rates (percentage of participants who completed all questions within the given time limit).

Table 2.1

Descriptive Statistics for the Reading Comprehension and Reading Rate Measures

	N	Mean	SD	Range	Skew	Kurtosis	α
WRMT-R	229	57.54	4.65	45-68	-.220	-.267	.761
Full ND	170	28.01	6.11	11-38	-.633	-.253	.841
Brief ND	61	19.13	2.65	13-23	-.797	.015	.563
Full SATA	88	38.11	6.48	23-50	-.538	-.500	.741
Brief SATA	138	20.00	2.98	11-26	-.220	-.657	.807
CBM Maze	235	39.83	8.33	18-61	-.070	-.237	.945
NDRR	230	241.78	67.64	84-398	.722	.002	
Exp. RR	221	149.26	37.80	84-248	.539	-.063	
SATA RR	229	173.08	59.50	80-330	.623	-.148	

Note. WRMT-R= *Woodcock Reading Mastery-Revised* reading comprehension subtest; Full ND= Full version of the *Nelson-Denny Reading Test* reading comprehension subtest; Brief ND= Brief version of the *Nelson-Denny Reading Test* reading comprehension subtest; Full SATA=Full version of the *Scholastic Abilities Test for Adults* reading comprehension subtest; Brief SATA= Brief version of the *Scholastic Abilities Test for Adults* reading comprehension subtest; CBM Maze= Curriculum Based Measurement Maze reading comprehension task; NDRR= *Nelson-Denny Reading Test* Reading Rate measure; Exp. RR= Experimental Reading Rate measure; SATA RR = Reading Rate of the 4th passage on the *Scholastic Abilities Test for Adults* reading comprehension subtest.

The mean time to complete the brief SATA was approximately 9 minutes and the mean time to complete the brief ND was approximately 13 minutes; both times represent a saving of 5 minutes compared to the full versions of these tests. Further, 94 (55 %) and 21 (24 %) participants did not complete all the items in 20/15 minutes given for the full versions, whereas only three participants did not complete the brief ND version and all participants completed the brief SATA version within the given time. Thus, the brief measures appear to be purer measures

Table 2.2

Mean Completion Times (minutes) and Rates (%) of Reading Comprehension Tests

	Time	Rate
Full ND	18.35	45
Brief ND	13.43	95
Full SATA	13.99	76
Brief SATA	8.84	100

Note. ND= *Nelson-Denny Reading Test* reading comprehension subtest; SATA= *Scholastic Abilities Test for Adults* reading comprehension subtest

of reading comprehension with performance on the full versions likely affected more by the respondents' reading rate.

The first-order correlations between the measures are presented in Table 2.3. Using Cohen's criteria (Tabachnick & Fidell, 2007), correlations above .50 are considered large and correlations above .30 are considered moderate. In general, correlations between reading comprehension measures were moderate. The only exceptions to this were the large significant correlations between the full and brief versions of the SATA and the WRMT-R passage comprehension subtest. The full version of the ND was moderately and significantly correlated with the WRMT-R passage comprehension subtest, while the brief version of the ND had a significant but weak positive correlation with the WRMT-R passage comprehension test. The full version of the ND was moderately and significantly correlated with both versions of the SATA, whereas the brief version of the ND was not significantly correlated with the full or brief versions of the SATA.

The full versions of the ND and SATA measures were also more strongly correlated with the reading rate measures than their respective brief versions, as further evidence that comprehension performance on the full versions may be more dependent on reading rate than comprehension performance on the brief versions.

Table 2.3

Correlation Coefficients between Reading Comprehension Variables

	3	4	5	6	7	8	9
1. Full ND	.344*	.308**	.377**	.416**	.242**	.362**	.401**
2. Brief ND	.212	.340	.283*	.231	.129	.094	-.015
3. Full SATA			.585**	.272*	.194	-.100	.396**
4. Brief SATA			.540**	.115	.062	.051	-.134
5. WRMT-R				.304*	.296**	.178*	.201**
6. CBM					.429**	.485**	.349**
7. NDRR						.373**	.307**
8. Exp. RR							.417**
9. SATA RR							

Note. WRMT-R= *Woodcock Reading Mastery-Revised* reading comprehension subtest; Full ND= Full version of the *Nelson-Denny Reading Test* reading comprehension subtest; Brief ND= Brief version of the *Nelson-Denny Reading Test* reading comprehension subtest; Full SATA=Full version of the *Scholastic Abilities Test for Adults* reading comprehension subtest; Brief SATA= Brief version of the *Scholastic Abilities Test for Adults* reading comprehension subtest; CBM Maze= Curriculum Based Measurement Maze reading comprehension task; NDRR= *Nelson-Denny Reading Test* Reading Rate measure; Exp. RR= Experimental Reading Rate measure; SATA RR = Reading Rate of the 4^{th} passage on the *Scholastic Abilities Test for Adults* reading comprehension subtest.
$*p < .01$. $**p < .001$.

The CBM Maze task was moderately correlated with the WRMT-R passage comprehension subtest and with the full version of the ND. There was also a significant but weak correlation between the CBM Maze task and the full version of the SATA. The CBM Maze task, a timed reading comprehension measure, was also moderately and positively correlated with all three reading rate measures.

As seen in Table 2.3, all correlations between the reading rate measures, including the CBM Maze task, were moderate but significant. Somewhat surprisingly, these correlations were not more substantial than correlations between comprehension measures. In general, correlations between reading comprehension and reading rate measures were weak, with the exception of the SATA reading rate measure that correlated moderately with both full versions of the ND and SATA.

Discussion

The first purpose of the current study was to examine whether brief reading comprehension measures could be used to reliably estimate reading comprehension level. The results of the current study indicate, not surprisingly, that brief versions of standardized reading comprehension measures are faster to administer than full versions of the measure, about 5 minutes faster in both cases. Although three passages were removed in the brief ND, the test was not as efficient (i.e., under 10 minutes) as hoped. The computerized version of the SATA, however, appeared to be more efficient to administer than the paper-pencil format of the ND. The brief SATA took on average less than 9 minutes to complete, which we consider efficient for obtaining an estimate of reading comprehension. In addition, the brief SATA was strongly correlated with the WRMT-R passage comprehension subtest, supporting the validity of the test. The correlations between the brief and full SATA versions with the WRMT-R were comparable and the only large correlations observed in this study despite the different response formats of the tests. The brief SATA also had comparable internal consistency to the full version of the SATA.

The SATA also appeared to provide a reasonable estimate of reading rate when administered on a computer. The SATA reading rate measure was moderately correlated with other measures of reading rate. It was also correlated with full versions of both ND and SATA reading comprehension measures, but not the brief version, suggesting that the 20 and 15-minute time limits for these tests are not sufficient for some university students to complete all items, and that the brief version of the SATA may be a purer measure of reading comprehension and less of a power test (i.e., a reading comprehension test influenced by time). In sum, these results suggest that the brief computerized version of the SATA gives an adequate estimate of both reading rate and comprehension, which could be useful in research protocols where reading comprehension must be assessed but is of secondary interest. In contrast, the brief version of the ND had poorer internal consistency and slower administration time. It also had a weaker correlation with the WRMT-R, compared to the moderate positive correlation between the full version of the ND and the WRMT-R, suggesting that the brief version of the ND may not be as accurate as the full version in measuring reading comprehension.

The final brief measure of reading comprehension was the CBM Maze task, which had the fastest administration time in three minutes. It was also moderately correlated with both the full version of the ND and the WRMT-R. As a power test, the CBM Maze task was also moderately correlated with all measures of reading rate, indicating that it may also be used to estimate reading rate. Overall, the CBM Maze task presents as a good brief screening measure for both reading comprehension and rate. These results are consistent with earlier studies that have found CBM Maze tasks to be effective measures of reading comprehension with children (Fuchs & Fuchs, 1992) and, more recently, with adults (Gellert & Elbro, 2013; Williams et al., 2011).

The second purpose of the study was to examine associations between different reading rate measures. The experimental sentence reading rate measure was moderately correlated with both the ND and SATA reading rate measures, suggesting that it could be used as an alternate measure of reading rate. The sentence reading rate measure attempted to measure post-secondary students reading rate by using adult reading level sentences, controlling for students skimming or scanning text by requiring them to decide if the sentence was reasonable or not by pressing the Y or N keys. Unfortunately, not all sentences were judged with 100% accuracy, which may have been due to some of them being slightly ambiguous or including difficult vocabulary. Further comparisons of the experimental reading rate measure with other measures of reading rate would be useful in future research.

The current study was unable to compare participants' performances on brief ND and SATA versions with their respective full versions due to an unavailability of parallel forms. To support the external validity of the brief versions, future studies may wish to administer full and brief versions of these measures to the same participants with an appropriate amount of time between administrations.

Interestingly, the full version of the ND was only moderately correlated with the full version of the SATA and the WRMT-R, suggesting that these common reading comprehension tests may capture different aspects of reading comprehension. This finding suggests that if in depth understanding of adult reading comprehension is the primary interest of study, multiple measures are needed. Studies comparing reading comprehension tests with children, and more recently with adults, have begun to examine which cognitive processes account for variance in different reading comprehension tests (Cutting & Scarborough, 2006; Keenan, Betjemann & Olson, 2008; Williams et al., 2011). Further research is needed to examine which cognitive processes contribute to different reading comprehension tests and whether some of the tests offer a better overall estimate. In addition, further research could compare full and brief version of standardized tests to examine whether shorter versions of tests are capturing the same processes. Our results extend these concerns of substantial test-specific variance to measures of reading rate that also showed only moderate inter-correlations. In general, correlations between reading rate measures were not stronger than correlations between reading comprehension measures. The fact that individual differences in reading rate tasks appear to be affected by the type of task challenges the assumption that reading rate reflects only decoding automaticity and further research is needed to better understand factors affecting reading rate across different tasks.

The current study was completed with a specific and limited population of university students. To further examine the generalizability of the findings, future research should include a wider range of adult readers at multiple levels of educational attainment. In addition, more research is needed to examine the discriminating ability of reading comprehension measures between struggling and non-struggling readers (Williams et al., 2011). As this study used an unselected sample, it was not possible to ascertain if the brief reading comprehension measures could validly predict reading difficulties or disorders, and in turn, help determine accommodations in post-secondary education.

In conclusion, the results of the study suggest that the computerized brief SATA can produce a quick and reliable estimate of reading comprehension level and is appropriate for use in reading research studies where reading comprehension is of secondary focus. For situations where a quick screening of reading comprehension is required to ensure an individual can understand information provided (e.g., medical information, consent forms), the CBM Maze test provides the most efficient estimate of reading comprehension. In addition, both of these measures produce an estimate of reading rate if one is required.

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Chapter III: Examining the Different Processing Demands of Adult Reading Comprehension Tests

Introduction

Reading is a complex task that involves a number of processes at multiple levels with the ultimate goal to understand text (Plaut, 2006). For example, Perfetti, Landi and Oakhill (2005) discuss the complexity of reading comprehension and how it involves word level processes, such as word identification, phonological awareness and decoding, and higher level processes, such as inference making and comprehension monitoring. The complexity of reading comprehension has made it difficult to construct tests that measure these various processes that contribute to the process of reading comprehension (Paris, 2007; van den Broek et al., 2005). Tests that measure reading comprehension often treat reading comprehension as a unitary construct, failing to recognize the multiple skills and processes involved. This also leads to the assumption that different reading comprehension tests are measuring the same underlying skill when this is not always the case (Keenan, Betjemann, & Olson, 2008). Performance on different reading comprehension tests can be variably affected by different component skills, resulting in two reading comprehension measures that may not correlate significantly with each other or only correlate moderately (Keenan et al., 2008). The purpose of the current study is to examine how four different adult reading comprehension tests are affected by word reading rate, sentence and text reading rate, and working memory skills that are all considered to be important component skills of reading comprehension.

