INFLUENCE OF DISTAL AND PROXIMAL COGNITIVE PROCESSES ON WORD READING

J. P. DAS, GEORGE GEORGIOU, and TROY JANZEN

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**INFLUENCE OF DISTAL AND PROXIMAL COGNITIVE PROCESSES ON WORD READING**

*J. P. DAS, GEORGE GEORGIOU, and TROY JANZEN*
INFLUENCE OF DISTAL AND PROXIMAL COGNITIVE PROCESSES ON WORD READING

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The objectives of the present study were twofold: (a) to explore the interrelationship among distal, proximal cognitive skills, and word reading; and (b) to identify those cognitive processes that predict phonological awareness and rapid naming. Seventy First-Nation Canadian children attending grades 3 and 4 were examined on phonological awareness, rapid naming, Word Identification, Word Attack, and the cognitive processing measures of planning, attention, successive, and simultaneous (PASS). Results indicated that phonological awareness and rapid naming uniquely predicted reading, whereas PASS variables did not, when the effects of phonological awareness and rapid naming were controlled. Finally, both phonological awareness and rapid naming were predicted by planning. Implications for diagnosis of children at risk for reading difficulties and remediation are discussed.

Phonological awareness and rapid automatized naming (RAN) speed are known to be associated with reading for some years now, and this association has gained importance in understanding dyslexia or poor reading as well as in guiding programs aimed at remediation of reading difficulties (e.g., Bowers & Newby-Clark, 2002; Das & Papadopoulos, 1998; Kirby, Parrila, & Pfeiffer, 2003; Lovett, Steinbach, & Frijters, 2000; Manis, Doi, & Bhadha, 2000; Parrila, Kirby, & McQuarrie, 2004; Scarborough, 1998; Stanovich, 1992; Wolf & Bowers, 1999). However, it is not certain that a deficit in phonological awareness and slow RAN are the only cognitive factors that determine reading performance. Low IQ had been suggested for a long time to be an explanation of reading difficulties, but this view is much less favored now as poor readers are found at different IQ levels (Siegel, 1989). This has led to the proposition...
that IQ may be irrelevant to the definition of learning disabilities. While IQ may not be relevant for reading difficulties, cognitive processing skills, such as planning, attention, simultaneous, and successive (PASS) processing, have been shown to be relevant in understanding reading difficulties (Das, Naglieri, & Kirby, 1994; Naglieri & Reardon, 1993). Thus, one may conclude that traditional IQ is irrelevant to reading disabilities—intelligence is not (Naglieri & Reardon, 1993).

Since cognitive processes are more useful than IQ in regard to an understanding of reading and, especially, reading difficulties, we should look beyond phonological coding and consider the fundamental cognitive processing that may be of critical importance in acquiring reading among beginning readers and among the population with dyslexia. We suggest that for the reader failing to learn to read, the process that lies beyond phonological coding is a difficulty in sequencing; that is, in appreciating the succession of letters within a word and of words within a sentence. Therefore, a rational method for helping the child who has word-reading difficulties should begin with facilitating successive or sequential processing.

Successive processing is one of the four major cognitive processes in a theory of intelligence, a theory that is an alternative to IQ. Intelligence in this theory is conceptualized in terms of four interdependent cognitive processes, namely, planning, attention, simultaneous, and successive (PASS; Das et al., 1994). The PASS theory is operationalized in the Das-Naglieri Cognitive Assessment System (CAS; Naglieri & Das, 1997). Because a considerable number of papers have been published on the PASS theory (see, e.g., Das, 2005; Das et al., 1994; Das & Naglieri, 2001; Das, Parrila, & Papadopoulos, 2005; Naglieri & Das, 2005), for the purposes of this article, we will only focus on how the PASS cognitive processing skills are related to phonological awareness, RAN, and word and pseudo-word reading.

**Proximal and Distal Cognitive Processes**

Undoubtedly, reading acquisition is a complex task that demands the synchronous operation of several processing skills. When a beginner reader comes across a novel word, he is faced with at least five interrelated tasks, which must be undertaken to reliably...
recognize the word. First, all of the letters have to be recognized. Second, the sounds of the letters or letter combinations must be retrieved and differentiated from their phonetically confusing neighbors. Third, all phonemes must be stored in working memory in their exact order of presentation. Fourth, the entire set of phonemes in working memory has to be blended together to form a phonological representation of the whole word. Finally, this phonological representation of the word has to be used to gain access to the lexicon. If the word is in the child’s lexicon, he can read it and move on to the next word. This simple account of word reading is to identify the interacting operations, not as a chain of operations actually happening in discrete steps.

To accomplish these five tasks, a beginner reader will require the use of both proximal and distal cognitive processes. The proximal cognitive processes are the linguistic skills that are directly related to the five tasks mentioned above. The most frequently recognized proximal processes in word reading are phonological processes, such as phonological awareness and RAN. The distal cognitive processes are more general and modality-unspecific underlying cognitive processes and are expected to enable the development of proximal processes. Thus, the influence that distal cognitive processes have on reading ability is not necessarily direct but can be mediated by one or several proximal processes. As discussed later, PASS cognitive processing skills can be considered typical examples of distal cognitive processes. In what follows we will first review the effect of proximal cognitive processes (phonological awareness and RAN) on reading acquisition. Then, we will elaborate on how PASS cognitive processes are related to phonological awareness, RAN, and reading ability, and finally we will present the current study aimed directly at examining the relationship between the proximal and distal cognitive processes with reading.

