Naming Speed Deficits in Adults with Reading Disabilities: A Test of the Double-Deficit Hypothesis

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Abstract

The present study investigated the persistent nature of naming speed deficits within the context of the double-deficit hypothesis in a university sample of adults with reading disabilities (RD). Twenty-five university students with RD were compared to 28 typically achieving readers on measures of reading skill, phonological processing, and naming speed. The results indicated that both naming speed and phonological processing deficits characterized the RD group. In a regression analysis, neither naming speed nor phonological processing were important variables in explaining comprehension when reading rate was in the model. The results of the present study are mixed at best and are consistent with earlier conclusions that support for the double-deficit hypothesis of dyslexia remains limited.

There is a consensus that phonological awareness plays a critical role in reading acquisition and that for the majority of children with reading disabilities (RD), deficits in phonological processing have been identified as the core deficit (e.g., Bradley & Bryant, 1983; Stanovich, 1992). This phonological deficit hypothesis has been supported by a number of studies that have specifically identified delays in sensitivity to rhyme, alliteration, and phonemic segmentation as precursors to the development of RD (e.g., Bradley & Bryant, 1983; Lundberg & Hoen, 1989; Olson, Wise, & Rack, 1989). These findings have also been extended to adult populations. Specifically, recent research has focused on whether phonological processing skill development in children is correlated with age and reading ability and whether phonological deficits persist into adulthood. Studies have shown differences between adults with RD and typically achieving adults in phonological awareness (Bruck, 1990, 1992; Felton, Naylor, & Wood, 1990; Shafrir & Siegel, 1994; Pennington, Van Orden, Smith, Green, & Haith, 1990; Snowling, Nation, Moxham, Gallagher, & Frith, 1997; Wilson & Lesaux, 2001), verbal short-term memory (Pennington et al., 1990), and sound–spelling relationships (Bruck, 1990). Phonological deficits have also been found in young adults with RD attending university who had acquired age-appropriate reading skills (Wilson & Lesaux, 2001).

Although the phonological deficit hypothesis is able to account for the large majority of reading impairments, there remain individuals with adequate phonological skills but poor comprehension (Wolf, 1999). Recently, a competing hypothesis, the double-deficit hypothesis of developmental dyslexia (Wolf & Bowers, 1999, 2000), has emerged to account for this subgroup of individuals. The double-deficit hypothesis implicates naming speed as a second, independent core deficit of RD (Wolf & Bowers, 1999, 2000). Three subtypes of individuals with RD are thus hypothesized: (a) the phonological deficit subtype, defined by a phonological deficit in the presence of average phonological skills; and (c) the double-deficit subtype, defined as showing both naming speed and phonological deficits. Wolf and Bowers (1999, 2000) hypothesized the double-deficit group to be the subtype showing the most severe impairment, the phonological subtype to show moderate impairment, and the naming speed group to show the least impairment. It is argued that these subgroups of RD are necessary to adequately address the needs of each subgroup. Although naming speed is proposed to be a core deficit of dyslexia in this model, the diagnostic specificity of naming speed has yet to be determined (Denckla & Cutting, 1999; Denckla & Rudel, 1976b; Wolf, 1999).

Unlike the phonological deficit hypothesis, neither naming speed nor the double-deficit hypothesis has been widely investigated in adult populations; much of the evidence supporting naming speed as a core deficit in RD and supporting the double-deficit hypothesis comes from child samples. The naming speed literature, primarily based on child samples, suggests that a naming speed deficit characterizes some
children with RD (Denckla & Rudel, 1976a, 1976b; Fawcett & Nicolson, 1994; Wolf, Bally, & Morris, 1986), particularly those with severe reading impairments (Meyer, Wood, Hart, & Felton, 1998a; Pennington, Cardoso-Martins, Green, & Lefly, 2001). The preliminary evidence from adult studies suggests that naming speed deficits may persist into adulthood, although more research in this area is needed. Using adults with childhood diagnoses of RD, Felton et al. (1990) investigated the cognitive correlates of RD in 115 adults. They found that once the effects of IQ and socioeconomic status were controlled, measures of rapid naming, phonological awareness, and nonword reading discriminated between adults with and without a history of reading difficulties. They concluded that measures of rapid naming remained sensitive to childhood difficulties in learning to read (Felton et al., 1990). Likewise, Korhonen (1995) found naming speed deficits to persist into adulthood in a sample of nine adults with childhood diagnoses of RD.

