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Rapid Naming Speed and Reading in Adults with and without Dyslexia

by

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Abstract

This study sought to examine (a) if Rapid Automatized Naming (RAN) differentiates between dyslexic and normal readers in adulthood, and (b) if RAN is more strongly related to reading in adult readers with dyslexia than to normal readers. The participants in this study were assessed on two RAN tasks (Letters and Objects), in addition to: Raven's Matrices; Phoneme Elision; Word Identification; Word Attack, and Reading Comprehension. They were also asked to complete a questionnaire on their reading history that was used for the initial screening of the participants. The results revealed that RAN continues to differentiate between dyslexic and normal readers in adulthood and that RAN was similarly related to reading in the two groups of readers. These results add to the literature regarding RAN and reading in adulthood, suggesting that RAN continues to influence reading throughout development.

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Chapter 1: Introduction

Several cognitive processes important for reading have been identified in the literature. One such cognitive process is Rapid Automatized Naming or RAN (Blachman, 1984; Bowers, Sunseth, & Golden; 1999; Bowey, McGuigan, & Ruschena, 2005; Cirino, Israelian, Morris, & Morris, 2005; Georgiou, Parrila, Kirby, & Stephenson, 2008; Manis, Doi, & Bhadha, 2000; Misra, Katzir, Wolf, & Poldrack, 2004; Parrila, Kirby, & McQuarrie, 2004; Roman, Kirby, Parrila, Wade-Woolley, & Deacon, 2009; Wolff, Michel, & Ovrut, 1990). Also known as naming speed, RAN is defined as the ability to name as quickly as possible highly familiar visual symbols, such as letters, digits, objects, and colors (Wolf & Bowers, 1999). There are two types of RAN tasks: alphanumeric and non alphanumeric (Kirby, Georgiou, Martinussen, & Parrila, 2010). The alphanumeric RAN tasks consist of RAN-Letters and RAN-Digits and the non alphanumeric RAN tasks include RAN-Objects and RAN-Colors. The current literature indicates that the alphanumeric RAN tasks correlate more strongly with reading than non alphanumeric RAN tasks (Cronin & Carver, 1998; Compton, 2003). However, with young children where letters and digits are not yet fully learned to the extent that they are highly familiar, it is preferable to utilize non alphanumeric RAN tasks to predict reading achievement.

It is accepted that RAN is correlated with reading (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Bowers, 1995; Bowers & Wolf, 1993; Bowey et al., 2005; Felton, Naylor, & Wood, 1990; Manis et al., 2000; Misra et al., 2004;

Roman et al., 2008; Savage et al., 2005; Torgesen, Wagner, & Rashotte, 1994; Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997) and that difficulties with RAN tasks are demonstrated by children with dyslexia (Conrad & Levy, 2007; Denckla & Cutting, 1999; Felton, Naylor, & Wood, 1990; Savage et al., 2005; Wimmer, 1993). For this study, dyslexia is defined according to the definition of the American Psychiatric Association. Specifically, dyslexia is reading achievement (reading accuracy or speed) that falls substantially below that expected given the individual's age, intelligence, and education (American Psychiatric Association, 2000). It is noted that this definition of dyslexia applies to the current study only, as definitions tend to vary between studies. Swanson, Trainin, Necoechea, and Hammill (2003), in their meta-analysis, found that RAN's median correlation coefficient with reading skills was 0.46, indicating a moderately positive correlation. Additionally, numerous studies have found that children with dyslexia perform more poorly on RAN tasks than children without dyslexia (Conrad & Levy, 2007; Denckla & Rudel, 1972; Jones, Branigan, & Kelly, 2009; Meyer, Wood, Hart, & Felton, 1998). In fact, because RAN is influential to reading skills, some researchers have proposed that RAN is one of the main reading deficits experienced by dyslexic readers (Wolf & Bowers, 1999).

Although RAN's influence in children's reading skills is widely accepted, RAN's role in adult reading skills is less well understood as there have been few studies that have used adult readers. Furthermore, these studies have produced conflicting results (Arnell et al., 2009; Everatt, 1997; Wolff et al., 1990). First, it is not clear whether or not RAN differentiates between dyslexic and ‘normal’ readers in adulthood, as it does in children (Denckla & Rudel, 1976; Wolf, 1986). For the purpose of this study, the term “normal” will refer to non-dyslexic readers. Regarding the question of whether or not RAN differentiates between dyslexic and normal readers in adulthood, Vukovic, Wilson, and Nash (2004), for example, found that dyslexic adult readers performed worse on tests of RAN than normal adult readers, whereas Parrila, Georgiou, & Corkett (2007) found no significant differences between dyslexic and normal readers on the RAN tasks regarding Objects, Digits, and Letters. Additionally, there are also conflicting results regarding whether RAN relates more strongly to reading in dyslexic adult readers as opposed to normal adult readers. A search of the literature revealed no studies that have investigated this issue in adult readers.

Controversy regarding whether RAN is more strongly related to reading in dyslexic or normal readers however, still exists within the children’s population of readers. For example, Scarborough (1998) found that RAN was more important for predicting reading ability in poor readers, whereas Swanson et al. (2003) found that RAN was more important for predicting reading ability in good readers. These conflicting findings indicate the need for further inquiry into RAN’s ability to predict reading in both populations; those consisting of good and poor child readers as well as those of good and poor adult readers. Further, if RAN is found to be a predictor of reading skills in adulthood, then RAN could be a target of intervention during childhood, since children with dyslexia often continue to experience reading difficulties throughout their lives.