Proximal Cognitive Processes: Phonological Awareness

The most widely acceptable view is that most children experiencing reading difficulties have a core phonological deficit that interferes with their ability to develop phonological awareness and learn to decode (e.g., Goswami, 2002; Stanovich, 1992; Vellutino, Fletcher, Snowling, & Scanlon, 2004). Phonological awareness,
broadly defined as the ability to perceive and manipulate the sounds of spoken words, has been repeatedly shown to be a strong predictor of reading ability in alphabetic (e.g., Badian, 2001; Bus & van Ijzendoorn, 1999; Caravolas, Vólin, & Hulme, 2005; Goswami, 2002; Hulme, Snowling, Caravolas, & Carroll, 2005; Papadopoulou, 2001; Parrila et al., 2004; Patel, Snowling, & de Jong, 2004; Share & Stanovich, 1995; Stanovich, 1992; Torgesen, Wagner, & Rashotte, 1994) as well as in non-alphabetic orthographies (e.g., Hu & Catts, 1998; McBride-Chang & Ho, 2005; McBride-Chang & Kail, 2002). It is, therefore, of no surprise to us that Scarborough (1998), in her meta-analysis, reported correlations between phonological awareness and reading to be approximately .46 (see also Swanson, Trainin, Necoechea, & Hammill, 2003; for similar meta-analysis findings).

Empirical studies have demonstrated that phonological awareness measured prior to or at the onset of reading instruction successfully predicts reading performance in later years even after controlling for possible confounding variables such as print exposure, letter knowledge, or verbal intelligence (Blachman, 1984; Goswami & Bryant, 1990; Kirby et al., 2003; Manis et al., 2000; Muter, Hulme, Snowling, & Stevenson, 2004; Wagner et al., 1997). For example, Parrila et al. (2004) investigated concurrent and future predictive influence of phonological processing measures on reading development in a 4-year longitudinal study. The results demonstrated that phonological awareness, measured in grade 1, was the strongest predictor of grade 3 reading after controlling for the effect of prior reading skills (word identification measured in grade 1). Furthermore, phonological awareness measured in kindergarten and grade 1 accounted for unique variance in all reading measures, even after measures of other phonological processing variables (articulation rate, verbal short-term memory, and RAN) were taken into account. Similarly, Kirby et al. (2003) reported that phonological awareness measured in kindergarten was a strong predictor of reading performance in the first 2 years of schooling, after controlling for general intelligence and prior reading achievement (measured with letter recognition).

Evidence in support of a causal relationship between phonological awareness and reading has also been provided in studies in which the performance of dyslexics on several cognitive measures was compared with that of chronologically and reading-matched
controls (e.g., Caravolas et al., 2005; Hatcher, Snolwing, & Griffiths, 2002; Snowling, Nation, Moxham, Gallaher, & Frith, 1997; Swan & Goswami, 1997). A causal role in dyslexia has been suggested for those component skills that are significantly worse in the dyslexic group compared to younger normal children at the same reading level (Bryant & Goswami, 1986). The basic rationale for this argument is that if reading development is responsible for the development of a language skill, older dyslexic subjects should be at least as strong in that language skill when compared to younger normal subjects at the same reading level. In one of this kind of study, Swan and Goswami (1997) examined the performance of 15 dyslexic children, 15 reading age-matched controls, and 15 chronologically age-matched controls on several literacy skills. Chronologically age-matched controls were significantly better than any of the other two groups in all the measures used in the study. Importantly, dyslexics were significantly poorer than reading age-matched controls on phoneme tapping and initial/final phoneme judgment tasks.

By itself the phonological-core deficit does not appear to account for all that is known about the development of reading problems. In addition, phonology-based training programs have not been able to prevent or remediate reading difficulties completely (Torgesen et al., 2001). Consequently, researchers began to examine other possible sources of individual differences in reading. Recently, in their review paper, Wolf and Bowers (1999) argued that RAN is a second core deficit in reading disabilities that accounts for variance in reading over and beyond the contribution of phonological awareness.

Proximal Cognitive Processes: Rapid Naming Speed

RAN has been defined as the ability to name as quickly as possible visually presented familiar symbols such as letters, digits, colors, and objects. RAN performance has been shown to distinguish average from poor readers during childhood (e.g., Badian, Duffy, Als, & McAnulty, 1991; Cornwall, 1992; Wolf, Bally, & Morris, 1986) and into adulthood (Felton, Naylor, & Wood, 1990; Korhonen, 1995). In addition, even after statistically controlling for IQ (Cornwall, 1992), reading experience (Badian, 1993; Parrila et al., 2004), attention deficit disorder (Compton, Olson, DeFries, & Pennington,
Despite the acknowledged importance of RAN in predicting reading, there is still no consensus as to what cognitive process or processes are driving the relationship between RAN and reading and what RAN tasks measure. For example, Torgesen, Wagner, and their colleagues (see, e.g., Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wagner & Torgesen, 1987; Wagner et al., 1997) subsumed RAN under the phonological processing family, maintaining that RAN tasks assess the rate of access to and retrieval of stored phonologically based information from long-term memory. On the other hand, other researchers have accepted RAN as an independent proximal process for reading and proceeded with developing competing models to explain why RAN is related to reading (e.g., Bowers & Wolf, 1993; Martens & de Jong, 2004; Savage & Frederickson, 2005; Wolf & Bowers, 1999). Bowers, Wolf, and their colleagues (see Bowers, 1995; Bowers & Newby-Clarke, 2002; Wolf, Bowers, & Biddle, 2000) have advanced this line of research, reaffirming that RAN requires the integrated and coordinated use of attentional, perceptual, conceptual, lexical, and motoric sub-processes. Importantly, Wolf and Bowers (1999) also argued that RAN tasks may be positioned at a “lexical midpoint” (p. 428) in a cascading system between apparent problems in reading and wider perceptual-motor deficits. This view clearly suggests that links should be evident between RAN and distal cognitive processes, such as successive processing or planning, which we review next.