There is conflicting evidence in the literature with children that naming speed represents a deficit independent of phonological processing (e.g., Torgesen, Wagner, Rashotte, Burgess, & Hecht, 1997; Wagner & Torgesen, 1987; Wagner, Torgesen, & Rashotte, 1994). Some research has shown that naming speed accounts for unique variance in reading ability over and above phonological processing across the spectrum of reading ability (Bowers & Swanson, 1991; Manis, Doi, & Bhadha, 2000), whereas other studies have suggested that the contribution of naming speed is minimal (Torgesen et al., 1997). It has also been suggested that naming speed may be associated with word reading only in poor readers (McBride-Chang & Manis, 1996). In contrast, Torgesen et al. (1997) found the contribution of naming speed to be reduced in poor readers. In an adult study, Chiappe, Stringer, Siegel, and Stanovich (2002) found both phonological processing and naming speed to contribute unique variance to word reading. However, only one quarter of the variance in word reading accounted for by naming speed was independent of phonological processing (Chiappe et al., 2002). The authors concluded that naming speed likely reflected problems in phonological processing and noted that further research was required to determine the role of naming speed deficits in RD (Chiappe et al., 2002). To our knowledge, no further research in this area with adults has been conducted, and the topic thus remains inconclusive.

There is also a lack of research investigating the double-deficit model in adult populations. As there are no published studies of the double-deficit hypothesis using adults, the evidence for this model is based strictly on child samples. The research on the double-deficit hypothesis is difficult to interpret, as few studies use samples that are characterized by reading impairment, and in those that do, the identification of subtypes is problematic. For example, Manis et al. (2000) found support for the double-deficit hypothesis, as they were able to classify second-grade children into the reading impairment subgroups hypothesized by Wolf and Bowers (1999, 2000). However, their double-deficit reading impairment group had reading scores ranging from below the 25th percentile to the 48th percentile and, thus, was not representative of RD. Similarly, Sunneth and Bowers (2002) found the existence of three reader subtypes in their third-grade sample; however, it is difficult to use this study as support for the double-deficit hypothesis of developmental dyslexia, as these readers had an average standard score of 100 on a standardized measure of reading ability. Lovett, Steinbach, and Frijters (2000) classified 166 children (ages 7 to 13 years) with clearly defined RD into the hypothesized subtypes. They found that the double-deficit group showed the most severe impairments on measures of reading, spelling, and arithmetic, followed by the phonological deficit group and the naming speed deficit group, respectively. A careful examination of the double-deficit subtypes, however, reveals that the naming speed deficit group was in fact also characterized by phonological deficits and would have been better classified as double-deficit readers. Similarly, Deeney, Wolf, and O’Rourke (2001) described the results of a case study with a student with one of the most severe naming speed deficits ever encountered by the authors. However, the child’s performance on some phonological tasks could not be described as intact, which calls into question the results of the study. That the samples in studies used to validate a model of reading impairment are not restricted to individuals with RD limits the evidence for the double-deficit hypothesis. Furthermore, that the identification of the subtypes hypothesized in the double-deficit model has not been documented in samples with RD also limits the utility of the model.

An additional limitation of double-deficit research, and one that has received minimal attention, is the selection of appropriate samples necessary to adequately test the model. Specifically, the double-deficit hypothesis was developed to account for those children with RD who showed adequate decoding yet poor comprehension (Wolf, 1999; Wolf, Bowers, & Biddle, 2000). Yet in the few studies that do attempt to define an RD group, word reading ability is used as the indicator of RD (e.g., Manis et al., 2000; Sunneth & Bowers, 2002). No studies that use comprehension as an indicator of RD have been conducted despite the prediction of the model that naming speed deficits may be responsible for those comprehension problems. Furthermore, in those studies that have used comprehension as an outcome variable, the role of naming speed is minimal. In a sample of children and adolescents, Pennington et al. (2001) found that when controlling for word reading ability, verbal IQ, and age, phoneme awareness contributed unique variance to Word Attack, spelling, and comprehension, whereas naming speed contributed unique variance only to
oral reading rate. In a study with 945 children, Schatschneider, Carlson, Francis, Foorman, and Fletcher (2002) found that at the end of second grade, naming speed accounted for only 3% of the total variance in comprehension, whereas phonological awareness accounted for 19%. Based on the double-deficit literature, it is difficult to make the claim that the double-deficit model has utility in children with RD. The utility of the model in adult populations is unknown.