Nation and Snowling (1997) questioned which underlying processing skills reading comprehension tests were measuring in assessment of children aged 7-9 years old. They examined how word reading accuracy and listening comprehension skills predicted performance on two tests: the *Suffolk Reading Scale* (Hagley, 1987), which is a multiple choice sentence completion test (also known as a maze task), and the *Neale Analysis of Reading Ability* (Neale, 1989), which is a test read aloud followed by oral comprehension questions. Results revealed that the reading comprehension measures were highly correlated (r= .75) and influenced by word reading, but that word reading better predicted performance on the *Suffolk Reading Scale*, while listening comprehension better predicted performance on the *Neale Analysis of Reading Ability*. Nation and Snowling (1997) concluded that the tests were measuring somewhat different cognitive skills and suggested that maze reading comprehension tests may load more into word recognition skills.

Similarly, Cutting and Scarborough (2006) examined possible processes that may contribute to performance on different reading comprehension tests in children aged 7 to 15 years. In addition to word recognition/decoding accuracy and listening comprehension, they examined reading speed, working memory, rapid naming, intelligence and attention. They selected three widely used reading comprehension subtests varying in format: the *Gates-MacGinitie Reading Test-Revised* (GM-R; MacGinitie, Maria, & Dreyer, 2000), the *Grey Oral Reading Test-Third Edition* (GORT-3; Wiederholt & Bryant, 1992) and the reading comprehension subtest from the *Wechsler Individual Achievement Test* (WIAT; Wechsler, 1992). The GM-R involves silently reading passages and then answering multiple-choice questions, the GORT-3 involves reading passages aloud followed by multiple-choice questions, and the WIAT involves silently reading passages followed by open-ended questions. Consistent with findings of Nation and Snowling (1997), Cutting and Scarborough also found that word/nonword reading and listening comprehension skills predicted reading comprehension performance, but the unique contributions of each varied depending on the reading comprehension test. Word/nonword reading skills affected performance more on the WIAT subtest than on the other tests (explaining 11.9% of unique variance), while listening comprehension skills affected performance on the GM-R (explaining 15% of unique variance). In addition, Cutting and Scarborough found that reading speed, as measured by the rate of reading words in a story (text), contributed unique variance in all three reading comprehension measures, concluding that text reading rate is an important predictor of reading comprehension. Measures of working memory, overall intelligence, rapid naming skills, and attention did not account for unique variance in any of the measures.

In another study, Keenan and colleagues (2008) examined how word decoding and listening comprehension skills influenced performance on widely used reading comprehension measures in a large sample of 510 children ranging in age from 8 to 18 years of age. Word decoding skills were measured using both timed and untimed word and pseudoword reading tasks. They examined reading comprehension measures from the *Gray Oral Reading Test-3* (GORT-3; Wiederholt & Bryant, 1992), the *Qualitative Reading Inventory-3* (QRI-3; Leslie & Caldwell, 2001), the *Woodcock-Johnson Test of Achievement-III* (WJ-III; Woodcock, McGrew & Mather, 2001) and the *Peabody Individual Achievement Test* (PIAT; Dunn & Markwardt, 2001). Tests used were those that involved silently reading passages and then providing a missing word (i.e., cloze tasks; WJ-III), silently reading sentences and then selecting a picture that matched the meaning (PIAT), reading passages aloud and then answering multiple choice questions (GORT-3), and reading passages aloud and then recalling details and answering short-answer questions (QRI-3). Correlations among the different reading comprehension measures were modest (ranging from .31 to .70), suggesting that they may have been measuring different skills. Further regression analyses revealed that performance on the PIAT and WJ-III reading comprehension measures was influenced more by word decoding skills, while performance on the GORT-3 and QRI-3 was influenced more by listening comprehension skills.

More recently, Kendeou, Papadopoulos and Spanoudis (2012) examined possible processing skills contributing to reading comprehension tests beyond that of word recognition and listening comprehension in Greek speaking children. Specifically, they examined how rapid naming, phonological processing, orthographic processing, word reading rate, vocabulary, and working memory skills predicted individual differences in three commonly used reading comprehension tests: the *Woodcock-Johnson* passage comprehension subtest (WJ; Woodcock et al., 2001), a Curriculum-Based Measurement Maze test (CBM-Maze; Deno, 1985), and a recall test, which included spontaneous and cued recall of central and non-central events from the narrative (van den Broek, 1990). Consistent with studies in English, results indicated that different component processes predict performance on different reading comprehension tests. Orthographic processing and working memory skills were significant predictors of performance on the WJ subtest, whereas word reading rate and vocabulary skills were significant predictors of performance on the CBM-Maze test, and orthographic, phonological, and working memory skills were significant predictors of performance on the recall test. In a subsequent study, Papadopoulos, Kendeou and Shiankalli (2015) examined 8 year-old poor Greek readers' performance on the WJ, CBM-Maze, and recall comprehension tests and discovered four groups of poor reader profiles. Children who performed poorly on the WJ and recall tests also performed poorly on word reading rate and phonological processing measures, while children who performed poorly on the CBM-Maze test also performed poorly on rapid naming, phonological processing, word reading rate and word reading accuracy measures.

The above evidence from child samples supports the argument that reading comprehension tests do not always involve the same component processes, however, there is little research examining whether the same is true for adults' reading comprehension measures. It is possible that different processes have greater or lesser influence on reading comprehension demands as reading development occurs or when reading skills are fully developed, such as in high-functioning adult readers. For example, Gough, Hoover and Peterson (1996) performed a meta-analysis on studies that had measured word reading, listening comprehension and reading comprehension using a variety of tests across education levels. Results of the meta-analysis revealed that the association between reading comprehension and word reading decreased across educational levels (i.e., Kindergarten to University), while the association between listening comprehension and reading comprehension increased. Keenan et al. (2008) also found that the contribution of decoding skills decreased with age on certain reading comprehension tests, most apparently on the PIAT and WJ tests.

Landi (2010) examined whether decoding and vocabulary skills predicted reading comprehension in post-secondary students using the *Nelson-Denny Reading Test* (passages with multiple choice questions; see description below) and results revealed that decoding skills predicted less than 1% of unique variance, while vocabulary predicted 40%. While ceiling effects may have affected these estimates, these results suggest that word reading skills are less crucial for reading comprehension in adults. In contrast, Holmes (2009) investigated the relationship between word recognition skill efficiency and reading comprehension in university students also using the *Nelson-Denny Reading Test* and found a strong correlation between the measures, suggesting that word reading is a crucial process even in highly skilled readers. Finally, Williams, Ari and Santamaria (2011) examined different post-secondary reading comprehension test formats to determine whether performance was correlated and if not, which processes were predicting the different measures. They compared a cloze maze reading comprehension task, an open-ended cloze reading comprehension task and the reading comprehension subtest from the *Nelson-Denny Reading Test*. They found that the different reading comprehension measures were moderately-to-strongly correlated (correlation coefficients ranging between r =.51 to .68) and that vocabulary contributed equally to all three measures, suggesting that the tests were measuring a similar construct.

Present Study

Existing research on component reading processes contributing differentially to performance on different reading comprehension measures have primarily focused on children. In adults, it is less clear which component processes of reading comprehension different reading comprehension tests capture. To build on existing research, the present study investigated how word reading rate, sentence and text reading rate, and working memory skills contribute to reading comprehension measures in university students. Reading development within this population is assumed to be advanced and fully developed. Studying reading comprehension within this population allows researchers examine it without the presence of substantial reading comprehension deficits (Landi, 2010). Additionally, the contribution of vocabulary and listening comprehension in adult reading comprehension has been well established, as studies have consistently shown them to be strong predictors of reading comprehension in adults (Gough, Hoover & Peterson, 2008; Keenan et al., 2008; Landi, 2010; Williams, Ari & Santamaria, 2011). Therefore, the current study examined factors beyond these skills.

The first goal of the present study was to examine whether the contributions of the word reading rate, sentence and text reading rate, and working memory vary depending on the reading comprehension measure in adults. Since previous studies measuring children's reading comprehension have suggested that predictors of reading comprehension vary with test format, four different reading comprehension tests were selected: the passage comprehension subtest from the *Woodcock Reading Mastery Test-Revised* (Woodcock, 1998), the reading comprehension subtest from the *Nelson-Denny Reading Test* (Brown, Fishco & Hanna, 1993), the reading comprehension subtest from the *Scholastic Abilities Test for Adults* (Bryant, Patton, & Dunn, 1991), and a Curriculum-Based Measurement-Maze task. Together, these reading comprehension tests provided two timed tests with passage reading followed by multiple choice questions (one with the ability to review responses), one untimed test with a cloze open-ended reading passage format, and one timed test with a cloze-maze reading passage format (three word choices). Within each of the four reading comprehension tests, the influence of different component processes on reading comprehension performance was examined.

There are mixed findings regarding whether or not accurate and efficient basic word reading skills are important predictors of reading comprehension in adults. Hence, another goal of the present study was to investigate whether decoding and word reading skills are important contributors to reading comprehension in highly skilled adults readers. In previous studies, decoding and word reading skills have been measured using timed (Papadopoulos et al., 2015) and non-timed tests (Cutting and Scarborough, 2006; Nation & Snowling, 1997) or both (Keenan et al., 2008). The timed isolated decoding and word reading tests (word reading rate tests) measure low-level automaticity of translating graphemes to phonemes or context-free word reading rate. In contrast, other measures of reading rate involve reading words connected to text, such as sentences or paragraphs, and have context (sentence or text reading rate). Some studies with children have reported that word reading rate accounts for more variance than sentence and text reading rate in reading comprehension (e.g., Wise et al., 2010), while other studies have found that sentence and text reading rate account for more variance than word reading rate in reading comprehension (Fuchs, Fuchs, Hosp & Jenkins, 2001; Jenkins, Fuchs, van den Broek, Espin & Deno, 2003). For the present study, timed word reading and decoding rate tasks were selected in addition to sentence and text reading rate tasks in order to investigate whether these skills make different contributions to reading comprehension in adults, and how the contributions vary across tests.

The final goal of the study was to examine whether working memory is an important predictor of reading comprehension test performance in high-functioning adults. Working memory involves the storage and processing of information (Cowan, 2008) and it has been shown to be a significant predictor of reading comprehension in children and adults (Cutting & Scarborough, 2006; Daneman & Merikle, 1996; Kendeou, Papadopoulos, & Spanoudis, 2012). Contrary to word reading skills, however, the relationship between working memory and reading comprehension has been shown to increase with years of education (Signeurie & Ehrlich, 2005), suggesting that it could be an important contributor to reading comprehension in highly skilled adult readers. Working memory has also been shown to be a significant predictor of academic success (Alloway & Alloway, 2010), which depends to a large part on reading comprehension; therefore if there is variability in the contributions of working memory skills on reading comprehension performance across tests, then tests that have a higher contribution may be better to use with individuals at higher levels of education.