**Distal Cognitive Processes: PASS Processing Skills**

As mentioned earlier, in response to the need to better conceptualize and measure intelligence, new approaches have been proposed. One of the most recent of these approaches is the planning, attention, simultaneous, and successive (PASS) theory of intelligence (Naglieri & Das, 1997). According to Naglieri and Das (1997), *planning* is the ability to formulate a strategy, execute the strategy, and verify whether the strategy is effective for solving a problem. *Attention* has been defined as selectively attending to relevant stimuli while inhibiting distracting or irrelevant stimuli.
Simultaneous processing has been defined as the ability to survey several elements to form an integrated whole. Finally, successive processing has been defined as the ability to process information in serial order.

A substantial body of evidence has established that successive processing is central to early reading (Das et al., 1994; Das & Papadopoulos, 1998; Papadopoulos, 2001). It is significantly involved in word decoding, especially for pseudo-words and words to be read aloud (requiring punctuation; Das, Mok, & Mishra, 1994). Tasks used to operationalize successive processing correlate strongly with these basic reading requirements, the best correlation being with the Speech Rate task (the fast repetition of three simple words), the Naming Time task (naming rows of single letters, digits, color strips, or simple and familiar words), and the serial memory tasks for words and sentences (Sentence Repetition). Simultaneous processing also plays an important part in basic reading skills, such as blending (in word reading) and comprehension of meaning (Das et al., 1994).

In spite of the theoretical importance of examining the antecedents of phonological awareness, RAN, and reading ability among the PASS cognitive processing skills, only a few studies have explored these relationships. For example, Joseph, McCahran, and Naglieri (2003), in a sample of 62 primary-grade children referred for reading problems, showed that both successive and simultaneous processing accounted for 33% of the variance in phonological awareness. Planning and successive processing accounted for 27% of the variance in RAN. In addition, Joseph et al. (2003) demonstrated that PASS variables were accounting for a small, but still significant, amount of variance in Letter-Word Identification and Word Attack even after the effects of phonological awareness and RAN were controlled for.

Likewise, working with Greek-speaking grade 1 children, Papadopoulos (2001) demonstrated that successive processing and planning were significantly correlated with phonological awareness measures (Sound Isolation and Phoneme Elision). Nevertheless, their effect faded out when entered into the regression equation after phonological awareness measures. If we assume that distal cognitive processes influence reading through their influence on the proximal cognitive processes, then we should
find no additional effect of PASS processes after controlling for the effect of proximal cognitive processes.

One of the major contributions of this study is that it has examined the relationship between proximal and distal cognitive processes in a sample of older children. Joseph et al.’s (2003) and Papadopoulos’s (2001) studies were conducted with beginner readers. It would be important to determine (a) how the relation between the PASS skills and reading ability may change over time and (b) whether PASS theory can provide an alternative way of identifying reading difficulties as opposed to traditional intelligence measures in a sample of older readers.

Additionally, the results of this study will have practical benefits for intervention. Once we identify the most important processing needs of the child, we can concentrate remediation in those areas. Notably, several researchers pointed out that there are children who are unresponsive to remediation that focuses solely on phonological processing practices (e.g., Allor, Fuchs, & Mathes, 2001; Al Otaiba & Fuchs, 2002, 2006; Blachman, 1994; Torgesen, 2002; Torgesen et al., 2001). Blachman (1994) called these children “treatment resisters.” We believe that while these students did not benefit from a remediation targeting the proximal cognitive processes, it is possible that they could have benefited if the remediation targeted the distal cognitive processes (Papadopoulos, Charalambous, Kanari, & Loizou, 2004; Papadopoulos, Das, Parrila, & Kirby, 2003).

The Present Study

The purpose of the present study was to examine the relationship between PASS cognitive processes, phonological awareness, RAN, and reading ability with a sample of grade 3 and 4 Native Canadian children. An additional purpose was to determine which PASS variables best predict phonological awareness and RAN. The present work was motivated by our interest in understanding the widely prevalent reading disability among children of the American Indian and Native Canadian communities, the First Nation’s (FN) children (e.g., Janzen, 2000; Krywaniuk & Das, 1976). Educational and school psychologists have to often decide how to regard the reading difficulties of Native or First Nation’s children in school. For example, to what extent is their poor reading an inherent...
predisposition for a specific cognitive style or learning style? In
a recent summary of cognitive styles of FN children (Hilberg &
Tharp, 2002), it was stated that a global or holistic style of organizing
information and a visual style of information representation
may characterize FN individuals. FN students scored higher on
simultaneous processing, whereas Caucasian students preferred
sequential processing. This is consistent with More’s (1989) earlier
review of cognitive styles of FN children. Because understanding
the relationship between reading and cognitive predisposition
is a first step toward framing special instructional and remedial
programs, research is necessary to test two competing hypotheses. If indeed the majority of FN children are characterized by a
specific cognitive style, then the variables that predict reading performance in the general population (non-FN) will not be entirely
relevant for FN children. On the other hand, if it can be reasonably established that FN children cannot be stereotyped in terms
of a specific cognitive or learning style, then the same findings in regard to cognitive processing correlates of reading in the general
population of learners will be expected among the FN learners.

Based on the existing literature, we aimed at examining the
following hypotheses:

1. Phonological awareness and RAN will make independent and
unique contributions to reading ability.
2. Specific cognitive processes, particularly planning and successive,
will predict phonological awareness and RAN and may account for variance in reading ability beyond the one accounted
for by phonological awareness and RAN if we assume that the
influence of distal processes is not mediated by proximal ones.