It seems that further exploration of the RAN-reading relationship in adults may provide information that could contribute to remedial directions for children with reading difficulties. The purpose of this study was two-fold: (a) to examine if RAN differentiates between dyslexic and normal readers in adulthood, and (b) to determine if RAN relates more strongly to reading in dyslexic adult readers than to normal adult readers.

In the remainder of this thesis, I will discuss the existing literature on RAN and reading, focusing on RAN in adulthood (Chapter 2). Next, I will present the methodology and data collection (Chapter 3) as well as the results of the study (Chapter 4). The thesis ends with a discussion of the results and directions for future research (Chapter 5).

Chapter 2: Literature Review

Rapid Automatized Naming (RAN) tasks require that the participant name the stimuli presented in the visual array of colors (RAN-Colors), objects (RAN-Objects), digits (RAN-Digits), or letters (RAN-Letters) (see Appendix A for samples of the RAN tasks used in this study). The stimuli are read from left to right as quickly as possible and the time taken to read all the stimuli is recorded as the participant's score. These RAN tasks have generated considerable research because of their capacity to predict reading ability and future reading success (Blachman, 1974; Bowers, 1995; Decker, 1989; Denckla, 1972; Denckla & Rudel, 1976; Felton et al., 1990; Savage et al., 2005; Scarborough, 1998; Schatschneider, Carlson, Francis, Foorman, & Fletcher, 2002; Torgesen et al., 1994; Vukovic, 2004; Wimmer, 1993; Wolf & Bowers, 1999; Wolff et al., 1990). This research goes as far back as the 1970's, when Denckla (1972) noted a "visual-verbal" disconnection in Grade 1 children with an unexpected reading failure. Specifically, Denckla (1972) found that a group of dyslexic children were accurate in naming the color stimuli, but were extremely slow. This finding stimulated further research on RAN that not only replicated Denckla's (1972) initial findings (Blachman, 1984; Bowers et al., 1999; Jones, Branigan, & Kelly, 2009; Meyer, Wood, Hart, & Felton, 1998), but also extended the findings by establishing a connection between RAN and future reading ability (Manis, Doi, & Bhadha, 2000; Parrila et al., 2004; Schatchneider, Carlson, Francis, Foorman, & Fletcher, 2002).

RAN's influence on reading has also been established in other orthographies, or languages, in addition to English. English is considered to be a "deep orthography." That is, it is a language where grapheme to phoneme correspondences are not 1 to 1. For example, in English the letter "a" can be pronounced in two different ways, such as an "a" in the word "cat" or "made." On the other hand, "shallow orthographies," such as Greek and Finnish, have 1 to 1 grapheme to phoneme correspondences (Kirby et al. 2010). Therefore, all the letters of their alphabet always make the same sound. This makes the Greek and Finnish languages much simpler to learn and reading acquisition is a much quicker process.

RAN-Reading Relationship Theory

Despite the acknowledged importance of RAN in predicting reading, researchers concur that we do not know why it is related to reading. Reading is extremely complex and many different skills, such as phonological awareness and orthographic knowledge contribute to reading skill and comprehension. Additionally, reading skills are hierarchical in nature. For example, in order to achieve orthographic knowledge, one must have first achieved phonological awareness. Because the overall goal of reading is to comprehend what was read, several theoretical accounts have been proposed in an effort to further understand the RAN-reading relationship (Bowers, 1995; Bowers et al., 1999; Bowers & Wolf, 1993; Kirby et al., 2010; Kail & Hall, 1994; Kail, Hall, & Caskey, 1999; Torgesen et al., 1994; Torgesen et al., 1997) and the difficulties that prevent accurate comprehension. The three main theoretical accounts discussed in this paper are as follows:

1. Phonological Processing;
2. Orthographic Processing; and
3. Speed of Processing

Phonological Processing Theory.

Originally, Torgesen and colleagues (Torgesen et al., 1994; Torgesen et al., 1997) argued that RAN was related to reading because it assessed the ability to access and retrieve phonological information from the long-term memory. This theory proposed that reading disabilities are a result of a singular deficit in phonological processing. Phonological processing is defined as the mental operations that make use of the sound structure of oral language when decoding written language (Torgesen et al., 1994) and it was hypothesized that RAN deficits were simply a manifestation of a primary phonological deficit. Therefore, those who demonstrated slow RAN performance were assumed to have poor phonological representations of letter names, letter, sounds or whole words (Elbro, Neilsen, & Petersen, 1994; Manis et al., 2000).

In support of this theory, Torgesen et al. (1994) found a 0.70 correlation between RAN performance and phonological decoding ability in grade two children. Conversely, Bowers and Newby-Clark (2002) found that dyslexic readers with remediated phonological processing abilities still had remaining RAN deficits, suggesting that RAN must be related to more than just phonological processing. In fact, studies have shown that RAN continues to predict reading over and above the contribution of phonological processing skills such as phonological awareness (Parrila et al., 2004).