In summary, there is a consensus that the core deficit in RD involves a deficit in phonological processing, and the persistence of phonological deficits into adulthood has been documented. The research on naming speed and the double-deficit hypothesis in adulthood is less clear. Specifically, the research remains inconclusive on whether naming speed deficits characterize adults with RD and whether naming speed makes a unique contribution to reading ability in adults. Furthermore, it is of interest whether the double-deficit hypothesis is applicable to individuals with comprehension difficulties and whether the model has utility in adult samples.

In order to address some of the limitations in the adult naming speed and double-deficit literature, the present study investigated phonological processing and naming speed in a sample of university students with RD. Reading comprehension was used as the indicator of RD, to more adequately explore the hypotheses of the double-deficit model. Furthermore, reading comprehension may be a better indicator of RD in adults, as comprehension tasks are more sensitive to the deficits of adults with RD (L. S. Siegel, personal communication, January 1, 2001). The specific hypotheses of interest were (a) the persistent nature of phonological processing and naming speed deficits in adults with RD; (b) the contribution of phonological processing and naming speed to reading ability; and (c) whether the double-deficit paradigm can be applied to a sample of adults with RD.

Method

Participants

The RD sample consisted of 30 participants (15 men and 15 women) with a documented history of reading difficulties and a certified reading disability. These students were recruited from a university’s learning disability resource center. The center required a diagnosis of RD from a certified psychologist completed within 3 years prior to entering university. To ensure a uniform sample, only individuals with reading comprehension scores below the 27th percentile were included in the analyses. This criterion for RD is consistent with the most current scientifically validated conceptualizations of RD (e.g., Lyon et al., 2001). Five students were excluded from the RD sample because of reading comprehension scores above the 27th percentile, which left 25 students in the final sample. The age of the RD sample ranged from 19 to 25, with a mean age of 21.12 years. Participants in the RD group received $10 per session for two sessions for their participation.

A control group of 33 students (15 men and 18 women) was selected either from first-year introductory psychology courses (n = 6) or from among those who had participated in the same research program in previous years (n = 27). We invited the latter to participate in the current study, as their age more closely approximated the RD sample. All potential control participants completed a group-administered screening survey, and only those who were average readers (reading comprehension score above the 30th percentile), had no history of learning problems nor of educational assistance, were exclusively right-handed, were not on medication, had not repeated a grade, and spoke English as a first language were included in the sample. Moreover, in order to ensure uniformity of educational experience of the samples, participants were not included if they had been out of school for more than 1 year. Five students were excluded from the analyses because of low reading comprehension scores. The 28 participants in the control sample ranged in age from 18 to 22, with a mean age of 19.39 years. Introductory psychology students received credit for their participation, and those who had previously volunteered were paid $10 per session.

Table 1 summarizes the characteristics of both groups on age and general ability measures. In order to gain estimates of verbal and nonverbal abilities, two subtests from the Wechsler Adult Intelligence Scale–Revised (WAIS-R; Wechsler, 1981) were administered to each participant. The Vocabulary and Block Design subtests were chosen, as they have the highest correlations with overall Verbal and Performance IQ scores (0.81 and 0.65, respectively) for this age group (Wechsler, 1981, p. 39). Furthermore, the Peabody Picture Vocabulary Test–Revised (PPVT; Form L; Dunn & Dunn, 1981) was administered. It correlates highly (median value .71) with the overall Verbal IQ Score of the WAIS-R (Dunn & Dunn, 1981, p. 63). There were no significant differences between the groups on age or measures of general ability.

Materials and Procedures

The tasks completed by students were designed to obtain measures of reading skills, phonological processing, and naming speed. These factors were examined using both standardized and experimental measures. Standardized tests have the advantage of well-developed procedures and normative data for comparison purposes, whereas experimental measures allow for the further delineation of specific aspects of these skills. All standardized measures were administered and scored using standardized instructions. Each participant was tested individually over two sessions lasting approximately 45 minutes each.

Reading Measures. Reading comprehension was assessed with the Reading Comprehension subtest of the Nelson-Denny Reading Test (N-D; Brown,
Fishco, & Hanna, 1993), a silent, timed test of comprehension. The test consisted of several passages, each followed by multiple-choice questions based on the passage. Students had 20 minutes to complete as much of the test as possible. A measure of reading rate was obtained through standard administration. Both Reading Comprehension and Reading Rate scores are reported in percentiles.