Method

Participants

Seventy-one Canadian native children (First Nation, or FN) in
grades 3 and 4 (31 boys and 40 girls, ages 8.5 to 11.9 years, M = 9.97,
SD = 0.82) from a reservation school in Alberta, Canada, partici-
pated in this study. The school follows English curriculum estab-
lished by the province. Some instruction in Cree is also taught in
the school. All children were expected to perform in English. The
school district recently adopted an early literacy program, which was implemented several years prior to this study. All of the children for this study resided on reserve and were coming from low-SES families. None of the children had an official diagnosis for any reading or behavioral problems and none of them was receiving any special education services.

**Measures**

**RAPID NAMING SPEED**

*Object Naming.* The Object Naming task from the CTOPP (Wagner, Torgesen, & Rashotte, 1999) was used as a measure of rapid serial naming. Participants were required to state as quickly as possible the names of six objects (pencil, boat, star, key, chair, fish). On two separate sheets, objects were arranged randomly in four rows with nine objects in each row. Prior to beginning the timed naming, each participant was asked to name the objects to ensure familiarity. The two pages were timed separately and the time in seconds to name the objects on both pages was the participant’s score. Wagner et al. (1999) reported test–retest reliability of .93 for Object Naming for ages 8 to 17.

*Color Naming.* The Color Naming task was adopted from the CTOPP (Wagner et al., 1999). This RAN task consists of a set of six colors (blue, red, green, black, yellow, and brown) that are displayed in random sequence six times for a total of 36 stimuli. The individual is told to name the colors from left to right as quickly as possible and the total time to complete the RAN task is recorded. Before naming the 36 colors, each participant was asked to name the colors in a practice trial. Wagner et al. (1999) reported test–retest reliability of .89 for Color Naming for ages 8 to 17.

*Digit Naming.* This task was adopted from the CTOPP (Wagner et al., 1999). This RAN task consists of a set of six digits (4, 7, 8, 5, 2, 3) that are displayed in random sequence six times for a total of 36 stimuli. Subjects are asked to name the digits from left to right as quickly as possible and the total time to complete the RAN task is recorded. Before naming the 36 digits, each participant was asked
Cognitive Predictors of Reading

... to name the digits in a practice trial. Wagner et al. (1999) reported test–retest reliability of .80 for Digit Naming for ages 8 to 17.

**Letter Naming.** This task was also adopted from the CTOPP (Wagner et al., 1999). Participants were asked to name as fast as possible the names of six letters (a, n, s, t, k, c). Letters were arranged randomly in four rows of nine letters in each row. As in the other naming speed tasks, children were asked to name the six letters in a practice trial before proceeding to the timed trials. The two pages were timed separately. Wagner et al. (1999) reported test–retest reliability of .72 for Letter Naming for ages 8 to 17.

**Phonological Awareness**

**Phoneme Elision.** The Phoneme Elision task from the CTOPP (Wagner et al., 1999) was used as a measure of phonological awareness. This task measures the extent to which an individual can say a word and then say what is left after dropping out designated sounds. The task consists of 20 items. For the first two items, the examiner says compound words and asks the examinee to say the word and then say the word that remains after dropping one of the compound words. For the remaining items, the individual listens to a word and repeats the word and then is asked to say the word without a specific sound. Participant’s score is the number of correct responses. Wagner et al. (1999) reported test–retest reliability of .79 for Phoneme Elision for ages 8 to 17.

**Word Segmentation.** The Word Segmentation task was adopted from CTOPP as well (Wagner et al., 1999). It consists of 20 items and it measures the ability of an individual to say separate phonemes that make up a word. The examinee is told to repeat a word and then to say it one sound at a time. For example, the examiner tells the examinee to say “book” and then to say it one sound at a time. Participant’s score is the number of correct responses. Wagner et al. (1999) reported test–retest reliability of .79 for Word Segmentation for ages 8 to 17.

**Cognitive Processing Tasks**

The Das-Naglieri Cognitive Assessment System (CAS; Naglieri & Das, 1997) is an individually administered test of cognitive functioning for children and adolescents ranging from 5 through 17
years of age that was designed to assess the four PASS cognitive processes (a) planning, (b) attention, (c) simultaneous, and (d) successive. The four PASS scales and the full scale standard scores are set at a mean of 100 and SD of 15. The basic battery, which was used for this research project, consists of 8 subtests; two subtests per PASS scale. Descriptions of the subtests and scales as well as evidence for the reliability of the individual subtest scores and PASS Scale scores are provided in the manual (Naglieri & Das, 1997). The CAS has good psychometric properties with average internal consistency alpha values for the basic battery as follows: planning = .85; simultaneous = .90; attention = .84; successive = .90; and full scale = .87.

The Planning subtests of the basic battery of CAS include Matching Numbers, Planned Codes. In the Matching Numbers subtest, children are presented with four pages containing eight rows of numbers. For each row, the child is instructed to underline the two numbers that are the same. The time and number correct for each page is recorded and the subtest score is calculated by combining both time and number correct. The Planned Codes subtest contains two pages, each with a distinct set of codes arranged in seven rows and eight columns. At the top of each page is a legend, which indicates how letters relate to simple codes (e.g., A = OX; B = XX; C = OO). The child is instructed to fill in the correct code beneath each corresponding letter in any manner he chooses. The subtest score is calculated by combining both the time and number correct for each page.