Methods

Participants

Participants were 237 university students recruited from a large Canadian University (181 females and 56 males). All participants reported normal or corrected-to-normal hearing and vision and English as their first language. The mean age of the participants was 22.22 years (*SD* = 3.36). Students were recruited through announcements in undergraduate classes and word-of-mouth. Students who were eligible received educational psychology course credit as compensation for their participation.

Measures

From a larger battery of administered tests, a subset of measures was selected for the analyses for this study. These included an adult reading history questionnaire, and measures of word reading rate, nonword reading rate, sentence reading rate, text reading rate, working memory, and reading comprehension.

Adult Reading History Questionnaire-Revised. Participants completed the elementary section of the *Adult Reading History Questionnaire-Revised* (Parrila, Corkett, Kirby & Hein, 2003). The questionnaire asks respondents to report their current demographic information, their reading and spelling ability, reading speed, attitudes toward school and reading, past school history of additional assistance received, repeating grades, effort required to succeed, and print exposure from elementary school. There were 15 Likert scale questions specific to elementary school experiences. Studies that have previously used this measure have reported a high level of internal consistency ($\alpha = .93$, Deacon, Cook & Parrila, 2012; $\alpha = .90$, Parrila et al., 2007). Cronbach's alpha calculated for the present sample was $\alpha = 0.87$. The questionnaire was used to gather demographic information and as a tool to screen for participants' performance levels.

Test of Word Reading Efficiency. The sight word efficiency (SW) and the phonemic decoding efficiency (PD) subtests from the *Test of Word Reading Efficiency* (TOWRE; Wagner, Torgesen & Rashotte, 1999) were administered. Both subtests were administered in the standardized format. The number of words and nonwords read within the 45-second time-limit were recorded. Raw scores were used in analyses. These tests have mean standard scores of 100.

Nelson-Denny Reading Test. The reading comprehension subtest from the *Nelson-Denny Reading Test*, Form G (ND; Brown et al., 1993) was administered to assess participants' reading rate and comprehension, which involves silent passage readings followed by multiple-choice questions. The ND was administered in its standardized format. As per instructions, participants were given a time limit of 20 minutes to read seven passages and answer 38 questions, which involved deriving facts or making inferences. The number of questions participants answered correctly within the 20-minute time limit determined their reading comprehension score, and the number of words read on the first passage in 1 minute determined their reading rate score. Raw scores were used for data analyses. Two scores were removed from analysis because the participants did not report any history of reading difficulties but scored below 50% on the ND reading comprehension measure. These low scores were thought to be due to participants' lack of motivation rather than ability. The test has a mean standard score of 200.

Scholastic Abilities Test for Adults. The *Scholastic Abilities Test for Adults* (SATA; Bryant et al., 1991) involves silent reading of 10 passages, each followed by 6 multiple-choice questions including both literal (explicit information) and inferential (infer and integrate information) questions for each passage. The SATA was administered on the computer using Direct RT ©. In contrast to the standardized paper and pencil version, the computerized version did not allow participants to go back and review text or answers. Passages were presented individually on the screen. Once participants were finished reading the passage, they were instructed to press the space bar to continue with the questions about the passage. Multiple choice questions were presented one at a time and participants pressed the number key that corresponded to the answer they thought correctly answered the question before proceeding to the next question. As per standardized instructions, participants were given a time limit of 15 minutes. The number of questions participants answered correctly within the 15- minute time limit determined their reading comprehension score. Raw scores were used for data analyses. Again, two scores were removed from the analysis because the participants did not report any history of reading difficulties but scored below 50% on the SATA reading comprehension measure.

Woodcock Reading Mastery Tests-Revised. The reading comprehension subtest from the *Woodcock Reading Mastery Tests-Revised* (WRMT-R; Woodcock, 1998) is a passage level cloze task. The test consists of short cloze passages (two or three sentences), with the goal to identify a key word missing from the passage. Participants are instructed to read the passages silently and then state a word that belongs in the blank space that would make the passage make sense. Testing was administered in the recommended standardized manner, and was stopped after six consecutive errors, as recommended in the manual. The participant's score was the number of correct missing words named. Raw scores were used for data analyses.

Curriculum Based Measurement-Maze Test. Reading comprehension was also measured using a Curriculum-Based Measurement (CBM)-Maze Test. Participants read a passage that had a three-word choice for every 7^{th} word in each sentence (not including the first sentence). The three word choices were designed so that the correct word is 'obvious' in the context of the sentence (e.g., The birds are still say/or/in training."). The test is considered to be a strong measure of both reading comprehension and word recognition (Fuchs & Fuchs, 1992). There was a 3-minute time limit and the number of correct choices was recorded and used in analysis.

Yes/No Decision Reading Rate Measure. The Yes/No Decision reading rate task is a sentence-level reading accuracy and rate measure. Participants were presented with 20 sentences one at a time that they had to judge as either reasonable (e.g., *The lumbermen worked long hours in order to obtain the necessary amount of wood*) or unreasonable (e.g., *The intensity of the fire was starting to dwindle so he removed another log to keep warm*). Sentences were presented individually on the computer using Direct RT ©. If participants judged the sentence as reasonable, they pressed the Y key and if they judged the sentence as unreasonable, they pressed the N key. Sentences were adapted from an adult reading span task (Daneman & Carpenter, 1980). For analysis, items that were not answered with a 70% accuracy rate in the sample were eliminated. In total, three items were deleted from the analysis. Total reaction times (ms) for sentence reading and yes/no decision-making were recorded for each item. Each total reaction time was then divided by the number of words in the item. These times were then added together and averaged to give each participant a mean Y/N decision reading rate time. Subject and item outlier values (i.e., times that exceeded 2 standard deviations from the mean) were also eliminated. Any responses below 200ms were deleted as they were considered anticipatory responses. A total of 19% of scores were deleted. All mean Y/N decision reading rate times were multiplied by -1 for the analyses.

Operation Span. An automated Operation span (OSPAN) task was administered to assess working memory (Unsworth, Heitz, Schrock & Engle, 2005). The OPSAN task measures working memory by requiring participants to remember letters while solving math problems. It requires simultaneous storage and processing of information. The task involves a three step practice session followed by the test trials. First to practice the letter span, participants were presented with letters that appear on the computer screen one at a time, and then were asked to recall these letters in the same order they saw them. Participants provided their responses by clicking the box next to the appropriate letters on the computer screen (no verbal response is required). Recall was untimed and the number of letters correctly recalled was provided as feedback. Next, participants practiced the math portion of the experiment. Participants were shown a math operation (e.g. (1*2) + 1 = ?) and once they knew the answer they clicked the mouse to advance to the next screen. This portion of the task was timed. Participants then saw a number (e.g. "3") and were required to indicate if the number was the correct solution by clicking on "True" or "False." Their accuracy was confirmed after each answer as feedback. Participants were encouraged to maintain 85% accuracy and this feedback was provided on the top right of the screen. The final practice session had participants perform both the letter recall and math portions together, just as they did in the earlier test trial. The test trial consisted of 75 letters to be recalled and math questions to be answered. To prevent participants from rehearsing letters instead of doing math calculations, the program automatically advanced to the next trial and was scored as an error if participants were taking longer than their individual mean time plus 2.5 SD, as calculated during the math practice trials. The order of sets was randomized for each participant. Some participants did not receive an OSPAN score due to computer error. At the end of the real trial participants were given an OSPAN score, which is the traditional absolute scoring method that calculates the sum of all perfectly recalled sets.

Reading Span. A Reading Span task was also administered to assess working memory (Singer, Andrusiak, Reisdorf, & Black, 1992). The Reading Span task is based on Daneman and

Carpenter's working memory task that has been used throughout reading comprehension research (1980). Participants read a set of unrelated sentences, one sentence at a time on a computer screen. Once all sentences were presented, participants were asked to recall the final word of each sentence in the set by saying it aloud. Next, participants were presented again with one of the sentences from the set that they had just finished recalling, however, two words were missing from the sentence. Participants were asked to recall aloud the missing words from the sentence. The task is a measure of working memory as it requires participants to remember final words, while at the same time reading full sentences (distraction task). Similar to OSPAN, it requires simultaneous storage and processing of information. The examiner recorded all of the responses. Participants were given a score of the total of final correctly recalled words.

Procedure

All sessions were completed in a laboratory at a large Canadian university. Participants completed tests of word and nonword reading rate, sentence and text reading rate, working memory, and reading comprehension measures in a randomly assigned order. Since the data collected were being used for other research purposes, not all participants completed all of the reading comprehension measures. Unless participants were unable to complete the measures due to time constraints, all participants were administered the WRMT-R, CBM, TOWRE, sentence reading rate, text reading rate, and working memory measures. Measures were individually administered and sessions lasted approximately 2 hours.

Results

Visual inspection of data plots confirmed that score distributions were all approximately normal for each variable. No violations of the assumptions of normality, heteroskedasticity, or linearity were observed. An examination of correlations revealed that no independent variables were highly correlated, thus multicollinearity was unlikely to be a problem (Tabachnick & Fidell, 2007). Following Tabachnick and Fidell's (2007) guidelines, for all measures, outlying scores were adjusted so that they were one unit above or below the next highest or lowest score in the sample, which was not an extreme score. The ND, SATA and WRMT-R scores had one outlier each and the CBM-Maze had three outliers. There were missing cases due to observations/evidence of tests being invalid, participants being unable to complete tasks, and experimenter/computer error. The amount of missing data ranged from 0.4% to 9.3% on individual tasks. To allow the use of cases with missing values and maximize available data, a pairwise deletion method was used to handle missing data.

Table 3.1 provides a summary of descriptive statistics for all measures. The mean reading comprehension performances on the ND, SATA and WRMT-R demonstrated above average performances. A raw score of 28 on the ND corresponds to a standard score of 219 (grade equivalent of 14.4). A raw score of 38 on the SATA corresponds to a standard score of 13 (84^{th} percentile). A raw score of 57 on the WRMT-R corresponds to a standard score of 533 (grade equivalent of 16.5). A raw score of 91 on the TOWRE SD corresponds to a standard score of 101 (53^{rd} percentile) and a raw score of 54 on the TOWRE PD corresponds to a standard score of 104 (61^{st} percentile). A raw score of 241 on the ND reading rate measure corresponds to an approximate standard score of 204. Participants' mean performances on the automated OSPAN and RSPAN working memory tasks were comparable to that of previous studies (Allan, Snow, Crossley, Jackson & McNamara, 2014; Unsworth, Heitz, Schrock & Engle, 2005; Singer, Andrusiak, Reisdorf, & Black, 1992).

Table 3.1

Descriptive Statistics for all Measures

Variables	N	Mean	SD	Minimum	Maximum
ND	168	28.15	6.00	11	38
SATA	83	38.90	5.76	26	50
WRMT-R	229	57.54	4.65	45	68
CBM	235	39.83	8.33	18	61
TOWRE SW	236	91.89	10.72	63	108
TOWRE PD	236	54.14	6.79	37	65
ND RR	225	241.53	67.43	84	398
Y/N RR	221	785.91	185.63	332	1273
OSPAN	215	41.33	16.29	3	75
RSPAN	232	38.88	7.38	19	56

Note. ND = *Nelson-Denny Reading Test*, comprehension subtest; SATA = *Scholastic Abilities Test for Adults*, comprehension subtest; WRMT-R = *Woodcock Reading Mastery-Revised*, passage comprehension subtest; CBM = Curriculum-Based Measurement- Maze comprehension measure; TOWRE SW = *Test of Word Reading Efficiency* sight word subtest; TOWRE NW = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.