Wolf and Bowers (1999) put forth the ‘Double Deficit Hypothesis’ that further highlighted the suggestion that RAN was a measure of more than phonological processing. The Double Deficit Hypothesis proposed three possible impairments related to reading disabilities:

(a) A phonological deficit;

(b) A naming speed deficit; and

(c) A double deficit in both areas (phonological and naming speed)

Wolf and Bowers (1999) hypothesized that those readers with phonological deficits would display difficulties with phonological processing and word recognition, whereas those readers with naming speed deficits would have good phonological processing abilities but have difficulties in naming speed and word recognition (Bowers et al., 1999). Further, the study stated that those readers with a deficit in both areas would be the most severely impaired readers of all. Not only would these readers have difficulty in identifying letters and their corresponding sounds (phonological deficit) they would also be very slow at reading text (naming speed deficit). Therefore the Double Deficit Hypothesis proposed that naming speed deficits could occur independently of, or concurrently with, phonological deficits.

Orthographic Processing Theory.

Some researchers suggested that RAN was related to reading because it contributed to the development of orthographic processing (Bowers, 1995;

Bowers & Newby-Clark, 2002; Bowers & Wolf, 1993). The focus of the current study, this theory suggested that RAN deficits were independent of phonological processing deficits. Orthographic processing occurs when groups of letters or entire words are processed as single units rather than as a sequence of grapheme-phoneme correspondences (Kirby et al., 2010). For example, to develop skilled orthographic processing a reader must have had extensive exposure to print, and it is through repetitive exposure to reading that a reader can begin to form orthographic representations that contribute to skilled reading ability (Torgesen et al., 1997). It has been argued that when letter identification proceeds slowly, as reflected by slow RAN performance, letter representations in words are not activated quickly enough to solidify common orthographic patterns (Bowers & Wolf, 1993). Thus, words are processed as individual units rather than chunked together. For example, in the word "carpenter" each individual letter would be sounded out rather than chunking groups of letters and reading the words "car," "pen," and "ter." This type of reading strategy, where individual letters are sounded out separately rather than chunked together, has been found to be characteristic of dyslexic readers (Bowers & Wolf, 1993).

In support of this orthographic processing theory, it was found that dyslexic readers continued to apply these strategies long after their same aged peers began to develop orthographic processing skills (Bowers & Wolf, 1993). In fact, Bowers and Wolf indicated that normally progressing readers tended to develop orthographic letter-cluster codes automatically, whereas dyslexic readers did not. However, there is research that challenges the orthographic processing theoretical account as well (Bowers et al., 1999; Conrad & Levy, 2007). For example, Bowers et al. (1999) found that children with dyslexia were able to utilize the orthographic structure of words to assist them in reporting letters after viewing a group of letters for a limited amount of time.

Speed of Processing Theory.

Finally, some researchers proposed that RAN predicted reading ability because it tapped the efficiency of processing speed (Breznitz, 2005; Kail, Hall, & Caskey, 1999). Processing speed is defined as the rate at which cognitive processing occurs, and Kail and Hall (1994) argued that RAN performance was reflective of one's speed of cognitive processing. Further, they suggested that superior performance on RAN tasks was a reflection of developmental changes in processing speed. As such, they proposed that slow RAN performance was a result of delays in one's cognitive development. In support of this theory, Breznitz (2005) found that speed of processing was slower in dyslexic readers when performing a RAN task. She found that dyslexic readers took longer to perceive, discriminate, and process stimuli. However, there is also evidence contradicting the theory regarding the speed of processing in the RAN-reading relationship (Cutting & Denckla, 2001; Georgiou et al., 2009; Powell et al., 2007). For example, Powell et al. (2007) found that children with slow or fast RAN performance did not differ on measures of processing speed. Additionally, Cutting and Denckla (2001) found that even when speed of processing was controlled for, RAN continued to contribute to reading skill.

RAN and Reading in Adulthood

Although RAN has been found to be predictive of early reading ability (Blachman, 1984; Bowers et al., 1999; Bowey et al., 2005; Compton, 2003; de Jong & van der Leij, 1999; Kirby et al., 2003; Misra et al., 2004; Parrila et al., 2004; Schatschneider et al., 2004), it remains unclear if this relationship holds true throughout development into adulthood. This is important to examine because it would assist us in further understanding the influence of RAN as reading skills develop. Additionally, it would help inform intervention and the skills to be targeted during this process. For example, if it were found that RAN deficits still persist in adults with dyslexia, RAN as a skill could be targeted in children with dyslexia in an effort to mediate the detrimental effects slow RAN have on reading. Teaching skills such as prosody (expression) would be one such skill to target in childhood.

To date, only a few studies have examined the RAN–reading relationship in adulthood and they have produced conflicting findings. On the one hand, some studies found that RAN continued to predict reading into adulthood (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Decker, 1989; Jones, Branigan, Hatzidaki, & Obregon, 2010; Miller et al., 2006; Wile & Borowsky, 2004). Arnell et al. (2009), for example, found that RAN accounted for 10% of the variance in reading comprehension and 17% of the variance in reading rate.

On the other hand, studies have shown that RAN did not significantly predict reading in adulthood. For example, Everatt (1997) found that none of the four RAN tasks, RAN-Letters, RAN-Objects, RAN-Digits, or RAN-Colors, predicted non-word reading in adults (non word reading is a task that requires the reading of ‘made up’ words, thereby assessing phonological awareness). Some researchers have in fact suggested that RAN lost its predictive ability beyond Grade 3 (Georgiou et al., 2009; McBride-Chang & Manis, 1996). For example, Roman et al. (2008) found that RAN was not a significant predictor of word identification and pseudoword reading (made up words), when considered with phonological awareness and orthographic knowledge.