The Attention subtests of the basic battery of the CAS include Expressive Attention and Number Detection. For Expressive Attention, children 8 years and older are given three pages to complete. For the first page, the child reads color words (i.e., blue, yellow, green, and red). The words are presented in a quasi-random order. On the second page, the child is instructed to name the colors of a series of rectangles printed in aforementioned colors. On the third page, the color words are printed in a different ink color than the color the words name (e.g., the word “red” may appear in blue ink). The task on the third page is for the child to name the color of ink while not saying the color word. The subtest score is calculated using time and number correct. The Number Detection subtest asks children to find the target stimuli (e.g., the numbers 1, 2, and 3 printed in an open font) among many distracters (e.g.,...
the same numbers printed in a different font). The subtest score is a ratio of accuracy (total number correct minus the number of false detections) to total time taken to complete all items. The Simultaneous subtests of the basic battery of the CAS include Nonverbal Matrices and Verbal Spatial Relations. Nonverbal Matrices items present a variety of shapes and geometric designs that are interrelated through spatial or logical organization. For each item the child is required to decode the relationships and choose the best of six possible answers to complete the grid. The subtest score is the total number correct. Verbal Spatial Relations measures the comprehension of logical grammatical descriptions of spatial relationships. In this subtest, the child is presented with six drawings, arranged in a specific spatial manner, and a printed question. Then, the child is instructed to choose one of the six drawings that best answers the question within the 30-second time limit. The subtest score is calculated by adding up the total number of items answered correctly.

The Successive subtests of the basic battery of the CAS include Word Series and Sentence Repetition. In Word Series, the examiner reads the child a series of words and then asks her to repeat the words in the same order. This subtest uses the following nine single-syllable, high-frequency words: book, car, cow, dog, girl, key, man, shoe, and wall. The presentation rate is one word per second. The subtest score is the total number of words series correctly repeated. For Sentence Repetition the child is read 20 sentences aloud and is asked to repeat each sentence exactly as presented. The sentences are composed of color words (e.g., “The blue yellow the green”), which reduces the influence of simultaneous processing and removes semantic meaning for the sentences. The subtest score is the total number of sentences repeated correctly.

**Word and Pseudoword Reading Measures**

The Woodcock-Johnson Tests of Achievement (WJIII; Woodcock, McGrew, & Mather, 2001) was used to assess word reading ability. The Word Identification subtest involves the reading of individual words with some early items that require correct letter identification. Word Attack is a phonetic decoding task where the child is required to pronounce nonsense words. All reading tests scores were calculated using the accompanying computer scoring program. Scores in reference to a norm group reported for this paper.
were relative to age norms. Woodcock et al. (2001) report split-half reliabilities of .98 for Word Identification and .94 for Word Attack.

Procedure

This study involved individually administered tests. Assessment was carried out by graduate-level students who had some training in individual psychological test administration. All testers were thoroughly trained by two of the authors, who also supervised the testing. Testing typically took place in a quiet and semi-private room within the school. All instructions were given in English because that was the primary language of the children.

In terms of test order, the reading, the phonological awareness, and the RAN tests were given first during a separate sitting from the administration of the cognitive processing measures. Reading, phonological awareness, and RAN tests could generally be completed within 30 minutes and the cognitive measures generally took around 45 minutes to complete. All subjects were assessed with the above measures in May and June of the school year. Parents’ consent was obtained prior testing.

Results

Preliminary Data Analysis

Descriptive statistics for all the variables used in the study are presented in Table 1. One participant who was a multiple outlier was removed from further analyses. In line with previous studies (e.g., Das, Georgiou, & Janzen, 2006; Janzen, 2000), the FN students were particularly deficient in word identification ($M = 86.39, SD = 13.16$), whereas their word-decoding skills were within average ($M = 95.11, SD = 9.19$). Repeated measures ANOVA’s were then conducted in order to determine whether the variation among the mean CAS scale scores was significant for this sample of children, because no significant variation among CAS scores is expected in a sample of normally achieving students. Findings indicated that there were significant differences in performance on mean CAS scale scores; $F(3, 210) = 13.12, p < .000, \eta^2 = .434$. Post hoc analyses revealed that students performed significantly lower on the Planning, Successive, and Simultaneous scale than on the
TABLE 1 Descriptive Statistics for all the Variables in the Study

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<td>10.11</td>
<td>1.76</td>
<td>5</td>
<td>15</td>
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<tr>
<td>Cognitive Measures (CAS)*</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Matching Numbers</td>
<td>8.36</td>
<td>2.22</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>Planned Codes</td>
<td>8.97</td>
<td>2.12</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>Planning Scale</td>
<td>92.28</td>
<td>11.05</td>
<td>65</td>
<td>115</td>
</tr>
<tr>
<td>Nonverbal Matrices</td>
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<td>2.35</td>
<td>4</td>
<td>15</td>
</tr>
<tr>
<td>Verbal Simultaneous</td>
<td>8.88</td>
<td>2.61</td>
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</tr>
<tr>
<td>Simultaneous Scale</td>
<td>93.10</td>
<td>11.68</td>
<td>67</td>
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</tr>
<tr>
<td>Expressive Attention</td>
<td>9.62</td>
<td>2.43</td>
<td>5</td>
<td>18</td>
</tr>
<tr>
<td>Number Detection</td>
<td>10.37</td>
<td>2.04</td>
<td>3</td>
<td>15</td>
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<tr>
<td>Attention Scale</td>
<td>99.96</td>
<td>8.91</td>
<td>82</td>
<td>124</td>
</tr>
<tr>
<td>Word Series</td>
<td>8.86</td>
<td>2.48</td>
<td>4</td>
<td>14</td>
</tr>
<tr>
<td>Sentence Repetition</td>
<td>7.88</td>
<td>2.56</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Successive Scale</td>
<td>90.59</td>
<td>12.34</td>
<td>61</td>
<td>122</td>
</tr>
<tr>
<td>CAS Full Scale</td>
<td>91.54</td>
<td>10.22</td>
<td>68</td>
<td>111</td>
</tr>
</tbody>
</table>


Attention scale \( p < .001 \). There were no significant differences between students' performance on the Simultaneous, Successive, and Planning scales. With the exception of the significant difference between the scores on the Attention scale and the rest of the CAS scale scores, these findings suggest that the FN children behave the same way as other normally achieving children.