Correlational Analyses

Pearson correlation coefficients for the variables are displayed in Table 3.2. Correlation coefficients between the reading comprehension measures ranged from .23 to .55 indicating a large amount of non-shared variance. All relationships were statistically significant except for the relationships between ND and SATA. The ND, WRMT-R and CBM reading comprehension measures were significantly correlated with all predictor variables (word reading rate, nonword reading rate, sentence reading rate, text reading rate, OSPAN working memory and Reading Span working memory); SATA was significantly correlated only with the TOWRE phonemic decoding task, the *Nelson-Denny Reading Test* reading rate measure, and the Reading Span working memory measure. Correlation coefficients ranged from .15 to .47. All reading comprehension measures had a stronger relationship with phonemic decoding than with sight word reading with the exception of CBM, for which the relationship was equal. Text reading rate (*Nelson-Denny Reading Test* reading rate) had a stronger relationship with SATA and WRMT-R, while sentence reading rate (Yes/No Decision Task) had a stronger relationship with ND and CBM. Regarding working memory tasks, Reading span had a stronger relationship than Operation span with all reading comprehension measures. Similar to children's reading comprehension measures, these variations among inter-test correlations suggest that the examined reading comprehension measures may be measuring different skills (Keenan et al., 2008).

Table 3.2

Correlation Coefficients (*n* in parenthesis) between Variables

	1	2	3	4	5	6	7	8	9	10
1. ND	-	.28 (48)	.36** (165)	.40** (166)	.21** (167)	.22** (167)	.25** (166)	.34** (158)	.20* (156)	.39** (165)
2. SATA		-	.55** (77)	.23* (83)	.03 (83)	.29** (83)	.30** (78)	.17 (78)	.06 (74)	.23* (82)
3. WRMT-R			-	.30** (227)	.15* (229)	.29** (229)	.31** (222)	.17* (216)	.26** (208)	.46** (226)
4. CBM		.		-	.34** (234)	.34** (234)	.42** (223)	.47** (219)	.16* (213)	.33** (230)
5. SWR					-	.49** (236)	.26** (224)	.27** (221)	.14* (215)	.27** (232)
6. PD						-	.34** (224)	.26** (221)	.27** (215)	.32** (232)
7. ND RR							-	.39** (212)	.09 (205)	.27** (221)
8. Y/N RR								-	-.01 (202)	.21** (217)
9. OSPAN									-	.35** (212)
10.RSPAN										-

Note. ND = *Nelson-Denny Reading Test*, comprehension subtest; SATA = *Scholastic Abilities Test for Adults*, comprehension subtest; WRMT-R = *Woodcock Reading Mastery-Revised*, passage comprehension subtest; CBM = Curriculum-Based Measurement- Maze comprehension measure; SWR = *Test of Word Reading Efficiency* sight word reading subtest; PD = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.
*p < .05; **p < .01; ***p < .001

Regression Analyses

Four regression analyses were completed for each of the reading comprehension measures. In the first regression analysis (A), all predictors were entered into the model simultaneously. In the following analyses (B), word reading rate, sentence and text reading rate, and working memory measures were entered as predictors in Step 1 in pairs with no other variables to examine their unique contributions.

Predicting ND Reading Comprehension Scores. When all of the predictor variables were entered to predict ND reading comprehension raw scores, the model explained 23.4% of variance (F (6, 149) = 7.605, $p < .001$); the Yes/No Decision reading rate task ($\beta = .245$, $p < .01$) and the Reading Span working memory task ($\beta = .279$, $p < .01$) were the only statistically significant predictor variables. When the predictor variables were entered in pairs, all models were significant. Word reading variables predicted 6.5% of the variance (F (2, 164) 5.657, $p < .01$), reading rate variables predicted 13.1% of the variance (F (2, 155) = 11.696, $p < .001$), and working memory variables predicted 15.7% of the variance (F (2, 153) 14.290, $p < .001$) in ND reading comprehension. Consistent with results from the first analysis, the Yes/No Decision reading rate task ($\beta = .286$, $p < .01$) and the Reading Span working memory task ($\beta = .387$, $p < .001$) were the only variables that contributed significantly to their respective models. A summary of the analyses can be seen in Table 3.3.

Predicting SATA Reading Comprehension Scores. When all of the predictor variables were entered to predict SATA reading comprehension raw scores, the model explained 17.3% of variance (F (6, 67) = 2.329, $p < .05$); however, none of the variables contributed significantly to the model, although phonemic decoding was approaching significance ($p = .053$). When the predictor variables were entered in pairs, only the word reading and reading rate variables were

Table 3.3

Summary of Multiple Regression Predicting Nelson-Denny Reading Comprehension Scores

		R	R^2	*B*	*SE*	*β*	*t*
A.	**Step 1** (n = 156)	.484	.234***				
	SWR			.023	.047	.041	.48
	PD			.009	.078	.010	.12
	ND RR			.005	.007	.055	.67
	Y/N RR			.008	.003	.245	3.06**
	Rspan			.227	.066	.279	3.41**
	Ospan			.033	.029	.089	1.13
B.	**Step 1** (n = 167)	.254	.065**				
	SWR			.076	.048	.136	1.58
	PD			.140	.076	.158	1.83
	Step 1 (n = 158)	.362	.131***				
	ND RR			.012	.007	.138	1.70
	Y/N RR			.009	.003	.286	3.52**
	Step 1 (n = 156)	.397	.157***				
	Rspan			.299	.064	.397	4.63***
	Ospan			.025	.029	.069	.87

Note. SWR = *Test of Word Reading Efficiency* sight word reading subtest; PD = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.
*$p < .05$; **$p < .01$; ***$p < .001$

significant. When word reading variables were entered, 9.7% of variance was predicted (*F* (2, 80) 4.311, $p < 0.5$); phonemic decoding was the only variable that contributed significantly to the model ($\beta = .355$, $p < .01$). When reading rate variables were entered, 9.6% of variance was predicted (*F* (2, 75) = 3.987, $p < .05$); the ND reading rate measure was the only variable that contributed significantly to the model ($\beta = .279$, $p < .05$). A summary of the analyses can be seen in Table 3.4.

Table 3.4

Summary of Multiple Regression Predicting SATA Reading Comprehension Scores

		R	R^2	*B*	*SE*	*β*	*t*
A.	**Step 1** (n = 74)	.415	.173*				
	SWR			-.106	.070	-.197	-1.51
	PD			.228	.116	.268	1.97
	ND RR			.018	.011	.214	1.69
	Y/N RR			.001	.004	.043	.35
	Rspan			.113	.099	.145	1.15
	Ospan			-.020	.043	-.058	-.47
B.	**Step 1** (n = 83)	.312	.097*				
	SWR			-.076	.065	-.141	-1.16
	PD			.302	.103	.355	2.93**
	Step 1 (n = 78)	.310	.096*				
	ND RR			.024	.010	.279	2.35*
	Y/N RR			.002	.004	.064	.54
	Step 1(n = 74)	.227	.052				
	Rspan			.184	.096	.235	1.91
	Ospan			-.009	.044	-.026	-.21

Note. SWR = *Test of Word Reading Efficiency* sight word reading subtest; PD = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.
**p* < .05; ***p* < .01; ****p* < .001

Predicting WRMT-R Reading Comprehension Scores. When all of the predictor variables were entered to predict WRMT-R reading comprehension raw scores, the model explained 26.6% of variance (F (6, 195) = 11.758, $p < .001$); the *Nelson-Denny Reading Test* reading rate task ($\beta = .172$, $p < .05$) and the Reading Span working memory task ($\beta = .351$, $p < .001$) were the only statistically significant predictor variables (see Table 3.5). When the predictor variables were entered in pairs to predict WRMT-R reading comprehension all models were significant. When word reading variables were entered, 8.4% of variance was predicted (*F*

(2, 226) 10.427, $p < .001$); phonemic decoding was the only variable significantly contributing to the model ($\beta = .285$, $p < .001$). When reading rate variables were entered, 9.7% of variance was predicted (F (2, 209) = 11.233, $p < .001$); the *Nelson-Denny Reading Test* reading rate measure was the only variable significantly contributing to the model ($\beta = .284$, $p < .001$) When working memory variables were entered, 21.9 % of variance was predicted (F (2, 205) 28.750, $p < .001$); the Reading Span working memory measure was the only significant model contributing to the model ($\beta = .417$, $p < .001$).

Table 3.5

Summary of Multiple Regression Predicting WRMT-R Reading Comprehension Scores

		R	R^2	*B*	*SE*	β	*t*
A.	**Step 1** (n = 202)	.515	.266***.				
	SWR			-.029	.031	-.066	-.92
	PD			.084	.052	.123	1.64
	ND RR			.012	.005	.172	2.46*
	Y/N RR			.000	.002	.015	.22
	Rspan			.221	.044	.351	5.02***
	Ospan			.027	.019	.095	1.41
B.	**Step 1** (n = 167)	.291	.084***				
	SWR			.005	.032	.011	.15
	PD			.196	.050	.285	3.92***
	Step 1 (n = 158)	.312	.097***				
	ND RR			.020	.005	.284	3.98***
	Y/N RR			.001	.002	.059	-.84
	Step 1 (n = 156)	.468	.219***				
	Rspan			.263	.042	.417	6.34***
	Ospan			.032	.019	.111	1.68

Note. SWR = *Test of Word Reading Efficiency* sight word reading subtest; PD = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.
*$p < .05$; **$p < .01$; ***$p < .001$

Predicting CBM-Maze Reading Comprehension Scores. When all of the predictor variables were entered simultaneously to predict CBM reading comprehension, the model explained 34.9% of variance (F (6, 195) = 17.455, $p < .001$); the *Nelson-Denny Reading Test* reading rate task ($\beta = .208$, $p < .01$), the Yes/No Decision reading rate task ($\beta = .307$, $p < .001$) and the Reading Span working memory task ($\beta = .134$, $p < .05$) were the three statistically significant predictor variables. When the predictor variables were entered in pairs, all models were significant. Word reading variables predicted 15.2 % of the variance was predicted (F (2, 231) 20.698, $p < .001$); both sight word reading and phonemic decoding variables significantly

Table 3.6

Summary of Multiple Regression Predicting CBM Reading Comprehension Scores

		R	R^2	*B*	*SE*	*β*	*t*
A.	**Step 1** (n = 202)	.519	.349***				
	SWR			.092	.053	.118	1.745
	PD			.087	.087	.071	1.00
	ND RR			.026	.008	.208	3.16**
	Y/N RR			.014	.003	.307	4.75***
	Rspan			.151	.074	.134	2.03*
	Ospan			.033	.032	.065	1.02
B.	**Step 1** (n = 234)	.390	.152***				
	SWR			.174	.054	.224	3.22**
	PD			.281	.085	.229	3.30**
	Step 1 (n = 213)	.535	.286***				
	ND RR			.035	.008	.287	4.53***
	Y/N RR			.016	.003	.354	5.60***
	Step 1 (n = 212)	.337	.114***				
	Rspan			.355	.079	.315	4.52***
	Ospan			.027	.036	.053	.76

Note. SWR = *Test of Word Reading Efficiency* sight word reading subtest; PD = *Test of Word Reading Efficiency* phonemic decoding subset; ND RR = *Nelson-Denny Reading Test* reading rate measure; Y/N RR= Yes / No Decision Reading Rate Task; OSPAN = Operation Span working memory measure; RSPAN = Reading Span working memory measure.
*$p < .05$; **$p < .01$; ***$p < .001$

contributing to the model. Reading rate variables predicted 28.6 % of the variance (F (2, 209) = 41.9161, $p < .001$); both the *Nelson-Denny Reading Test* and the Yes/No Decision reading rate variables significantly contributing to the model. Working memory variables predicted 11.4 % of the variance (F (2, 209) 13.390, $p < .001$); the Reading Span working memory measure was the only significant model contributing to the model ($\beta = .315$, $p < .001$). A summary of the analyses can be seen in Table 3.6.