The inconsistency surrounding the role of RAN on reading in adulthood has also been documented in studies with dyslexic and non-dyslexic adult readers. Some studies have shown that RAN tasks differentiate between adult dyslexic and normal readers (Decker, 1989; Felton et al., 1990; Jones et al., 2010; Swanson, 2012; Thomson, Fryer, Maltby, & Goswami, 2006; Vukovic et al., 2004; Wolff et al.,1990). Decker (1989), for example, found that adult dyslexic readers performed more poorly than normal readers on all four RAN tasks. These results were duplicated by Jones, Branigan, and Kelly (2009) who found that dyslexic adult readers were consistently slower than normal readers on the RAN-Letters task.

In contrast, only three studies showed that RAN tasks did not differentiate between dyslexic and non-dyslexic readers (Everatt, 1997; Lindgrén & Laine, 2010; Parrila, Georgiou, & Corkett, 2007). Lindgrén and Laine (2010), for example, found no significant differences between dyslexic and non-dyslexic readers on RAN Objects, Digits, and Letters tasks. This may be due to the fact that Lindgrén and Laine’s (2010) study was performed in Finnish and Swedish languages and not English. Everatt (1997) found that dyslexic and normal readers did not differ on RAN-Colors and RAN-Objects tasks. However, Everatt (2007) administered the RAN tasks in a discrete format where stimuli were presented one at a time. This format deviated from the traditional RAN task which presented stimuli in serial format. Lastly, Parrila et al. (2007) found that the RAN-Colors task did not distinguish between dyslexic and non-dyslexic groups. However, the RAN-Colors and RAN-Digits tasks administered were shortened to 36 stimuli rather than the traditional 80 stimuli.

Whether RAN is more strongly related to reading in dyslexic or normal adult readers is also a conflicting issue (Frijters, Lovett, Steinbach, Wolf, Sevcik, & Morris, 2011; Kirby et al., 2010; McBride-Chang & Manis, 1996; Meyer et al., 1998; Savage et al., 2005; Scarborough, 1998; Swanson & Hseih, 2009; Swanson et al., 2003). To date, no studies have examined this question in an adult population of readers. However, studies that have used children continue to demonstrate contradictory findings. For example, some studies have found that RAN is more strongly related to reading in groups of poor readers than good readers (Frijters et al., 2011; Meyer et al., 1998; Savage et al., 2005; Scarborough, 1998). Meyer et al. (1998), for example, compared the contribution of RAN to reading in normal and dyslexic children and found that all four RAN tasks accounted for unique variance in reading only in the group of dyslexic children.

In contrast, other studies found that RAN was more strongly related to reading in good readers than in poor readers (Swanson & Hseih, 2009; Swanson et al., 2003). For example, Swanson et al. (2003), in their meta-analysis, found that the correlation between RAN and reading in the group of dyslexic children was significantly lower than the correlation between RAN and reading in the group of normal readers. They state that the “correlations associated with poor readers are substantially weaker than those associated with skilled readers” (p. 430).

There are also studies that have found no differences in the RAN-reading relationship between good and poor adult readers (Bekebrede, van der Leij, & Share, 2009; Pennington & Lefly, 2001; Torgesen et al., 1997). For example, Torgesen et al. (1997) examined the effects of RAN on word identification and pseudoword reading in a group of poor readers and found no differences between groups. Additionally, Pennington and Lefly (2001) performed a longitudinal study finding that the predictors of literacy skills, including RAN, did not differ according to the type of reader.

The Present Study

The purpose of the current study was two-fold: (a) to examine if RAN differentiates between dyslexic and normal readers in adulthood, and (b) to examine if RAN is more strongly related to reading in the group of dyslexic adult readers than in the group of normal adult readers.

As can be seen from the literature review, the evidence regarding these two questions is conflicted. Some studies have found that RAN differentiates between dyslexic and normal readers in adulthood (Decker, 1989; Felton et al., 1990; Jones et al., 2010; Swanson, 2012; Thomson et al., 2006; Vukovic et al., 2004; Wolff et al., 1990), while others have found that RAN does not differentiate between dyslexic and normal adult readers (Everatt, 1997; Lingrén & Laine, 2010). Furthermore, although no studies have been conducted regarding the predictive relationship between RAN and reading in adult participants, some studies have found that RAN is more strongly related to reading in child dyslexic readers (Frijters et al., 2010; McBride-Chang & Manis, 1996; Meyer et al., 1998; Scarborough, 1998) while other have found that RAN is more strongly related to reading in normal child readers (Swanson & Hseih, 2009; Swanson et al., 2003). These conflicting results highlight the importance of the current study, which will attempt to contribute to an eventual resolution of these discrepancies.

Chapter 3: Methodology

Participants

Two groups of university students participated in the study. The experimental group consisted of 27 adults (19 females, mean age = 26.960 SD = 5.77) with a self-reported history of reading difficulties (RD) and with scores on the elementary education section of the Adult Reading History Questionnaire – Revised (ARHQ-R; Parrila, Corkett, Kirby, & Hein, 2003) indicating presence of reading difficulties during childhood. An additional inclusionary criterion for the dyslexia group was a score of 1 standard deviation (SD) below the control group's mean on at least one reading or spelling outcome. The dyslexic participants were recruited through the Specialized Support and Disabilities Services (SSDS) at the University of Alberta or through poster advertisements on campus, and received a $20 honorarium for their participation in the study.