Correlations Among the Different Measures

The correlations between the different measures used in this study are shown in Table 2. From this table we can see that planning among the CAS measures was moderately related with both reading outcomes. Simultaneous processing was significantly related
TABLE 2 Correlations Among the Different Measures

<table>
<thead>
<tr>
<th>Measures</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. WID</td>
<td></td>
<td>-.89**</td>
<td>.41**</td>
<td>.21</td>
<td>.08</td>
<td>.28*</td>
<td>.38**</td>
<td>.55**</td>
<td>.33**</td>
<td>.52**</td>
<td>.28*</td>
</tr>
<tr>
<td>2. WAT</td>
<td></td>
<td>.42**</td>
<td>.29*</td>
<td>.07</td>
<td>.23</td>
<td>.39**</td>
<td>.47**</td>
<td>.32**</td>
<td>.51**</td>
<td>.31**</td>
<td></td>
</tr>
<tr>
<td>3. Planning</td>
<td></td>
<td>.46**</td>
<td>.35**</td>
<td>.19</td>
<td>.73**</td>
<td>.49**</td>
<td>.30**</td>
<td>.33**</td>
<td>.33**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Simultaneous</td>
<td></td>
<td>.08</td>
<td>.24*</td>
<td>.66**</td>
<td>.09</td>
<td>.23</td>
<td>.17</td>
<td>.03</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Attention</td>
<td>.16</td>
<td>.58**</td>
<td>.32**</td>
<td>.41**</td>
<td>.11</td>
<td>.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Successive</td>
<td></td>
<td>-.60**</td>
<td>.23</td>
<td>.36**</td>
<td>.19</td>
<td>.28*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Full Scale</td>
<td>.39**</td>
<td>.43**</td>
<td>.29*</td>
<td>.33**</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. RAN-DL</td>
<td></td>
<td>-.62**</td>
<td>.40**</td>
<td>.17</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9. RAN-CO</td>
<td></td>
<td>-.29*</td>
<td>.23</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Elision</td>
<td>.23</td>
<td>.58**</td>
<td>.32**</td>
<td>.41**</td>
<td>.11</td>
<td>.22</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Segmentation</td>
<td></td>
<td>.60**</td>
<td>.23</td>
<td>.36**</td>
<td>.19</td>
<td>.28*</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

*Note. RAN DL = RAN Digits and Letters; RAN CO = RAN Colors and Objects; WID = Word Identification; WAT = Word Attack.
* p < .05. ** p < .01.

only with Word Attack and successive processing only with Word Identification. Attention was not significantly related to any reading outcome. In terms of the RAN-reading relationship, the alphanumeric RAN (Digits and Letters) was moderately correlated with Word Identification and Word Attack. In line with previous studies (see, e.g., Bowey, McGuigan, & Ruschena, 2005; Cardoso-Martins & Pennington, 2004; Parrila et al., 2004, Uhry, 2002; Wolf, Bowers, & Morris, 1986), the non-alphanumeric RAN (Colors and Objects) was only weakly correlated with Word Identification and Word Attack. It is also important to note that the correlations between the RAN measures and reading were generally higher for Word Identification than for Word Attack, a finding that has been reported in other studies as well (Manis et al., 2000; Manis, Seidenberg, & Doi, 1999; Wolf & Bowers, 1999; Wolf et al., 2000). Phoneme Elision was moderately correlated with Word Identification (r = .52, p < .01) and Word Attack (r = .51, p < .01). On the other hand, Word Segmentation was only weakly correlated with both reading measures.

Correlations between the PASS variables, RAN, Phoneme Elision, and Word Segmentation revealed that planning had relatively higher correlations with all of these variables. From the remaining CAS scales, successive processing had a significant but still small correlation with Word Segmentation (r = .28, p < .05) and...
attention with alphanumeric rapid naming ($r = 32$, $p < .01$) and non-alphanumeric rapid naming ($r = 41$, $p < .01$).

**Regression Analyses With PASS Variables Predicting Phonological Awareness and RAN**

In order to examine which PASS cognitive processes best predict phonological awareness and RAN, stepwise multiple regression analyses were conducted. Age was controlled before the entrance of the PASS variables in the regression equation. The analyses revealed that both phonological awareness and RAN were predicted by planning ($\beta = .288$, $p < .05$ for phonological awareness and $\beta = .423$, $p < .001$ for RAN). Simultaneous, successive, and attention processing did not enter into the equation and therefore did not significantly predict performance on either phonological awareness or RAN.

**Regression Analyses With PASS Variables, Phonological Awareness, and RAN Predicting Word Identification and Word Attack**

We then conducted hierarchical regression analyses in order to answer two important questions; namely, whether phonological awareness and/or RAN were uniquely predicting reading ability and whether the effects of the PASS variables were contributing to reading even after factoring out the effects of phonological awareness and RAN. In order to examine the contribution of RAN and Phonological Awareness on Word Identification and Word Attack, we entered Phoneme Elision and alphanumeric RAN as independent variables into the regression equation after first controlling for age. Based on the correlations obtained in Table 2 we decided to use the alphanumeric RAN to represent RAN and Phoneme Elision to represent phonological awareness. Both of these measures had the strongest correlations with Word Identification and Word Attack. The results of this analysis are of particular interest in the context of arguments that RAN should not be subsumed under the overarching category of phonological processing because it accounts for unique variance in reading over and above the one explained by phonological awareness (see, e.g., Bowers & Newby-Clark, 2002; de Jong & van der Leij, 1999; Manis et al., 2000; Parrila et al., 2004; Wolf & Bowers, 1999; Wolf et al., 2000). Table 3 shows
### TABLE 3
Summary of Hierarchical Regression Analysis with Age, Phonological Awareness, RAN, and PASS Variables as the Predictors and Word Identification and Word Attack as the Dependent Variables