Discussion

The present study investigated whether word reading rate, sentence and text reading rate, and working memory skills predicted reading comprehension on four different adult reading comprehension measures: ND (paper-pencil timed passage reading with multiple choice questions and the ability to review), SATA (timed passage reading with multiple choice questions and no ability to review), WRMT-R (untimed cloze-open ended reading passage) and CBM-Maze (timed cloze-maze reading passage). The first goal was to examine whether the contributions of these skills vary depending on the reading comprehension measure in adults. Consistent with studies on children's reading comprehension tests, correlations between the tests revealed they were either not significantly correlated or only modestly correlated suggesting that the four reading comprehension tests measure at least partly differing skills (Cutting & Scarborough, 2006; Keenan et al., 2008). Further regression analyses replicated findings with children's reading comprehension measures demonstrating variability in contributions made by different tasks assessing word and pseudoword reading, sentence and text reading rate, and working memory. The total amount of variance explained by these tasks varied between 17% and 35%. Basic word reading rate skills explained between 6% and 15% of variance, sentence and text reading rate explained between 10% and 29% of variance, and working memory explained between 5% and 22% of variance across the four reading comprehension measures.

With regard to the ND reading comprehension test, sentence and text reading rate and working memory scores were the only significant predictors of performance and made similar contributions. Though the SATA has a similar format of measuring reading comprehension to the ND, it was poorly predicted by the variables. There was no contribution of working memory to performance on the SATA, and only modest contributions from word reading rate and sentence and text reading rate. Performance on the WRMT-R reading comprehension test had the most contribution from working memory measures. Word reading rate and sentence and text reading rate also made contributions towards WRMT-R performance, with text and sentence reading rate being more important. The CBM-Maze was the reading comprehension measure best explained by the predictor variables, with sentence and text reading rate being more important than word reading rate, and working memory adding additional contribution to reading comprehension performance. Overall, these findings are consistent with studies with children that have demonstrated that contributions of components skills of reading comprehension vary with the measure of reading comprehension that is used (Cutting & Scarborough, 2006; Keenan et al., 2006). These findings add to the growing body of research that has primarily focused on children's reading comprehension measures, by examining and finding similar variability in adult reading comprehension measures.

The second goal of the study was to investigate whether decoding and word reading skills are important predictors of reading comprehension in adults. The total amount of variance explained by decoding and word reading skills varied between 6% and 15%. Word reading skills were only a modest predictor of performance on the SATA and, although they did contribute unique variance, they were not the most important predictor variables on ND, WRMT-R and CBM performance. Current findings suggest that word reading rate may not be as crucial in predicting reading comprehension in highly functioning adult university students as they are in children. Although these results showed that decoding and word reading skills accounted for more variance in reading comprehension performance than those of Landi (2010), our results are consistent with her research with skilled adult readers suggesting that decoding and spelling skills account for minimal variance in adult reading comprehension performance. This is also consistent with findings of Keenan and colleagues (2008) who found that the contribution of decoding skills to reading comprehension decreased with age (8 to 18 years of age), and with those of Gough and colleagues (2006) who found that importance of word reading skills decreased with increased education levels. These results also add to the evidence that word reading skills have less of an impact on reading comprehension performance in skilled readers and may only be a strong predictor in children and less-skilled adult readers (Landi, 2010).

Measures for timed decoding and word reading were selected in order to investigate whether word reading rate and sentence and text reading rate make independent contributions to adults' reading comprehension, as has been argued for children (Wise et al., 2010). The current findings suggest that sentence and text reading rate, as measured with the ND reading rate and the Yes/No decision reading rate tasks, are better predictors of reading comprehension performance than word reading rate in highly skilled adult readers. This is consistent with Cutting and Scarborough's (2006) study, which found that text reading rate contributed unique variance to reading comprehension performance in children across multiple measures of reading comprehension.

The final goal of the study was to investigate whether working memory is an important factor in predicting reading comprehension in adults. Consistent with past findings, this seems to be the case (Daneman & Merikle, 1996; Seigneurie & Ehrlichm 2005). More specifically the Reading Span working memory measure was a significant predictor for three of the four reading comprehension measures. The largest contribution was found for the WRMT-R task, where approximately 20% of the variance was explained by Reading Span scores. Since working memory is an important predictor of academic success (Alloway & Alloway, 2010), it could be beneficial to use the WRMT-R when testing individuals with higher levels of education. It is important to note that the Reading Span working memory measure had stronger relationships with the reading comprehension measures than the Operation Span working memory measure. Some researchers argue that the stronger relationship between Reading Span and reading comprehension is due to word knowledge (Engle, Nations & Cantor, 1990) or reading-specific skills used to comprehend (Danemen & Carpenter, 1980). To explain the strong relationship between working memory and reading comprehension, Daneman and Carpenter suggested that stronger readers have more efficient word and sentence reading strategies, leaving more space for working memory capacity storage, rather than having larger working memory capacity. Since Operation span measures working memory capacity independent of reading, the current findings support Daneman and Carpenter's theory that efficient word processing skills, rather than working memory capacity per se, may be responsible for the relationship between working memory and reading comprehension (Conway et al., 2005; Daneman & Carpenter, 1980; Turner & Engle, 1989).

The total amount of variance explained by word reading rate, sentence and text reading rate, and working memory skills did not exceed 35% on any of the reading comprehension measures, which is likely due to the fact that the current study did not include listening comprehension or vocabulary as predictor variables. Vocabulary and listening comprehension have been shown to be strong predictors of reading comprehension (Landi, 2010). In skilled readers, vocabulary has been found to predict up to 45% of unique reading comprehension variance in previous studies (Landi, 2010). Future research examining different reading comprehension factors beyond word reading rate, sentence and text reading rate, working memory, vocabulary, and listening comprehension may lead to discovery of additional factors that contribute to reading comprehension within the university population, who presumably have highly developed reading abilities. Such factors may include higher-level processes such as inference making. Previous research has suggested that higher level processes may account for as much 34-60% of variance in reading comprehension skills in adult readers (Hannon, 2012). Further exploration of additional factors may also help better explain why the tests of adult reading comprehension examined in this study are not highly correlated. It would also be interesting to investigate whether relative contributions of predictors of reading comprehension differ for adult readers of different reading skill levels, education levels, and in those with specific reading disorders.

Results of the current study may be specific to the selected measures. Word reading skills were measured using word reading rate tasks instead of word reading accuracy tasks. Previous studies that have found larger contributions of word reading to reading comprehension have not solely used word reading tests with time constraints (Cutting & Scarborough, 2006; Keenan et al., 2008; Nation & Snowling, 1997), which may partly explain why our word reading skills made less of a contribution to reading comprehension. With regards to text and sentence reading rate measures, the ND reading rate measure has been criticized for poor reliability, especially in university students (Lewandowski et al., 2003; Perkins, 1984), which may have also affected present findings. In addition, the experimental reading rate measure was created for the present study and has not been widely used in research. To further examine the importance of reading rate in predicting adult reading comprehension performance, other approaches to measuring reading rate, though limited, could be used and may lead to more robust findings (Lewandowski et al., 2003).

Practical implications of the present study parallel those of research with children's reading comprehension measures. Reading comprehension measures are used frequently not only for the purpose of research but also in the diagnosis of reading disorders. The assumption that reading comprehension tests are measuring the same unitary construct is inaccurate and may be influencing outcomes of research and diagnoses. More frequently, students with reading difficulties are attending university and require a current psycho-educational assessment to receive accommodations (Lewandowski et al., 2003; Williams, Ari & Santimaria, 2011). Depending on the measures administered as part of an assessment, deficits of reading may not be captured, resulting in refusal to support students who may be in need. For example, if a student has a deficit in word reading efficiency, but the reading comprehension measure administered does not capture that deficiency, the student may not qualify for much needed supports. To improve assessment of reading without administering a plethora of tests, Kendeou and colleagues (2012) have suggested creating a reading comprehension measure that loads cognitive processes equally. Although this was suggested for assessment of reading comprehension in children, it would also be useful for adults. To create such a measure, Cutting and Scarborough (2006) have recommended systematic investigation of the similarities and differences between different reading comprehension tests to examine what might be the best explanation for the differences. Until these differences are clear and there is a comprehensive measure of all skills, the best practice should be to continue to use multiple measures when assessing reading comprehension in research and in clinical practice.

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Chapter IV: Examining reading comprehension text and question-answering time differences in university students with and without a history of reading difficulties

Introduction

Several recent studies have focused on reading skills in university students who report a significant history of reading difficulties (HRD) (Bergey, Deacon, & Parrila, 2015; Hatcher, Snowling, & Griffiths, 2002; Kemp, Parrila, & Kirby, 2009: Stack-Cutler, Parrila, & Torppa, 2015), who, among other students with a history of learning disabilities, are becoming increasingly prevalent within the university population (Vogel et al., 1998). Surprisingly, while students with HRD are enrolled in and coping with the high demands of post-secondary education, they still have persistent difficulties with basic word reading skills, such as word and nonword reading accuracy and rate, and phonological awareness (Deacon, Cook, & Parrila, 2012; Parrila, Georgiou & Corkett, 2007). Further, they have slower text reading rate than students without a history of reading difficulties (NRD) and seem to benefit from extra time in reading comprehension tasks (Deacon et al., 2012; Kemp et al., 2009; Parrila et al., 2007). Despite consistent findings of difficulties with basic reading skills and rate, Simmons and Singleton (2000) suggested that the main reason why students with HRD take longer to complete reading comprehension tasks may not be poorer reading rate, but slower responding to reading comprehension questions. In the present study, we examine differences between students with and without a history of reading difficulties on word reading, nonword reading and two different text reading rate measures. Further, we examine whether there is a difference between the groups on question response times, as indicated by Simmons and Singleton (2000), and if yes, whether the difference exists across different types of reading comprehension questions, and can be explained by reading rate differences.

Differences in word and nonword reading rate between university students with HRD and students without a history of reading difficulties (NRD) have been reported in several studies. For example, Wilson and Lesaux (2001), and Trainin and Swanson (2004) timed word and nonword reading rates, and found that students with diagnosed reading difficulties completed the tasks slower than the NRD students. Furthermore, Parrila et al. (2007) compared performance of university students with and without a self-reported HRD on regular word, irregular word, and pseudoword reading rate. They reported that students with HRD (self-reported or formally diagnosed) had slower word reading times than students with NRD on all three tasks; however, there were no group differences between the HRD students with and without formal diagnosis. Similarly, Deacon et al. (2012) compared word and nonword reading rates of university students with and without a self-reported HRD with those of students who were formally diagnosed with reading difficulties. Students with NRD were able to read more words and pseudowords in 45 seconds than both groups with reading difficulties, but there were no differences between the diagnosed and self-report groups.