The control group consisted of 34 adults (24 females, mean age = 22.94, SD = 4.89) with no self-reported history of reading difficulties and scores on the elementary education section of the ARHQ-R indicating absence of reading difficulties during childhood. The participants in the control group were recruited from a participant pool program in the Department of Educational Psychology at the University of Alberta and received 5% credit towards their course grade in return for their participation in the study. All participants in the control and RD groups reported English as their first language and had normal or corrected-to-normal vision.

Materials

Adult Reading History Questionnaire – Revised (ARHQ-R). (Parrila et al., 2007). This questionnaire was administered to assess the severity of developmental reading difficulties experienced by the participants. Therefore, only questions related to reading difficulties during elementary school years were administered. The elementary education section of the ARHQ-R included 8 items requiring a response on a Likert scale from 0 to 4. Higher numbers on the Likert scale reflected greater reading difficulty. A participant's score was equal to the sum of their responses divided by the maximum sum of responses (32). Therefore scores ranged from 0 to 1. Cronbach's alpha reliability coefficient in the sample was 0.96. Dyslexic participants scored above .45 (mean = 0.68, *SD* = 0.13) and controls scored below .28 (mean = 0.10, *SD* = 0.08).

General cognitive ability.

Raven's Progressive Matrices. This paper and pencil task measured non-verbal fluid reasoning and it was adopted from Raven's Standard Progressive Matrices (2003). It included 24 incomplete visual patterns that participants were asked to complete using one of eight choices of visual pattern pieces. Standardized administration procedures were followed. Cronbach's alpha reliability coefficient was reported in the assessment manual as 0.88.

Rapid automatized naming (RAN).

RAN- Letters. This task was adopted from the RAN/RAS test battery (Wolf & Denckla, 2005) and required participants to name a series of letters as fast as possible. Two separate RAN-Letters cards were administered on a laptop computer. The first card consisted of five letters (o, a, s, d, p) presented in eight rows of ten (see Appendix A). The second task consisted of 20 letters (g, h, j, w, y, and z were omitted from the 26 letters of the alphabet) also presented in eight rows of ten (see Appendix A). The participants were instructed to name all the letters from left to right, beginning at the top row, as fast as possible. The participant's score was the total time to name all the stimuli in each card. Prior to the timed item, participants were given a practice trial to ensure familiarity. Because the number of naming errors was negligible, it was not reported or used in further analyses. Wolf and Denckla (2005) reported test-retest reliability for RAN-Letters to be 0.92 across ages. The correlation between the two forms of RAN Letters in our sample was 0.95.

RAN-Objects. Administration format and procedures were identical to those of RAN-Letters except from the type of stimuli. The first task consisted of five objects (clock, star, fan, leaf, dress) presented in eight rows of ten (see Appendix A). The second task consisted of 20 objects (glass, box, clock, fish, nail, tape, pear, egg, tie, girl, fire, lion, rope, dress, car, broom, fan, leaf, star, kite) also presented in eight rows of ten (see Appendix A). The participant's score was the total time to name all the stimuli in each card. Wolf and Denckla (2005) reported test-retest reliability to be 0.84 across ages for RAN-Objects. The correlation between the two forms of RAN-Objects in our sample was 0.82.

Reading ability.

***Word identification*.** Form H Word Identification test from the Woodcock Reading Mastery Tests – Revised (WRMT-R; Woodcock, 1998) was used to assess word reading accuracy. This task presented individual real words, increasing in difficulty, on a computer screen which the participants were required to orally pronounce. The participant's score was the number of correctly read words (max = 106). Cronbach's alpha reliability coefficient in our sample was .88.

***Word attack*.** Form H Word Attack test from Woodcock Reading Mastery Tests – Revised (WRMT-R; Woodcock, 1998) was used to assess nonword reading ability. This task required participants to read aloud pronounceable nonwords of increasing difficulty. The participant's score was the number of correctly read nonwords (max = 45). Cronbach's alpha reliability coefficient in our sample was 0.90.

Reading comprehension. The Form G Comprehension test from the Nelson-Denny Reading Test (Brown, Fishco, & Hanna, 1993) was used to assess both reading comprehension and reading rate. The comprehension tests included seven passages and a total of 38 multiple choice questions, each with 5 answer choices. The time limit for this test was 20 minutes and the first minute was used to determine reading rate. Cronbach's alpha reliability coefficient in the sample was 0.80.

Spelling ability.

Peabody Individual Achievement Test – Revised (PIAT-R). This computerized task was a measure of spelling ability that included 85 items that increased in difficulty. Three practice items were first provided to ensure understanding. Items were presented on a computer screen with four possible answers, each of which was within one quarter of a quadrant. The participant was orally read a sentence by the examiner and asked to press a key corresponding to the quadrant they thought the correct word was in. Participants were scored based upon their accuracy. Cronbach's alpha reliability coefficient in our sample was 0.85.

Wide Range Achievement Test – 3 (WRAT-3). This paper and pencil task was a measure of spelling ability that included 40 items that increased in difficulty. Items were read orally by a recording. The target word to be spelled was first read, followed by a sentence using the target word, and ending with the target word. The participant was asked to write down their response on a provided answer sheet and their performance score was the number of correctly spelled words. Cronbach's alpha reliability coefficient in our sample was 0.90.