Decoding ability was assessed with the Word Attack subtest of the Woodcock-Johnson Tests of Achievement (WJ-R; Woodcock & Johnson, 1989). The Word Attack subtest is untimed and requires students to read a list of pseudowords of increasing difficulty. Percentile scores are reported.

Experimental measures were used to assess timed word recognition and decoding skills. The Word and Nonword Reading tasks developed by Bruck (1990) were used. Participants were instructed to read aloud 40 words of increasing difficulty, followed by 40 nonwords of comparable length and difficulty. There was only one possible pronunciation for each nonword. The number of errors made and the length of time in seconds to read each list were recorded.

Phonological Processing Measures. Phonological processing skills were assessed using the measures employed by Wilson and Lesaux (2001). Experimental measures had been selected from those used in previous adult studies to reduce possible ceiling effects and to allow for comparison with other studies.

Phoneme deletion task. Participants were asked to remove either the initial or the final sound of 24 nonsense words spoken to them by the examiner (e.g., say bink without the last sound). Total number of correct responses was recorded (Snowling et al., 1997).

Spoonerisms. Participants were orally presented with a formal name (first and last name) and were required to exchange the beginning sounds of the two words (e.g., Bon Jovi becomes Jon Bovi). Twelve test trials were administered. The number of errors was recorded, and response time was calculated in seconds for each item (Snowling et al., 1997).

Digit span. The Digit Span subtest of the WAIS-R was administered as a

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### TABLE 1

Descriptive Characteristics of RD and Control Groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>RD group*</th>
<th>SD</th>
<th>Control groupb</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>21.12</td>
<td>1.56</td>
<td>19.39</td>
<td>0.92</td>
</tr>
<tr>
<td>PPVT-R percentile</td>
<td>52.20</td>
<td>26.77</td>
<td>67.50</td>
<td>20.38</td>
</tr>
<tr>
<td>WAIS-R Vocabulary scaled score</td>
<td>9.64</td>
<td>2.69</td>
<td>10.64</td>
<td>1.68</td>
</tr>
<tr>
<td>WAIS-R Block Design scaled score</td>
<td>12.28</td>
<td>1.84</td>
<td>12.39</td>
<td>2.54</td>
</tr>
<tr>
<td>N-D Comprehension percentile</td>
<td>10.72</td>
<td>8.50</td>
<td>64.86</td>
<td>16.26</td>
</tr>
<tr>
<td>N-D Reading Rate percentile</td>
<td>13.54</td>
<td>21.47</td>
<td>48.14</td>
<td>22.76</td>
</tr>
<tr>
<td>WJ-R Word Attack percentile</td>
<td>44.20</td>
<td>27.92</td>
<td>79.00</td>
<td>22.60</td>
</tr>
<tr>
<td>WRAT-3 Spelling percentile</td>
<td>40.00</td>
<td>25.36</td>
<td>72.71</td>
<td>13.85</td>
</tr>
<tr>
<td>Word Reading errors (max. 40)</td>
<td>3.60</td>
<td>2.84</td>
<td>0.71</td>
<td>0.98</td>
</tr>
<tr>
<td>Word Reading time (sec)</td>
<td>62.33</td>
<td>54.87</td>
<td>32.40</td>
<td>7.14</td>
</tr>
<tr>
<td>Nonword Reading errors (max. 40)</td>
<td>10.00</td>
<td>5.61</td>
<td>3.11</td>
<td>2.70</td>
</tr>
<tr>
<td>Nonword Reading time (sec)</td>
<td>100.84</td>
<td>76.41</td>
<td>45.41</td>
<td>9.92</td>
</tr>
<tr>
<td>Phoneme Deletion correct (max. 24)</td>
<td>18.76</td>
<td>3.44</td>
<td>21.25</td>
<td>2.24</td>
</tr>
<tr>
<td>Phonemic Fluency</td>
<td>6.88</td>
<td>3.22</td>
<td>10.20</td>
<td>3.92</td>
</tr>
<tr>
<td>Spoonerisms correct (max. 12)</td>
<td>9.32</td>
<td>3.54</td>
<td>11.25</td>
<td>1.51</td>
</tr>
<tr>
<td>Spoonerisms time (sec)</td>
<td>6.55</td>
<td>3.72</td>
<td>3.62</td>
<td>2.60</td>
</tr>
<tr>
<td>RAN Composite time (sec)</td>
<td>28.71</td>
<td>5.86</td>
<td>22.83</td>
<td>3.06</td>
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<td>RAN Composite error</td>
<td>0.48</td>
<td>0.71</td>
<td>0.21</td>
<td>0.50</td>
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<tr>
<td>RAN Color time (sec)</td>
<td>30.95</td>
<td>7.71</td>
<td>24.65</td>
<td>3.45</td>
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<td>RAN Color error</td>
<td>0.12</td>
<td>0.33</td>
<td>0.07</td>
<td>0.26</td>
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<td>RAN Number time (sec)</td>
<td>21.02</td>
<td>3.85</td>
<td>18.20</td>
<td>3.92</td>
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<td>RAN Number error</td>
<td>0.08</td>
<td>0.40</td>
<td>0.04</td>
<td>0.19</td>
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<td>RAN Object time (sec)</td>
<td>40.42</td>
<td>8.81</td>
<td>31.15</td>
<td>4.31</td>
</tr>
<tr>
<td>RAN Object error</td>
<td>0.08</td>
<td>0.28</td>
<td>0.04</td>
<td>0.19</td>
</tr>
<tr>
<td>RAN Letter time (sec)</td>
<td>22.40</td>
<td>6.22</td>
<td>17.28</td>
<td>3.37</td>
</tr>
<tr>
<td>RAN Letter error</td>
<td>0.12</td>
<td>0.44</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>