Similar to findings for word and nonword reading rate, studies have also found consistent differences between students with and without a history of reading difficulties on tasks of text reading rate. Within this population, text reading rate is typically measured using the *Nelson-Denny Reading Test* reading rate measure, which measures how many words one can read during the first minute of a passage (ND; Brown, Fischo & Hanna, 1993; see below for details). For example, Kemp et al. (2009) found that university students without a history of reading difficulties had faster text reading rates than both diagnosed and undiagnosed students with self-reported HRD. Similarly, Jackson and Doelinger (2002) compared university students with diagnosed and undiagnosed reading difficulties to those without, and found that both groups of students with reading difficulties showed significantly slower text reading rate. Corkett, Parrila and Hein (2006) and Parrila et al. (2007) compared university students with diagnosed reading disorders to those with and without a self-reported HRD and found that university students with HRD (both diagnosed and self-reported) performed worse than controls on tasks of text reading rate; neither study found differences between the two groups of students with reading difficulties. Deacon and colleagues (2012) also found that university students without HRD performed better than both groups with reading difficulties on tasks of text reading rate; however, when comparing groups with reading difficulties, students with formal diagnoses read texts slower than students who self-reported HRD but who did not have a formal diagnosis.

Given the above difficulties with text reading rate, it is not surprising that several studies have shown that university students with HRD perform worse on reading comprehension tasks when there are time constraints (Corkett et al., 2006; Kemp et al., 2009; Parrila et al., 2007). For example, Kemp and colleagues (2009) found that both diagnosed and undiagnosed students with HRD performed just as well as their peers on a reading comprehension test with a 20-minute time constraint when the percentage correct ratio was calculated (total number of questions answered correctly divided by the total number of questions attempted), but significantly poorer on the number of correctly answered questions during the 20-minute time limit because they were unable to finish all of the items. The percentage correct ratio is a more fine-grained way to measure comprehension accuracy since it does not factor time constraints. Corkett et al. (2006) and Parrila et al. (2007) reported similar results. Furthermore, both studies failed to find differences between students with and without formal diagnoses. Deacon and colleagues (2012) also found that students with HRD had poorer reading comprehension on timed tasks than their peers; however, only students with formal diagnoses of reading difficulties performed as well as their peers on the percentage correct measure, whereas students without a formal diagnosis performed worse. Given their similar word reading efficiency, but faster text reading rate (see above), it appears that students who self-reported a history of reading difficulties but were not formally diagnosed (and presumably had not received appropriate remedial education) may have read the text too fast for their own understanding in this study.

The consistent finding that university students with a history of reading difficulties have slower word, nonword and text reading rate, and benefit from extra time in reading tasks, has led to the assumption that poor word decoding automaticity is responsible for slower completion of reading comprehension tests. However, Simmons and Singleton (2000) failed to find a significant difference in text reading rate and challenged this assumption. They created a reading comprehension measure in which the participants were presented with one passage followed by ten multiple-choice questions (five literal and five inferential) to answer. The time it took the participants to read the text and answer the questions was noted separately. Simmons and Singleton (2000) compared current university students or recent graduates with and without diagnoses of reading disorders, and failed to find a significant difference between the groups for the passage reading time (although the difference approached significance at $p = 0.059$); however, there was a significant difference on the time the groups took to answer the multiple choice questions. These results suggest that slower performance on reading comprehension tasks may involve processes needed to answer questions about the text as well as poor decoding automaticity. Unfortunately, Simmons and Singleton (2000) did not examine times for the literal and inferential comprehension questions separately; however, they did report that students with reading disorders showed poorer accuracy than typically reading students on inferential questions, but not on literal questions. This leaves open the possibility that the time differences reflected poorer comprehension in this sample of students.

Present Study

The first purpose of the present study was to examine whether these somewhat conflicting findings from studies with different samples of students can be replicated in one sample. By comparing university students with a self-reported HRD to students with no history of reading difficulties in similar tasks used in previous studies, it was possible to examine whether differences in results could be due to differences in samples of students examined (e.g., diagnosed versus not diagnosed). Second, we attempt to replicate Simmons and Singleton's (2000) findings by examining text reading and question answering times separately. The majority of studies that have found a significant difference between students with and without a history of reading difficulties on text reading rate have used the ND reading rate measure (ND; Brown et al., 1993; see below for details); therefore, we include the ND rate measure together with a measure of text reading rate similar to that used by Simmons and Singleton (2000). Further, we extend Simmons and Singleton's (2000) study by separately recording the time taken by the participants to answer five different types of questions (main idea, vocabulary, literal, inferential and background knowledge), and by examining whether slower question answering rate is specific to only some kinds of questions. Finally, we examine whether differences in reading comprehension or reading rate might account for the possible differences in question answering times.

Method

Participants

Participants included 229 students from a Canadian University. All participants were recruited through the university's participant pool or word-of-mouth. Eligible students received course credit for their participation. All participants completed elementary school questions from the Adult Reading History Questionnaire-Revised (ARHQ-R; see below for details). Students who obtained a score of .37 and above were considered to be students who are reporting a history of reading difficulties (history of reading difficulties group; HRD). Students who obtained a score of .24 and below were considered to be students who did not report a history of reading difficulties (no history of reading difficulties group; NRD). These cut-off scores were based on previous research studies (Deacon et al., 2012; Deacon et al., 2006). Of the 229 participants, 124 students (25 males and 99 females) were included in the NRD group and 43 (12 males and 31 females) participants were included in the HRD group. The mean age for NRD was 22.80 (*SD* = 4.50) and the mean age for HRD was 22.40 (*SD* = 3.89). The remaining participants (62) had scores that fell in the range of .25 and .36 on the ARHQ-R scale and did not meet criteria for the either of groups for the study.

Measures

Adult Reading History Questionnaire-Revised. Participants completed the elementary section of the *Adult Reading History Questionnaire-Revised* (Parrila, Corkett, Kirby & Hein, 2003). The questionnaire asks respondents about their current demographic information and their reading and spelling ability, reading rate, attitudes toward school and reading, additional assistance received, repeating grades, effort required to succeed, and print exposure in elementary school. There are 15 Likert scale questions specific to elementary school experiences. Cronbach's alpha for the present sample was 0.87.

Test of Word Reading Efficiency. The Sight Word Efficiency (SWE) and the Phonemic Decoding Efficiency (PDE) subtests from the *Test of Word Reading Efficiency* (TOWRE; Torgesen, Wagner & Rashotte, 1999) were administered as measures of word and nonword reading rate. Both subtests were administered in the standardized format. The number of words and nonwords read correctly within the 45-second time limit were recorded. Separate raw scores were used in analyses.

Nelson-Denny Reading Test: Reading Rate Measure. All participants read the first passage (601 words) of the *Nelson-Denny Reading Test*-Form G (ND; Brown et al., 1993). The number of words read during the first minute determined the reading rate score. There are eight comprehension questions that follow the passage. The number of correct responses determined participants' Nelson-Denny reading comprehension score.

Scholastic Abilities Test for Adults: Reading Comprehension. Participants were administered a computerized version of the reading comprehension subtest from *The Scholastic Abilities Test for Adults* (SATA; Bryant et al., 1991) using the reaction time software program Direct RT©. All participants completed the second (75 words) and the fourth (94 words) passages of the SATA reading comprehension test. Each passage is followed by six multiple-choice questions: the first requires identifying the main idea, the second involves vocabulary (e.g., "*In this story, the word EMPLOYED means…."*), the third and fourth are explicit (literal) questions, the fifth is an inferential question, and the sixth question involves background knowledge about the topic. Each passage and multiple choice question were presented individually on a computer screen. Participants pressed the space bar after reading the passage to continue with the questions, and pressed the number key corresponding to the answer they thought was correct when answering questions. Once a question was answered, the next question was immediately presented. This allowed for timing (in milliseconds) of each passage and type of question administered. For analyses, text and question answering times from the two passages were added together. To allow for comparisons between reading rate measures, text reading times were converted to words read per minute. Question answering times were converted to seconds. One literal question was deemed an outlier and removed from analyses because only 25% of participants answered the question correctly. The number of correct responses out of the 11 questions was used as the SATA reading comprehension score.

Procedure

All sessions were completed individually in a reading research laboratory and lasted approximately two hours. Participants completed additional tasks not reported in this paper for data collection that was being used for additional research purposes. Participants completed all tasks in a randomly assigned order.

Results

All variables were assessed for distributional properties separately for each group. Visual inspection of data plots confirmed that score distributions were all approximately normal for each variable. Following Tabachnick and Fidell's guidelines (2007), outlying scores were reassigned so that they were one unit or 100 ms above or below the next highest or lowest score in the sample that was not an extreme score to reduce their influence and correct for normality. Table 4.1 provides a summary of descriptive statistics for rate and comprehension measures. Raw scores were used for all analyses.

To determine whether the groups differed on word, nonword and text reading rate, a multivariate analysis of variance (MANOVA) with four reading rate scores as the dependent variables and group as the fixed factor was conducted. Results showed a significant main effect of group, Wilk's $\lambda = .676$, F (4, 159) = 19.08, $p < .001$. Follow-up univariate tests indicated the groups were significantly different on the TOWRE Sight Word Efficiency, F (1, 162) = 17.93, $p < .001$, $d = .73$, and Phonemic Decoding Efficiency, F (1, 162) = 67.05, $p < .001$, $d = 1.31$, the

ND reading rate, *F* (1, 162) = 25.82, *p* < .001, *d* = 1.02, and the SATA text reading rate, *F* (1, 162) = 7.37, *p* < .01, *d* = .50.

Table 4.1

Descriptive Statistics for Reading Rate and Comprehension Measures

Variable	Group					
	NRD (*n* = 124)			HRD (*n* = 43)		
	M	SD	Range	M	SD	Range
SWE	93.91	10.19	62-108	85.78	11.96	63-104
PDE	56.30	5.52	39-65	47.19	8.17	30-60
NDRR	264.21	78.41	137-519	198.60	45.83	106-325
SATAtext	181.82	56.74	85-308	156.37	43.59	94-247
NDcomp	6.72	1.27	3-8	7.13	.83	5-8
SATAcomp	9.65	1.28	6-11	9.37	1.23	6-11

Note. NRD = No reading difficulties; HRD = History of reading difficulties; SWE = Sight Word Efficiency; PDE = Phonemic Decoding Efficiency*;* NDRR = *Nelson-Denny Reading Test reading rate;* SATAtext = *Scholastic Abilities Achievement Test for* Adults text reading time; NDcomp = *Nelson-Denny Reading Test* reading comprehension score from passage one; SATAcomp = *Scholastic Abilities Achievement Test for Adults* reading comprehension score from passages one and two; n = 122 for NDRR and NDcomp; n = 42 for SWE and PDE.

To examine whether the groups differed in their reading comprehension, a separate MANOVA was completed comparing overall reading comprehension scores on the first passage of the ND reading comprehension test and the second and fourth passages of the SATA reading comprehension test. The main effect of group was not significant, Wilk's λ = .965, *F* (2, 159) = 2.91, *p* > .05. The groups did not differ on SATA, *F* (1, 160) = 2.11, *p* > .05, *d* = .22, or ND, *F* (1, 160) = 3.43, *p* > .05, *d* = .38. Furthermore, to determine whether comprehension scores differed between groups on different types of questions, group comparisons of accuracy scores on the different types of questions from the SATA were examined using z-test proportion analyses. The percentages of questions answered correctly for each type of question were used as accuracy scores. As seen in Table 4.2, no differences in accuracy scores were found between the groups.