<table>
<thead>
<tr>
<th>Step</th>
<th>Variable</th>
<th>Word Identification</th>
<th>Word Attack</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$\beta$</td>
<td>$\Delta R^2$</td>
</tr>
<tr>
<td>1.</td>
<td>Age</td>
<td>-.319</td>
<td>.10**</td>
</tr>
<tr>
<td>2.</td>
<td>Successive</td>
<td>.244</td>
<td>.06*</td>
</tr>
<tr>
<td>3.</td>
<td>PA</td>
<td>.441</td>
<td>.18***</td>
</tr>
<tr>
<td>3.</td>
<td>RAN-DL</td>
<td>.466</td>
<td>.19***</td>
</tr>
<tr>
<td>2.</td>
<td>Simultaneous</td>
<td>.139</td>
<td>.02</td>
</tr>
<tr>
<td>3.</td>
<td>PA</td>
<td>.439</td>
<td>.20***</td>
</tr>
<tr>
<td>3.</td>
<td>RAN-DL</td>
<td>.493</td>
<td>.22***</td>
</tr>
<tr>
<td>2.</td>
<td>Planning</td>
<td>.322</td>
<td>.09**</td>
</tr>
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<td>3.</td>
<td>PA</td>
<td>.415</td>
<td>.15***</td>
</tr>
<tr>
<td>3.</td>
<td>RAN-DL</td>
<td>.440</td>
<td>.14***</td>
</tr>
<tr>
<td>2.</td>
<td>PA</td>
<td>.471</td>
<td>.21***</td>
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<td>3.</td>
<td>RAN-DL</td>
<td>.376</td>
<td>.11***</td>
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<td>2.</td>
<td>RAN-DL</td>
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<td>.22***</td>
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<td>3.</td>
<td>PA</td>
<td>.345</td>
<td>.10***</td>
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<td>Successive</td>
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<td>.01</td>
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<td>4.</td>
<td>Simultaneous</td>
<td>.079</td>
<td>.01</td>
</tr>
<tr>
<td>4.</td>
<td>Planning</td>
<td>.080</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note. PA = Phonological Awareness; RAN-DL = Rapid Automatized Naming—Digits and Letters.

* $p < .05$. ** $p < .01$. *** $p < .001$. 

that both phonological awareness and RAN were unique predictors of Word Identification and Word Attack. Alphanumeric RAN accounted for an additional 11% of the variance in Word Identification and approximately 6% of the variance in Word Attack once age and phonological awareness were controlled. Similarly, phonological awareness accounted for a significant 10% of the variance in Word Identification and 12% in Word Attack once age and alphanumeric RAN were accounted for.

Furthermore, in order to examine whether the PASS variables could explain a significant amount of variance in reading before controlling for phonological awareness and RAN, we entered each of the PASS variables (with the exception of attention, because it had shown no significant correlations with reading outcomes) at the second step of the regression equation following age (entered at step 1). The results showed that planning significantly...
predicted both Word Identification and Word Attack, whereas suc-
cessive processing significantly contributed only in Word Identifi-
cation. Controlling for the effects of phonological awareness or
RAN (entered at step 2) showed that neither successive nor plan-
ning made a significant contribution to Word Identification and
Word Attack. Given that planning was a predictor of phonologi-
cal awareness and RAN, we also examined whether the effect of
planning on reading ability was mediated by the effect of phono-
logical awareness and RAN. Sobel’s $z$ statistic was used (Preacher &
Leonardelli, 2003). Indeed, phonological awareness mediated the
relationship between planning and Word Identification (Sobel’s
$z = 2.12$, $p = .033$) and Word Attack (Sobel’s $z = 2.11$, $p = .034$).
In addition, RAN mediated the relationship between planning and
Word Identification (Sobel’s $z = 2.95$, $p = .003$) and Word Attack
(Sobel’s $z = 2.64$, $p = .008$).
To sum, the results from our regression analyses suggest that
(a) planning was a common predictor of phonological awareness
and RAN, (b) phonological awareness and RAN made unique con-
tributions to reading ability, and (c) none of the PASS variables
accounted for unique variance in reading ability after factoring
out the effects of phonological awareness and RAN.

Discussion

One of the primary objectives of this study was to examine the
relationship between word reading on one hand and both the dis-
tal (PASS cognitive processes) and proximal cognitive processes
(phonological awareness and RAN) on the other. In regard to the
proximal cognitive processes, clearly, the results of this study replic-
ate previous research findings in spite of the ethnic status of the
participants and their low-average performance on real word iden-
tification. Our results suggest that both phonological awareness
and RAN have an additive effect on predicting reading ability (e.g.,
Chiappe, Stringer, Siegel, & Stanovich, 2002; Manis et al., 2000; Par-
rla et al., 2004; Savage & Frederickson, 2005; Wolf et al., 2002).
Despite the significant correlations observed between the
PASS variables and the reading measures, the PASS processing
contribution to reading did not survive the statistical control of
phonological awareness and RAN. This is a rather surprising find-
ing given previous reports on PASS cognitive processing skills and
their predictive power (e.g., Das et al., 1994; Das & Papadopoulos, 1998; Joseph et al., 2005; Kirby, Booth, & Das, 1996; Naglieri & Rojahn, 2004). Accordingly, some may consider the results as evidence against the usefulness of PASS skills in identifying children at risk for reading difficulties. One might further conclude that relying on the proximal cognitive processes will suffice to identify those children who struggle with reading. In fact, there is some evidence that phonological awareness, RAN, and letter knowledge alone can predict reading group membership with almost 100% accuracy (e.g., Badian et al., 1991; Savage et al., 2005). Nevertheless, we believe that such a conclusion would be premature because, as indicated in the analysis of the mediation effects, both phonological awareness and RAN mediated the effects of PASS processes on reading. It is not the case that PASS cognitive processes are no longer related to reading by themselves, but their effect on reading is indirect through the effect of proximal cognitive processes. It is possible that as the children gain reading experiences, the effect of proximal cognitive processes increases relative to the effect of distal cognitive processes due to the facilitatory effect reading has on proximal cognitive processes, such as phonological awareness and RAN (e.g., Compton, 2003; Perfetti, Beck, Bell, & Hughes, 1987; Torgesen et al., 1997). We cannot easily attribute the discrepancy between our results and those reported in previous studies to either ethnicity or the low-average word identification performance of the present sample.