* n = 25. ** n = 28.
measure of phonological recoding in working memory (Wagner & Torgesen, 1987). A scaled score was calculated for each participant.

**Phonemic fluency.** Participants were given 30 seconds to produce as many words as possible beginning with a certain sound (e.g., /m/, /d/, /s/). The average number of the three trials was calculated (Snowling et al., 1997).

**Naming Speed.** The original rapid automatized naming task (RAN; Denckla & Rudel, 1974) was used to measure naming speed. Participants were required to name as rapidly as possible a visual array of stimuli presented on a cardboard chart. Four different charts, each containing five stimuli of a given category randomly repeated 10 times were presented as follows: colors (black, blue, green, red, yellow), digits (2, 4, 6, 7, 9), objects (comb, key, scissors, umbrella, watch), and small letters (a, d, o, p, s). Sample trials were conducted to ensure that participants could name the individual stimuli in each category. Participants were instructed to name the stimuli in a left-to-right and top-to-bottom sequence “as fast as you can without making a mistake and without skipping any.” Time taken for each chart was recorded, as were any uncorrected errors.

**Results**

To minimize the chance of a Type I error when using multiple t tests, alpha was set to a conservative p = .01. Cohen’s d was used as a measure of effect size. Cohen’s (1988) criteria for effect size are as follows: .2 small, .5 medium, and .8 large. Table 1 summarizes the mean scores for both groups on measures of reading, phonological processing, and rapid naming.

**Persistence of Phonological and Naming Speed Deficits**

The control group scored significantly higher than the RD group on Reading Comprehension, t(51) = 14.92, p < .0001, d = 4.18; Word Attack, t(51) = 5.01, p < .0001, d = 1.40; and Spelling, t(51) = 5.92, p < .0001, d = 1.66. The control group made fewer errors than the RD group on the Word Reading test, t(51) = 5.05, p < .0001, d = 1.42, and on the Nonword Reading test, t(51) = 5.80, p < .0001, d = 1.62. The RD group was significantly slower than the control group on Reading Rate, t(51) = 5.61, p < .0001, d = 1.59; Word Reading time, t(51) = 2.86, p = .006, d = .80; and Nonword Reading time, t(51) = 3.81, p < .0001, d = 1.07.

On measures of phonological processing, the control group made significantly fewer errors than the RD group on Phoneme Deletion, t(51) = 3.15, p < .003, d = .88, and produced significantly more words in 30 seconds in Phonemic Fluency, t(51) = 3.35, p < .002, d = .94. The control group required significantly less time than the RD group to perform the Spoonerisms task, t(51) = 3.36, p = .001, d = .94, and made significantly fewer errors, t(51) = 2.63, p = .01, d = .74.

The control group was significantly faster than the RD group on the Nonword Reading test, t(51) = 3.91, p < .0001, d = 1.09; numbers, t(51) = 2.64, p = .01, d = .74; objects, t(51) = 4.94, p < .0001, d = 1.38; and letters, t(51) = 3.78, p < .0001, d = 1.06. The four RAN tasks were averaged to produce a RAN composite measure (Meyer et al., 1998a). The control group was significantly faster than the RD group on this composite, t(51) = 4.65, p < .0001, d = 1.30. There were no differences in accuracy between the two groups on any RAN measures.