Procedure

All participants were tested individually by a trained graduate student in a quiet room at the University of Alberta. Tasks were administered across two sessions, each lasting approximately one hour. Session A involved the computerized measures of RAN-Objects, RAN-Letters, PIAT, WRAT, word identification, and word attack. Session B involved the paper and pencil measures of ARHQ-R, Raven's Matrices, and Nelson-Denny reading comprehension.

Chapter 4: Results

Descriptive Statistics

A descriptive analysis and independent samples t-tests were conducted to determine if RAN differentiates between dyslexic and normal adult readers. Table 1 shows the descriptive statistics on all the measures used in the study as well as the results of the independent samples t-tests. The adults with dyslexia completed both RAN-Letters tasks, t (59) = -6.41, p <.001 and t (59) = -5.14, p <.001, and both RAN-Objects tasks t (59) = -3.01, p <.01 and t (59) = -2.22, p <.05, slower than the controls. Additionally, the controls made significantly fewer errors than the adults with dyslexia on PIAT, t (59) = .26, p <.05, WRAT, t (58) = 4.25, p < .01, Word Identification, t (59) = 3.48, p <.001, and Word Attack, t (59) = p < .001. There were no significant differences between the dyslexics and controls on Raven's Matrices and on Nelson Denny Reading Comprehension.

Correlational Analysis

Table 2 shows the correlations between the RAN and the reading measures in the study, separately for the two groups (the correlations for the dyslexics group appear below the diagonal and for the normal readers above the diagonal). To reduce the number of variables, an average time of the two RAN Letters' cards and an average of the two RAN Objects' cards was calculated. In the group of adults with dyslexia, both RAN measures correlated significantly with the reading outcomes (with two exceptions). In contrast, in the group of normal readers, only RAN Letters correlated with word identification.

Hierarchical Regression Analysis

A series of hierarchical regression analyses were conducted (a) to test the effects of RAN-Letters and RAN-Objects on Word Identification, Word Attack, and Reading Comprehension, and (b) if RAN was a stronger predictor of reading in one of the groups. To examine the latter, an interaction of RAN by group was calculated. The order of the variables entered in the regression equation was as follows: nonverbal intelligence (step 1), RAN Letters or Objects (step 2), and RAN by group interaction (step 3). The results of the hierarchical regression analyses are presented in Table 3. The results of the hierarchical regression analyses indicated that RAN Letters was a significant predictor of each reading outcome accounting for 16-36% of the variance after controlling for the effects of nonverbal intelligence. Likewise, RAN Objects explained 7% of the variance in reading comprehension and 8% of the variance in word identification, after controlling for the effects of nonverbal intelligence. Importantly, none of the interaction terms accounted for a significant amount of variance in the reading outcomes.

Table 1

Descriptive Statistics of Dyslexic and Non Dyslexic Adult Readers on Cognitive and Reading Measures

	Controls *(n = 34)*		Dyslexic Readers *(n = 27)*		t-test	Cohen's d
Measure	*M*	*SD*	*M*	*SD*		
Raven's Matrices	19.50	2.78	20.07	2.92	-0.78	-0.20
RAN-Letters (5x16)	24.27	39.58	33.10	67.03	-6.41***	-1.60
RAN-Letters (16x5)	26.27	46.43	35.78	86.68	-5.49***	-1.37
RAN-Obj. (5x16)	46.52	65.37	52.61	92.41	-3.01**	-0.76
RAN-Obj. (16x5)	53.25	93.50	60.60	15.07	-2.34*	-0.59
PIAT	91.12	4.36	88.19	5.36	2.36*	0.60
WRAT	45.87	4.75	40.42	5.33	4.25***	1.11
Reading Comprehension	31.76	5.05	29.37	6.44	1.63	0.41
Word Identification	99.62	4.55	93.19	11.64	3.48***	0.79
Word Attack	39.83	2.59	34.15	5.24	3.23***	1.30

Note. RAN = Rapid Automatized Naming; PIAT = Peabody Individual Achievement Test; WRAT = Wide Range Achievement Test; *p < .05; ** p < .01; *** p < .001.

Table 2

Pearson Correlations between the RAN Tasks and the Reading Outcomes

	1.	2.	3.	4.	5.	6.	7.
1. Age		0.09	-0.10	0.16	0.26	0.39*	0.03
2. Raven's Matrices	0.12		-0.04	0.33	0.15	0.18	0.38*
3. RAN-Letters	-0.05	-0.08		0.47**	-0.28	-0.56**	-0.20
4. RAN-Objects	0.14	-0.05	0.58**		0.04	-0.12	0.24
5. Reading Comprehension	0.14	0.40*	-0.41*	-0.35		0.43*	0.21
6. Word Identification	0.28	0.26	-0.63**	-0.49**	0.49**		-0.04
7. Word Attack	0.17	0.07	-0.54**	-0.05	0.37*	0.22	

Note. RAN= Rapid automatized naming. Below diagonal: dyslexic readers (n = 27); above diagonal: normal readers (n = 34). * $p < .05$; ** $p < .01$.