Table 4.2

Group Comparisons of Question Accuracy Rates (%)

Questions	Group		
	NRD (N=124)	HRD (N=43)	Z
Main idea	85	81	-0.93
Vocabulary	75	76	-0.33
Literal	60	49	1.33
Inferential	69	72	-0.43
Knowledge	91	81	1.92

Note. NRD = No reading difficulties; HRD = History of reading difficulties
* $p < .05$

Table 4.3 shows the descriptive statistics for question answering times. In order to examine if there were any significant differences between the groups in the answering times, a MANOVA was completed on all the answering times across the five different types of questions (main idea, vocabulary, literal, inferential and background knowledge). The results showed a significant main effect of group, Wilk's $\lambda = .853$, $F(5, 161) = 5.55$, $p < .001$. Subsequent univariate tests indicated that the HRD group took significantly longer to answer all five kinds of questions (all *p*s < .05, *d*s > .39). To determine whether students with reading difficulties took longer only when answering questions incorrectly, an additional series of univariate tests were conducted using response times from questions that were answered correctly. Univariate tests showed that there were still significant differences between the groups on vocabulary, literal, inferential, and knowledge questions (all *p*s < .01, *d*s > .54), but there were no longer significant differences on main idea questions, F (1, 139) = 1.07, $p > .05$, $d = .30$. These findings raise the issue that the small and nonsignificant between group differences in comprehension scores cannot explain the significant difference in time to answer vocabulary, inferential and knowledge questions, but question response accuracy may affect the groups differently when answering main idea questions.

Table 4.3

Descriptive Statistics for Question Answering Times (seconds)

Question type	Group					
	NRD (*n* = 124)			HRD (*n* = 43)		
	M	*SD*	Range	*M*	*SD*	Range
Main Idea	12.93	3.38	6-22	14.24	3.41	7-20
Vocabulary	15.28	4.46	8-26	17.34	4.32	9-26
Literal	17.51	4.77	8-29	21.43	6.30	12-38
Inferential	15.68	4.14	7-26	19.26	6.24	9-33
Knowledge	13.15	3.29	8-21	15.24	4.24	7-24

Note. NRD = No reading difficulties; HRD = History of reading difficulties

Finally, to examine whether the slower question answering times for the HRD group were simply due to slower word or text reading rate, three separate multivariate analysis of covariance (MANCOVA) were conducted using (1) TOWRE Sight Word Efficiency, (2) ND reading rate, and (3) SATA text reading rate as covariates in each analysis. When TOWRE Sight Word Efficiency was entered as a covariate, results showed a significant main effect of group, Wilk's $\lambda = .886$, $F(5, 159) = 4.11$, $p < .05$. Subsequent univariate tests indicated that when word reading rate is controlled, the HRD group still took significantly longer to answer vocabulary, literal, inferential, and background knowledge questions, but not main idea questions, $F(1, 163) = 3.36$, $p > .05$. When ND or SATA reading rate were entered separately as covariates, the main effect of group remained significant, as did the between group differences in literal, inferential, and background knowledge question. However, after controlling for text reading rate, using both the ND and SATA measures, differences in main idea and vocabulary questions were no longer significant.

Discussion

The first goal of the present study was to compare word, nonword, and text reading rates of university students with and without a history of reading difficulties. Consistent with previous studies, university students with a history of reading difficulties (HRD) demonstrated slower word and nonword reading (Deacon et al., 2012; Parrila et al., 2007; Trainin & Swanson, 2004; Wilson & Lessaux, 2001). Also similar to past findings, university students with a history of reading difficulties read fewer words per minute than their peers who did not report a history of reading problems on the commonly used ND reading rate measure (Corkett et al., 2006; Deacon et al., 2012; Kemp et al., 2009; Parrila et al., 2007), and while reading passages presented on a computer screen (SATA). The latter finding is inconsistent with Simmons and Singleton (2000), who failed to find a significant difference on text reading times using a similar reading task (timing a full passage). Given that Simmons and Singleton (2000) compared students with and without diagnosed reading disorders and we compared students with and without self-reported reading difficulties, ours was a conservative, yet unsuccessful, attempt to replicate their findings.

Overall, these findings confirm that university students with a history of reading difficulties have slower word and text reading rate than their peers, regardless of the task.

The second goal was to compare the groups on the time it took participants to answer different kinds of reading comprehension questions, and whether these differences varied depending on the type of question. Consistent with Simmons and Singleton's (2000) study and with their slower word and text reading performance, students with a history of reading difficulties took longer to answer questions than students without a history of reading difficulties. Specifically, students with a history of reading difficulties took longer to answer main idea, vocabulary, literal, inferential and background knowledge questions. These differences were also observed for vocabulary, literal, inferential and background knowledge questions when only correct responses were included, suggesting that the small nonsignificant difference in comprehension scores cannot explain the significant differences in time for these types of questions. Only when looking at correct responses to main idea questions, were the differences no longer significant, suggesting that accuracy may play a role in the time difference for this type of question. This finding suggests that while students with HRD did not answer more questions incorrectly, they did take a longer time with the main idea ones that did occur. If verified, this could indicate better response monitoring or less certainty with their answers.

After controlling for word reading rate, students with a history of reading difficulties still took longer to answer vocabulary, literal, inferential and background knowledge questions. After controlling for text reading rate, students with a history of reading difficulties still took longer to answer literal, inferential and background knowledge questions. These findings suggest that students with a history of reading difficulties not only take longer to read words and text, but also require extra time to answer at least some kinds of reading comprehension questions. Simmons and Singleton (2000) hypothesized that students with reading disorders may take longer to answer questions because they have to refer back to the text more frequently than their peers due to reasons such as poorer working memory, or not reading the text as carefully. Simmons and Singleton (2000) also suggested that students with reading disorders may be slower at answering questions related to texts because of poor metacognitive strategies when referring back to the text (e.g., reading the entire passage over instead of looking for key words). In the present study, these reasons cannot explain why students with a history of reading difficulties took longer to answer questions because they were unable to look back and reread the text. Simmons and Singleton's (2000) reasoning also does not explain why students with a history of reading difficulties would take longer on certain types of questions and not on others. To speculate, it is possible that students with a history of reading difficulties take longer to answer certain types of questions because of slower retrieval of information or lack of confidence in their answers, resulting in answering questions more carefully, and rereading questions and answer choices. Further studies are clearly needed to address this issue.

Although students with a history of reading difficulties were slower at reading texts than those without, there were no differences in reading comprehension scores on either the SATA or ND items administered. These results are consistent with past studies reporting that university students with a history of reading difficulties comprehend text just as well as their peers when given sufficient time (Corkett et al., 2006; Kemp et al., 2009; Parrila et al., 2007). Furthermore, there were no differences on the accuracy rates between the five types of questions on the SATA; these results were partly inconsistent with those of Simmons and Singleton (2000), who reported that in comparison to their typically reading peers, students with reading disorders performed worse on inferential questions but not on literal questions. It is possible that the inferential questions on Simmons and Singleton's (2000) reading comprehension measure were different from the ones in SATA in some fashion, and further research should be conducted to examine the source of this potential difference between students with and without reading difficulties.

The results of this study have implications for supporting university students with a history of reading difficulties. The findings confirm that students with a history of reading difficulties take longer to complete reading comprehension tests and may benefit from extra time to complete exams. This would suggest that when timed exams are necessary, criteria for accommodations should include self-report of difficulties. As the university student population becomes more diverse, it is imperative that more research is conducted on how to assess learning equitably, because standard traditional assessments may make differential demands on students' reading skills in ways we do not currently understand. Future research should examine why certain types of questions require more time to answer correctly, and what strategies students are using to answer them. In addition, how students with a history of reading difficulties are able to overcome their word reading difficulties and achieve university level comprehension performance is not currently understood. We need further studies of the comprehension processes that they are using to compensate for their basic word reading and reading rate difficulties.

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Chapter V: General Discussion

The focus of this dissertation was on factors associated with reading comprehension and reading rate in university students. University students are considered to be high-functioning adults that typically demonstrate advanced reading skills, allowing for insight into the end product of reading development (Deacon, Cook, & Parrila, 2012). However, the university population is becoming increasingly diverse as more students with a past history of learning and reading difficulties are successfully completing high school and pursuing post-secondary education (Vogel et al., 1998). As a result, there is a need to better understand reading comprehension within this population in order to assist with identification of reading difficulties and with designing accommodations and interventions. Despite the importance of examining adult reading skills, the majority of research in reading has focused on children (Snowling, 2000). The current dissertation presented three studies that examine reading comprehension and reading rate within the university population, and thus contributed to filling the current gap in understanding of these processes in adult reading research. The first study examined how we can measure adult reading comprehension and rate more effectively and efficiently. The second study examined how individual differences in various reading and cognitive skills account for individual differences in four different adult reading comprehension measures. The third study compared university students with and without a history of reading difficulties on measures of word and nonword reading rate, text reading rate and comprehension, and question-answering times.

The results of the first study suggested that a brief computerized version of the reading comprehension subtest from *Scholastic Abilities Test for Adults* (SATA; Bryant, Patton & Dunn, 1991) is not only faster to administer than the full version, but also provides a reliable estimate of reading comprehension. The brief SATA had an average completion time of eight minutes, with internal consistency comparable to the full version, and it was strongly correlated with the *Woodcock Reading Mastery Test-Revised* (WRMT-R; Woodcock, 1998) passage comprehension subtest, supporting its external validity. It also presented as less of a power test than the full version since it had weaker correlations with reading rate measures than the full version and all participants were able to complete it within the time-limit. Since the brief SATA was computerized, it was also capable of measuring text reading rate. The SATA text reading rate was moderately correlated with other measures of reading rate, including the commonly used *Nelson-Denny Reading Test* reading rate measure (ND; Brown, Fischo & Hanna, 1993). Overall, the brief SATA appears to be an adequate measure of reading comprehension and rate in studies where there is a need to measure reading comprehension quickly and reliably. Results also showed the curriculum-based measurement (CBM) maze test, which is a power test lasting only three minutes, was moderately correlated with both ND and WRMT-R passage comprehension. It was also moderately correlated with three different measures of reading rate. Overall, the CBM-Maze test appears to be an adequate brief screening measure of reading comprehension and rate that would be appropriate to use in situations where it is important to ensure adequate reading comprehension skills, for example, when providing informed consent, completing forms, or following written directions.

The purpose of the second study was to examine how different adult reading comprehension tests are affected by component skills of reading comprehension since previous studies measuring children's reading comprehension have suggested that predictors of reading comprehension vary depending on the reading comprehension measure. Results indicated that intercorrelations between adult reading comprehension measures were either not significant or only modest. This finding is consistent with studies of children's reading comprehension tests (Keenan, Betjemann, & Olson, 2008) and suggests that different cognitive skills contribute variably to individual differences in reading comprehension performance as measured by different tests. Indeed, regression analyses revealed variability in the contributions made by word and nonword reading rate, sentence and text reading rate, and working memory skills across the ND, SATA, WRMT-R and CBM-Maze reading comprehension tests. Most notably, word and nonword reading rate, which have consistently been shown to be strong predictors of children's reading comprehension (Landi, 2010), did not appear to strongly predict reading comprehension in highly-skilled adult readers as with children, accounting for only 6-15% of the variance. Instead, sentence and text reading rate were better predictors, accounting for 10 to 29% of variance across the measures. Working memory was also a significant predictor of adult reading comprehension, explaining between 5% and 22% of variance across the measures. In particular, the Reading Span working memory measure was a significant predictor for three of the four measures of reading comprehension and explained approximately 20% of variance in the WRMT-R scores. These findings are consistent with the extensive body of literature linking working memory to reading comprehension skills (Daneman & Merikle, 1996; Perfetti, Landi, & Oakhill, 2005; Singer, Halldorsen, Lear, & Andrusiak, 1992). Also, consistent with results from studies with children, this research adds to the growing body of studies finding dissimilarities among adult reading comprehension measures, and suggests that component skills required for various types of reading comprehension measures vary across tests and formats. These results also suggest that there is currently no test that adequately measures all of the component skills involved in reading comprehension. As a result, using a variety of tests that tap different skills can be informative for a more complete understanding of an individual's reading comprehension performance.