**Summary.** The control group performed significantly better than the RD group on all measures of reading. The RD group got fewer items correct on Phoneme Deletion and produced significantly fewer words in Phonemic Fluency. The RD group required significantly more time to perform the Spoonerisms task and produced significantly fewer correct responses than the control group. The control group was significantly faster than the RD group on all RAN measures, and there were no differences in accuracy.

**Contribution of Phonological Processing and Naming Speed to Reading Ability**

To assess the second hypothesis, three regression analyses were computed. In the first regression, Reading Comprehension was entered as the dependent variable, and vocabulary (PPVT-R), phonological processing (Phoneme Deletion), and naming speed (RAN composite) were entered as explanatory variables. Consistent with previous double-deficit research, vocabulary was entered as a predictor to control for general verbal ability (e.g., Manis et al., 2000; McBride-Chang & Manis, 1996; Pennington et al., 2001). Phoneme Deletion was selected as the indicator of phonological processing as it is the most commonly used index of phonological processing (e.g., Manis et al., 2000; Yopp, 1988), particularly in adult samples (e.g., Bruck, 1992; Chiappe et al., 2002). Furthermore, unlike the other measures of phonological processing used in the present study, phoneme deletion tasks are well researched, and their relation to phonological processing and RD has been consistently documented (e.g., Bruck, 1992; Chiappe et al., 2002; Manis et al., 2000; Torgersen et al., 1997; Yopp, 1988).

The first model yielded a significant equation, F(3, 59) = 12.09, p < .0001, R² = .38. To determine the importance of vocabulary, phonological processing, and naming speed to the overall model, the variance was partitioned using the Pratt Index (Thomas, Hughes, & Zumbo, 1998). The Pratt Index partitions R² in such a way that the contribution of each variable to the overall variance accounted for by the model can be examined. The results of the relative Pratt Index are presented in Table 2. Of the 38% of variance accounted for by the model, vocabulary accounted for 32.2%, phonological processing accounted for 7.2%, and RAN accounted for 60.4% of the overall variance. Based on the Pratt Index, naming speed and vocabulary were, in relative
order, the most important explanatory variables in the model. The contribution of phonological processing was found to be unimportant according to the criteria set by Thomas (1992).

Given that the outcome measure, Reading Comprehension, was a timed test, it was not clear from the preceding analysis whether the contribution of RAN was due to the speeded component of the task (general processing speed) or to something unique to rapid naming ability per se. To control for the speeded component, reading rate was added to the first model. Furthermore, as the diagnostic specificity of RAN has yet to be determined (Denckla & Cutting, 1999; Wolf, 1999), Reading Rate was entered into the model because it is unambiguous what reading rate indexes. This model accounted for a significant amount of the variance in reading comprehension, \( F(4, 57) = 24.50, p < .0001, R^2 = .63 \). The Pratt Index was applied to the variables in the model to determine variable importance. The results are presented in Table 2. Of the 63% of variance accounted for by the model, vocabulary accounted for 11.5%, phonological processing accounted for 5.2%, naming speed accounted for 8%, and reading rate accounted for 76% of the overall variance. With reading rate in the model, vocabulary, phonological processing and naming speed were unimportant to the model.

A further regression was conducted to determine whether phonological processing and naming speed accounted for unique variance beyond reading rate and vocabulary. A fixed-order hierarchical regression was conducted to determine the contribution of each variable to reading comprehension. The results are presented in Table 3. Reading rate and vocabulary were entered into the regression model first (Model 1), followed by phonological processing (Model 2) and then naming speed (Model 3). Model 1 accounted for a significant amount of variation in comprehension, \( F(2, 59) = 45.07, p < .0001, R^2 = .60 \). Over and above reading rate and vocabulary, phonological processing (Model 2) did not account for a significant amount of variation, \( \Delta R^2 = .02, \Delta F(1, 58) = 3.48, \text{ns} \).

Over and above Model 2, naming speed did not account for a significant amount of variation in comprehension, \( \Delta R^2 = .01, \Delta F(1, 57) = 0.84, \text{ns} \).

Summary. A regression model that included reading rate, vocabulary, phonological processing, and naming speed accounted for 63% of the variance in reading comprehension. The Pratt Index revealed that vocabulary, phonological processing, and naming speed had little importance in explaining comprehension in a model that included reading rate. In an alternate regression, neither phonological processing nor naming speed accounted for variance in reading comprehension when reading rate and vocabulary were controlled.