Table 3

Results of Hierarchical Regression Analyses with RAN-Letters and RAN-Objects tasks as Predictors of Word Identification, Word Attack, and Reading Comprehension

Step	*Variable*	*Word Identification*		*Word Attack*		*Reading Comprehension*	
		ß	ΔR^2	*ß*	ΔR^2	*ß*	ΔR^2
1.	Raven's Matrices	0.23	0.05	0.11	0.01	0.20	0.04
2.	RAN-Letters	-0.40	0.16***	-0.59	0.35***	-0.39	0.16**
3.	RAN-Letters X Group	-0.13	0.00	0.16	0.01	0.07	0.00
2.	RAN-Objects	-0.29	0.08*	-0.16	0.02	-0.26	0.07*
3.	RAN-Objects X Group	0.12	0.01	0.10	0.00	0.22	0.02

Note. RAN= Rapid Automatized Naming.
* $p < .05$; ** $p < .01$; ***$p < .001$.

Chapter 5: Discussion

The present study investigated the following two questions:

1. Does RAN differentiate between dyslexic adult readers and normal adult readers?
2. Does RAN relate more strongly to reading in the group of adults with dyslexia than to normal adult readers?

The first question was examined through descriptive analyses and independent t-tests. The results revealed significant differences between the dyslexic and non dyslexic groups, on both Rapid Automatized Naming (RAN) – Letters and Objects. That is, the dyslexic adult readers performed significantly poorer on the RAN tasks than the non dyslexic adult readers. Therefore, this study found that RAN does differentiate between dyslexic and non dyslexic adult readers.

These results indicated that RAN deficits, while often present in child dyslexic readers, can also be present in adult dyslexic readers. Even though the dyslexic participants may have compensated for their reading comprehension difficulties (no differences were found between the two groups on reading comprehension) through intensive intervention, the results showed that adult readers still have lingering difficulties in RAN. This finding was consistent with those of previous studies (Arnell, Joanisse, Klein, Busseri, & Tannock, 2009; Decker, 1989; Jones, Branigan, Hatzidaki, & Obregon, 2010; Miller et al., 2006; Wile & Borowsky, 2004), suggesting that even though dyslexic readers are able to compensate for their disability and become skilled enough to participate in university, they still have difficulties characteristic of dyslexia. It must be noted that compensation for reading disabilities can be a difficult and lengthy process, requiring intensive instruction that is ideally one on one, focusing on phonological awareness skills (Shaywitz, 2003). It is best if this intervention process is begun as early as possible.

An important extension of these results is how they can be used to inform reading instruction to support those with reading disabilities. Because the results showed that RAN deficits are lifelong, this suggested that RAN needs to be remediated as early as possible. Therefore, it should be a target of intervention during childhood. Appropriate methods for RAN remediation is an area for future research, as there is also conflicting evidence as to the best approach. Currently however, the research suggests that intervention in reading fluency is the best way to approach RAN remediation. Because RAN tasks only measure underlying reading related processes, reading fluency training can help to remediate RAN deficits, while targeting actual reading skills (Norton & Wolf, 2011).

Reading fluency is defined as the speed and quality of reading so that sufficient time and resources can be allocated to comprehension (Norton & Wolf, 2011). Because the overall goal of reading is to comprehend what is read, readers must be able to quickly and easily decode text so that they can devote their mental processes to comprehension. However, as indexed by RAN tasks, dyslexic readers are often unable to easily decode text and they are very slow at doing so. This is what was put forth by the Double Deficit Hypothesis (Wolf & Bowers, 1999). Specifically, because dyslexic readers are slow at reading, by the time they have reached the end of a sentence or paragraph, what has been read at the beginning of the sentence or paragraph is likely to be forgotten. Therefore, all of their mental resources are devoted to decoding and recognizing words rather than understanding the words.

In consequence of the Double Deficit Hypothesis, Norton and Wolf (2011) suggest that training in reading fluency will help dyslexic readers learn to read more efficiently so that they are able to devote their mental resources to comprehension. It has been proposed that such training would involve repeated reading (Norton & Wolf, 2011). This technique, which has been previously used as a way to improve reading fluency, has the reader read a passage multiple times with increasing speed. Over time, readers have been found to generalize the increased speed of reading to other text (Meyer & Felton, 1999).

Question two was examined by employing a hierarchical regression analysis to determine whether RAN was more strongly related to reading in dyslexic adult readers or to normal adult readers. The interaction effect of the RAN tasks between dyslexic and non dyslexic adult readers was used to predict scores on three reading measures: Word Identification, Word Attack, and Reading Comprehension. Because no significant interactions were found, this indicated that RAN was not related more strongly to either good or poor readers. Rather, RAN predicted reading similarly across the two groups. This finding was consistent with some of the current literature (Bekebrede, al., 2009; Pennington & Lefly, 2001; Torgesen et al., 1997). These results indicated that RAN is correlated with all types of readers, whether they are struggling or not. This result highlighted the importance of RAN in reading independent of the type of reader.

The results of the regression analyses further indicated that RAN was a significant predictor of reading in adulthood and its contribution was higher than that of RAN- Objects. The fact that RAN-Letters was a more powerful predictor of reading than RAN-Objects is not a surprise, given that RAN-Letters shares more characteristics with reading, namely the inclusion of letters. This has been found in the literature (Bowey et al., 2005; Compton, 2003; Cronin & Carver, 1998; Georgiou, Parrila, & Papadopoulos, 2008). The results of this analysis indicated that one's scores on RAN could be used to predict one's scores on reading measures. Firstly, these results demonstrated the predictive value of RAN. That is, RAN can be used to predict how well one is going to be able to read. Secondly, they showed that RAN and reading are highly dependent upon each other: How well one performs on RAN is indicative of how skilled one is at reading.