The third study found that students with a history of reading difficulties demonstrated slower word, nonword and text reading rate than their peers without a history of reading difficulties, which is consistent with past studies (e.g., Deacon et al., 2012; Parrila, Georgiou & Corkett, 2007). In addition, group differences were found on the time it took to answer questions. Even when word and text reading rate were statistically controlled, students with a history of reading difficulties took longer to answer most questions. Specifically, when word reading rate was controlled, students with a history of reading difficulties took longer to answer vocabulary, literal, inferential, and background knowledge questions. When text reading rate was controlled, they still took longer to answer literal, inferential, and background knowledge questions. These results suggest that students with a history of reading difficulties require extra time to complete reading comprehension measures for reasons other than just slower word and text reading rate. Despite slower reading and question-answering times, students with a history of reading difficulties did not demonstrate reading comprehension difficulties. These results are consistent with past studies reporting that university students with a history of reading difficulties comprehend text just as well as their peers when given sufficient time (Corkett, Parrila & Hein, 2006; Kemp, Parrila & Kirby, 2009; Parrila et al., 2007) and raises the question of how these students are compensating for their difficulties. Traditional theories of reading development, such as The Simple View of Reading, predict that students who struggle with word reading will consequently struggle to understand the meaning of what they are reading in text (Gough & Tunmer, 1986). University students with a history of reading difficulties who struggle with word reading, but have comparable reading comprehension to their peers, challenge traditional theories since they are unable to explain how they are able to comprehend so well with their word level difficulties. Future research should examine different comprehension processes that university students with a history of reading difficulties may be using to compensate for their basic word reading difficulties, since how they are able to overcome their word reading difficulties and achieve university level reading comprehension skills is not currently understood.

One main finding in this dissertation is that students with a history of reading difficulties may not only struggle with word and text reading rate, but also with answering certain types of questions in an timely and efficient manner. Although further research is required, this finding potentially has important ramifications for instruction and assessment. Students with a history of reading difficulties may benefit from being taught better question answering strategies. It is possible that they have not developed as efficient strategies as their typically reading peers when answering certain types of questions, and could benefit from instruction with those skills.

It is also important to note that students who reported a history of reading difficulties in this study were not necessarily formally diagnosed with reading difficulties. Despite not having formal diagnoses, they still performed slower on tasks of word reading, text reading and answering reading comprehension questions. In addition, despite their difficulties, they still managed to comprehend the text as well as their peers, when time was not a factor. This suggests that students who report a history of reading difficulties, even though they have not been formally diagnosed would likely benefit from extra time to complete exams in academic coursework in university. Currently, most post-secondary institutions require an up-to-date formal diagnosis in order for students to receive accommodations and supports, such as extra time, assistive technology, or tutoring. Obtaining a diagnosis is costly and few psychologists are skilled in assessing the kinds of reading skills that matter in university, resulting in many students who could benefit from supports being denied access to them. Self-report of reading difficulties appears to be an effective way of identifying students who could, for example, benefit from additional time to complete exams. Self-report is also cost-effective as it can be done with a brief questionnaire and does not require a large battery of assessment materials. Universities could possibly use self-report questionnaires, such as the ARHQ-R (Parrila, Corkett, Kirby & Hein, 2003), as a screening tool to help identify students who may be at-risk and in need of targeted supports.

Another important finding in this dissertation is that reading rate is likely a more complex construct than once thought. Word and nonword reading rate, sentence reading rate and text reading rate were all assessed in the three studies. As shown in the first and second studies, the different reading rate measures were only moderately correlated, suggesting that estimates of reading rate are greatly affected by the task used to measure it. In addition, different reading rate measures made unique contributions to reading comprehension measures, demonstrating that they tap at least partly different underlying cognitive processes. This suggests that not only should multiple measures be used when assessing reading comprehension in clinical situations, but the same is true for reading rate as well if a more complete understanding of it is the goal. Reading comprehension and reading rate are complex constructs, and using a single test to assess them may result in missing a reading deficit and consequently, under the current practices, depriving students of much needed supports.

As all three studies included in this dissertation examined university students, future research should include a wider range of individuals with more diverse educational backgrounds and levels of academic attainment. This would test whether the results reported here can be generalized to other adult populations. For example, results of the first study suggest that the

CBM-Maze test could be used as a quick screening measure of reading comprehension in situations where understanding a consent form, basic health literacy or instructions on how to take medication is important to establish; however, university students are generally not the population who have difficulties with these tasks. Replicating the study with individuals who have lower levels of education and literacy skills, or with individuals who are English language learners, is important to verify whether this tool is reliable in populations with which it may be most useful. Replicating the second study with more diverse samples would also allow examination of whether the contributions of different cognitive processing skills to reading comprehension depend on individuals' reading skills. It is possible that word reading is a more important predictor in adults with less education and lower literacy skills, similar to findings in children's reading comprehension research. Further, replicating the third study with participants from different education levels, such as college students, would allow us to explore whether similar groups of students with undiagnosed reading difficulties can be identified and whether their reading profiles resemble those observed in this study. These students could also benefit from being identified through use of self-report questionnaires (which may have to modified for different audiences) and would likely also benefit from academic supports. The third study also focused only on students with a history of reading difficulties, but future recruitment of students with diagnosed reading difficulties as participants would allow for even more comparisons between different groups. For example, it is possible that there are differences between students with and without diagnosed reading difficulties in question-answering time, in addition to differences in accuracy observed by Deacon et al. (2012).

In summary, the findings of the three studies reported herein provide more insight into university students' reading comprehension and reading rate. A brief reading comprehension measure and a quick screening measure of reading comprehension were identified as valid and reliable, and both can also provide a quick estimate of reading rate when needed. Analyses of individual differences across various adult reading comprehension measures confirmed that reading comprehension is not a unitary construct and that different skills, including word and text reading rate, contribute variably to performance on different reading comprehension measures. Finally, a comparison of university students with and without a history of reading difficulties revealed that students with a history of reading difficulties are slower in word reading, nonword reading, text reading and answering questions, despite comparable levels of comprehension. This dissertation contributes to a better understanding of reading comprehension, the cognitive processes and skills that contribute to it, and how they can be measured in adults. This information will help researchers and clinicians working with adults with reading difficulties to develop new approaches and protocols for improving assessment of reading and reading comprehension skills to support improved intervention and accommodation practices.

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Appendix A: Curriculum Based Measurement Maze Task

Cranes train for trip led by 'parent' plane

If there's a movie version, all **scary / nine / tape** of the rare whooping crane colts **hard / bug / will** fly in perfect V-formation. They'll soar **over / hat / jump** the Midwestern marsh in golden fall **page / light / rate**. Their ultralight "parent" will lead them **he / in / bat** a victorious circle over an awestruck **runs / take / crowd**. The plane, the golden light and **the / at / I'm** crowd were there, but in real **life / much / are**, nature wouldn't cooperate. At their long-**people / awaited / students** public debut, only one of five **this / young / asked** whoopers was able to break through **turbulent / consider / documents** air. He caught the plane's lift **school / wants / during** Saturday's demonstration flight. Four others flapped **them / far / how** behind, trying in vain to catch **up / of / per** with "mother."

The birds are still **say / or / in** training, but time is running out. **In / Him / Me** a few weeks they'll begin a 1,250-**about / mile / this** migratory journey to Florida. They'll follow **the / not / who** ultralight. The flight was briefer than **families / expected / dropped**. But Lyle Bradley didn't regret making **in / the / are** 200-mile trip from Andover to **out / see / then** it. "There aren't too many people **he / two / in** the United States who've seen whooping **cranes / young / losing** flying in formation," said the retired **decided / biology / shouldn't** teacher. He was one of about 700 **dealed / people / office** who gathered at the Necedah **Catching / National / Purpose** Wildlife Refuge for Saturday's public celebration. **It / An / By** was, in fact, the first time **too / now / in** more than a century that wild **whooping / directors / bookends** cranes have flown over the Midwest. **Over / And / Has** it was the first time they **were / but / earn** seen following an ultralight. "It's exciting **up / to / be** see this crazy idea come to **be / in**

/ the such a meaningful management technique," **best / said / free** Joan Galli. She drove from St. Paul **try / was / for** the event.

The crane colts are **part / work / ask** of an innovative effort. The effort **end / is / job** led by the men whose bird-**earnestly / training / speeches** methods inspired the 1996 movie "Fly **Sized / Sixth / Away** Home." Their organization is Operation Migration. **It / Has / For** is one of nine private and **clearly / public / graders** agencies that form the Whooping Crane Eastern Partnership. **It / Out / Ask** is the sponsor of the $1.3 **everyone / million / brushing** project. Whooping cranes came very close **of / to / be** extinction from habitat destruction and hunting. **Once / Less / Run** believed to have numbered in the **accompany / forgetting / thousands**, the population had dwindled to only 15 **birds / afraid / world** by 1941. Today, conservation efforts have **several / brought / easier** the number to about 400. Still, they're **popcorn / voided / hardly** out of danger. Less than half **and / of / who** the birds live in captivity; the **rest / made / laugh** are concentrated in two wild populations. **Sold / One / Buy**, a non-migrating flock of 86, **was / back / six** established in 1993. This flock lives **he'd / in / gum** central Florida. A single migrating flock **to / of / act** 174 breeds in northwest Canada and **winters / payment / several** on the Texas Gulf Coast. A single catastrophic event there -- such as a **themselves / employees / hurricane** or chemical spill -- could wipe out **the / void / kept** flock. That concern prompted the 1999 **computers / formation / unafraid** of the partnership. Its mission is **to / old / or** establish a second North American migratory **achievement / population / servitude** of the species.

Since 1988, Operation **Toystore / Controlled / Migration** has successfully taught migratory routes to **easier / floor / geese** and sandhill cranes. This is the **forgetting / supervised / partnership's** first attempt with the rare whoopers.

<u>Write / Last / Boss</u> year, it prepared by leading a **<u>trial / issue / came</u>** run with sandhill cranes over the **<u>when / same / and</u>** path. The birds followed Operation Migration's **<u>complained / ultralights / educational</u>** for the 40-day trip from Necedah **<u>I / an / to</u>** central Florida. This spring, all 11 **<u>star / birds / post</u>** returned to Necedah on their own. **<u>Teaching / Huddled / Analyzed</u>** the birds to follow the ultralight **<u>paid / and / ever</u>** keeping them from imprinting on humans **<u>boss / has / I've</u>** been challenging, but necessary. Keeping the **<u>back / start / birds</u>** wild is critical to the success of the experiment, said Joe Duff. He **<u>is / so / way</u>** co-founder of Operation Migration and one **<u>of / day / in</u>** the ultralight pilots.