### The Double-Deficit Model

As a further test of the double-deficit model, the RD group was disaggregated to examine the existence of the three hypothesized reading impairment groups. Specifically, the double-deficit hypothesis proposes the existence of three reading impairment groups characterized by either a phonological deficit, a naming speed deficit, or both. It was of interest whether these three groups could be identified in an adult sample. Table 4 summarizes the descriptive statistics of the subgroups hypothesized by the double-deficit hypothesis. To be included in the phonological deficit (PD) group, participants had to have naming speed scores (using the composite score) in the average range and below-average scores in phonological processing (us-
A deficit was defined as a performance 1 SD or more below the mean of the entire sample. The naming speed deficit (NSD) group had average phonological skills and below-average naming speed scores. The double-deficit (DD) group had below-average scores on measures of both phonological processing and naming speed. Individuals who did not fit the criteria were placed in the no deficit (ND) category. Four adults with RD were placed in the PD group and 11 were placed in the NSD group. Five adults with RD were identified as DD and five adults with RD did not fit the double-deficit criteria.

Although these results at first seem to support the double-deficit hypothesis, a closer examination of Table 4 reveals that the double-deficit groups...
do not have deficits in the skills predicted by Wolf and Bowers (1999). The average range for each measure is provided in the last column of Table 4 for comparison purposes. The average range was calculated from the entire sample of participants. Of particular interest for the double-deficit hypothesis is the finding that the NSD group did not have adequate phonological or decoding skills and that the DD group was not the one with the most severe reading comprehension impairment.

Discussion

The present study investigated the following hypotheses:

1. the persistent nature of hypothesized core deficits in adults with RD;
2. the relationship between these deficits and reading comprehension; and
3. a test of the double-deficit paradigm.

The results for Hypothesis 1 revealed that the RD sample displayed significant phonological processing deficits compared to their typically achieving peers. This finding is consistent with the adult literature on the persistence of phonological deficits in RD samples (e.g., Bruck, 1990; Shafrir & Siegel, 1994; Snowling et al., 1997; Wilson & Lesaux, 2001).

The results for Hypothesis 1 also provided support for the persistent nature of naming speed deficits in adults with RD. This is consistent with the few previous studies in this area (e.g., Chiappe et al., 2002; Felton et al., 1990). Although adult normative data on the RAN do not exist, it is possible to gain an estimate of the severity of naming speed impairment in the RD sample by using normative data for Grade 8 students (normative data provided in Meyer et al., 1998a; see Note). Compared to eighth-grade students, the control group performed between the 50th and 75th percentiles on RAN, which is expected if the skills used in naming speed plateau in adolescence. The RD sample performed between the 10th and 25th percentiles, which clearly shows a deficit in naming speed. In fact, the mean scores for the RD group approximated the 50th percentile for average readers in Grade 5. Clearly, not only is the naming speed deficit in the present sample persistent, but it is quite severe.

Having established the persistent nature of both phonological processing and naming speed deficits, the relationship between these processes and comprehension was examined. It is important to mention that although the results of the present study found that the RD sample differed significantly from controls on all phonological measures, for the purpose of further analyses (Hypotheses 2 and 3), we selected Phoneme Deletion as our measure of phonological processing. As mentioned previously, Phoneme Deletion is a well-established measure of phonological processing. Although it was important to include additional measures of phonological processes to further delineate the skills of adults with RD, there has been little empirical research with phonemic fluency or spoonerism tasks in adult samples. As the theoretical and empirical constructs of these tasks are thus less well defined than that of phoneme deletion, we concur with previous studies (Snowling et al., 1997) that until further research is conducted with these tasks, their use might be primarily in identifying adults with RD.

Although the double-deficit hypothesis evolved to account for children with adequate decoding but poor comprehension skills (Wolf, 1999), few studies have actually examined the role of naming speed in a sample with deficits in comprehension skills. The results of the present study revealed that naming speed was a significant contributor to reading comprehension in a model that included vocabulary and phonological processing skills. This finding suggests that naming speed may be the most important variable in reading comprehension in high-functioning adults with RD and provides support for the hypothesis of naming speed’s increased importance when fluency is emphasized (Torgesen et al., 1997). That naming speed was found to be more important to reading comprehension than vocabulary and phonological processing is consistent with the double-deficit hypothesis. However, this finding is inconsistent with previous naming speed research, which has found that naming speed is not related to reading comprehension (e.g., Bowers & Swanson, 1991; Meyer et al., 1998b; Pennington et al., 2001; Schatschneider et al., 2002; Wolf et al., 1986). The role of naming speed in comprehension should be investigated further.