The second objective of this study was to examine the predictors of phonological awareness and RAN among the PASS processing skills. Based on previous research findings (Das et al., 2000; Papadopoulos, 2001), we hypothesized that phonological awareness would be predicted by successive processing. Certainly, our results failed to support this hypothesis. Phonological awareness was predicted only by planning. However, the results are in line with previous findings in that with older children like the present sample, who do not have reading decoding difficulties to any significant degree, planning tests rather than successive tests are better predictors (Das, Mishra, & Kirby, 1994; Naglieri & Rojahn, 2004). Similar to phonological awareness, RAN was predicted by planning. According to Clarke et al. (2005), RAN’s relationship to reading might be attributed to the strategic control of where and how much to pause in between the articulations of the stimuli. This
argument is in line with Das et al.'s (1994) finding that poor readers not only paused longer than average readers in a naming task but also the decision of where to pause was inconsistent. Following Wolf and Bowers (1999), it is possible that RAN includes quite a number of processes, such as (a) attention to the stimulus, (b) identification of initial stimulus features, (c) integration of visual features and pattern information with stored orthographic representations in the case of letter naming, (d) integration of visual information with stored phonological representations, (e) access and retrieval of phonological labels, (f) activation of semantic information, and (g) motor programming leading to articulation. Although planning has not been explicitly stated as one of the subprocesses involved in RAN, it is possible that it taps on the timing mechanism, which demands a fine cooperation between the subprocesses. In essence, planning as a prefrontal lobe function involves executing behavior over time and integrating of information (Huey, Krueger, & Grafman, 2006).

The present findings may also have implications for the cognitive style of FN individuals: that they tend to be stronger in global, holistic, or simultaneous strategies and, by inference, weaker in sequential, successive strategies as discussed in the introduction (More, 1989). In fact, our present results show only a very slight elevation of simultaneous score compared to successive score (93.10 and 90.59, respectively), and the difference is not significant. A distinct cognitive style for FN children, according to the present study, is not supported. Our results also contradict the “chronically poor reader” labeling of FN children (Janzen, 2000), if reading disability is essentially due to decoding deficits best measured by pseudo-word decoding. Our sample was below average in real word recognition. While admittedly speculative, we suggest that the reason is poor vocabulary and inadequate exposure to literacy that builds up sight word knowledge. The implication for remediation, therefore, is an important one—if true dyslexia is closely related to word-decoding deficit, and not to knowledge-base (e.g., Vellutino et al., 2004), the FN children, in general, do not have a systemic deficit. Rather, their deficit arises due to inadequate instruction combined with prevalence of inadequate literacy environment at home and in the community. Consequently, programs that enable them to use appropriate cognitive strategies when confronted with reading and a general spread of literacy should succeed. Our
belief is reinforced by a recent study on the efficacy of cognitive enhancement training (Hayward, Das, & Janzen, in press).

**Limitations of the Study**

The major limitation of this study was its restriction to word reading level–dependent variables. Although the ultimate goal of reading is comprehension, we did not incorporate tasks of reading comprehension in our study. We also suggest that other tests of phonological awareness, such as blending and spoonerism, should be added to increase the strength of phonological awareness measure. Likewise, RAN is weakened if measured with Colors and Objects compared to Letters and Digits. Obviously, speed of naming objects and colors loses its salience in predicting reading by age 9 even among the FN who are almost close to the norm at least in one of the two tests of reading, in pseudo-word decoding but perform poorly in word identification. Finally, it is worth mentioning that future studies should look into direct comparisons between the predictors of reading in FN and Caucasian Canadian children rather than what has been reported in other studies.

**Conclusion**

Several studies have shown that phonological awareness and rapid naming are independent predictors of reading ability. Our study replicated this finding with a sample of FN children who were particularly deficient in word reading. In addition, we examined the predictors of phonological awareness and RAN among the PASS cognitive processing skills. Given that (a) the antecedents of individual differences in phonological awareness and RAN have been examined primarily under the rubric of home literacy environment and print exposure (see, e.g., Georgiou, Manolitsis, Parrila, & Stephenson, 2006; Lepola, Poskiparta, Laakkonen, & Niemi, 2005; Sénéchal, 2006) and (b) both phonological awareness and RAN share common genetic variance (see, e.g., Petrill, Deater-Deckard, Thompson, DeThorne, & Schatschneider, 2006; Samuelsson et al., 2005), we provided new evidence of the common ground of phonological awareness and RAN by showing that they were both predicted by the same distal cognitive processing; namely, planning. We have also showed that, in general, the FN
population of young readers are not dyslexics; those who are poor
readers among them do not have a systemic deficit associated with
their ethnic affiliation and therefore can benefit from remedial
programs that we have used before (Das, Mishra, & Pool, 1995;
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