How this valuable information can be applied to intervention practices is important to consider. Knowing that RAN can be used as a predictor of reading, RAN tasks can be powerful diagnostic tools beginning as early as kindergarten through university. Norton and Wolf (2011) highlighted the importance of RAN as part of a clinical assessment to identify risk for reading disabilities. For example, through the administration of RAN tasks to kindergarten students teachers can predict who will struggle with reading and therefore who will require extra support in reading instruction. Further, RAN tasks may be used with university students as evidence of their difficulties and to assist them in accessing required services and accommodations to complete their studies.

The results of this study confirmed much of the current literature that exists, and have helped to further clarify RAN's relationship with adult readers. Not only was it shown that RAN continued to discriminate between dyslexic and non dyslexic readers in adulthood, it was also seen that RAN continued to impact readers with dyslexia throughout their lives. Even though many adult dyslexic readers can compensate for their reading difficulties, they continue to demonstrate lower performance on RAN tasks compared to normal adult readers. Future studies should try to replicate the method with a larger sample, to ascertain whether the findings in this study are consistent with a larger sample. In addition, it may be interesting to add RAN-Digit and RAN-Colors so that all four types of RAN tasks are utilized in order to determine if any differences exist within the adult dyslexic and non dyslexic readers. Lastly, future research should explore appropriate intervention for RAN. This study not only highlighted the importance of RAN in both dyslexic and non dyslexic readers, it showed that RAN deficits are persistent even among those readers that have compensated for their disability.

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Appendix

Adult Reading History Questionnaire – Revised

1. Male _____ Female _____

2. Age ________

3. First language learned ______________________________________

4. Spoken language of preference ___________________________________

   Written language of preference ___________________________________

5. You prefer to use your: Right hand ___ Left hand ___ Ambidextrous ___

6. You have normal or corrected-to-normal vision Yes ____ No _____

7. Number of years of schooling (from elementary school to present) __________

8. To the best of your knowledge, did your parents ever report that either of them had a problem with reading or spelling?

   _______ Yes If **yes**, please give details: ______________________
   _______ No ____
   _______ Not Sure ____

9. To the best of your knowledge did your brother(s) and/or sister(s) ever have a problem with reading or spelling?

   _______ Yes If **yes**, please give details: ______________________
   _______ No ____
   _______ Not Sure ____

10. To the best of your knowledge, have any other members of your family (e.g., aunt, uncle, grandparents) ever had difficulties with reading?

    _______ Yes If **yes**, please give details: ______________________
    _______ No ____
    _______ Not Sure ____

Please circle the number of the response that most nearly describes your attitude or experience for each of the following questions or statements. If you think your response would be between numbers, place an “X” where you think it should be.

1. How much difficulty did you have learning to read in elementary school?

None				**A great deal**
0 ____________	1 ___________	2 ___________	3 ___________	4

---

2. How much extra help did you need when learning to read in elementary school?

No help	**Help from: Friends**	**Teachers/ parents**	**Tutors or special class 1 year**	**Tutors or special class 2 or more years**
0 ____________	1 ___________	2 ___________	3 ___________	4

---

3. How would you compare your reading skill to that of others in your elementary classes?

Above average		**Average**		**Below average**
0 ____________	1 ___________	2 ___________	3 ___________	4

---

4. Which of the following most nearly describes *your* attitude toward reading as a child?

Very positive				**Very negative**
0 ____________	1 ___________	2 ___________	3 ___________	4

---

5. When you were in elementary school, how much reading did you do for pleasure?

A great deal		**Some**		**None**
0 ____________	1 ___________	2 ___________	3 ___________	4

---

6. How would you compare your reading speed in elementary school with that of your classmates?

Above average		**Average**		**Below average**
0 ________	1 ________	2 ________	3 ________	4

7. How much difficulty did you have learning to spell in elementary school?

None		**Some**		**A great deal**
0 ________	1 ________	2 ________	3 ________	4

8. When you were in elementary school, how many books did you read for pleasure each *year*?

More than 10	**6-10**	**2-5**	**1-2**	**None**
0 ________	1 ________	2 ________	3 ________	4

RAN-Letters (Wolf & Denckla, 2005)

o	a	s	d	p	a	o	s	p	d
s	d	a	p	d	o	a	p	s	o
d	s	o	p	o	a	p	a	d	s
p	a	d	o	d	s	a	s	p	o
d	o	p	a	s	p	d	o	s	a
s	a	o	p	a	d	o	s	p	d
a	p	s	p	o	d	s	o	s	a
o	s	a	d	a	o	p	s	d	p

RAN-Letters (Wolf & Denckla, 2005)

k	a	m	d	p	x	o	s	v	f
e	d	a	c	l	q	p	i	s	r
t	x	b	i	m	s	u	k	c	o
n	e	p	l	v	t	q	f	u	p
d	o	l	c	x	n	i	b	r	a
q	m	t	u	s	u	f	o	n	k
i	d	v	a	l	e	s	b	q	f
k	p	x	r	e	b	m	c	v	t

RAN-Objects (Wolf & Denckla, 2005)

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