The aforementioned inconsistencies might be due to the yet unknown skills associated with RAN. McCandliss, Scarborough, and Catts (2001), among others (e.g., Denckla & Cutting, 1999; Wolf, 1999), have noted that “the core deficit underlying naming speed differences remains rather poorly specified” (p. 234). That it is not entirely clear what RAN measures, nor how it is related to RD, somewhat dampens the findings of the present study on the role of naming speed in reading comprehension. When reading rate was entered into a regression model, naming speed lost its unique contribution. This finding calls into question the utility of RAN as a diagnostic tool. Specifically, a model including reading rate not only accounted for a greater amount of variance in comprehension (38.1% accounted for in Regression 1, and 63.2% accounted for in Regression 2), but reading rate accounted for 76% of the variance explained by the second regression model. This finding suggests that whatever it is that is explained by rapid naming in comprehension is even better explained by a domain-specific measure such as reading rate. This is important when considering the implications of identifying a naming speed deficit versus a reading rate deficit. To date, the diagnostic specificity of naming speed is undefined, which renders the identi-
fication of a naming speed deficit problematic; if it is not clear what the deficit represents, intervention efforts are not possible. Identifying a reading rate deficit, however, is clear in its implications for intervention. The findings from Hypothesis 2 suggest that if one is interested in examining fluency, RAN may not be appropriate. Instead, if one is interested in fluency, a more domain-specific task such as reading rate seems to offer more useful diagnostic information. In summary, although the results from Hypothesis 2 provided evidence for the contribution of naming speed to comprehension, the value of this finding is questionable, given that naming speed itself is poorly specified and that a domain-specific test of fluency is a better model of comprehension.

Hypothesis 3 was a direct test of the double-deficit hypothesis. The double-deficit hypothesis predicts three RD subtypes: readers with phonological deficits in the presence of average naming speed (PD); readers with naming speed deficits in the presence of average phonological skills (NSD); and readers with a double deficit (DD). Wolf and Bowers (1999, 2000) hypothesized that those in the NSD group would show the least impairment, those in the PD group would show moderate impairment, and those in the DD group would show the most severe impairment.

The analyses from the present study revealed that the three subtypes of RD were identifiable in the present sample of adults with RD, which supports the double-deficit paradigm. Of the 25 adults with RD, 4 were classified as PD (as measured by Phoneme Deletion), 11 were classified as NSD (as measured by RAN composite), 5 had a double deficit, and 5 could not be classified. Although the existence of these subgroups seems consistent with the double-deficit hypothesis, a careful examination of the characteristics of these groups reveals findings quite contrary to the model. An examination of Table 4 reveals that adequate decoding and phonological processing skills characterize none of the subgroups. Although this is an expected finding for the PD and DD groups, it is directly contrary to the double-deficit hypothesis. This is problematic for the double-deficit model, as there is no convincing evidence that an NSD group exists. Furthermore, that the DD group did not have the most severe deficit on reading comprehension is also contradictory to the double-deficit hypothesis. Although these findings call into question the utility of the double-deficit framework in an adult sample, more research is needed with more diverse RD types and larger sample sizes. However, previous research with child samples has also questioned the utility of the double-deficit framework (e.g., Pennington et al., 2001).

It is of theoretical interest that the RD sample in the present study was made up of university students. That this group is able to perform at a high-functioning level despite significant deficits in reading comprehension should be further explored. The results of the present study indicated that the RD sample was significantly slower than their typically achieving peers on the speed of word recognition and decoding skills, despite standardized measures of decoding in the average range. This suggests that time may be an important factor to consider in adult samples with RD. As comprehension in the present study was measured using a timed test, one hypothesis is that the performance of the RD group could have been improved with additional time. Specifically, given the average performance on standardized measures of reading skills (i.e., decoding and spelling), it may be the case that the RD group would have performed at a more age-appropriate level had they received additional time to complete the reading comprehension test, although this hypothesis should be investigated empirically. Furthermore, it would be interesting to determine the relation of phonological processing and naming speed to comprehension in an untimed test of reading comprehension.

Another area of future research is the investigation of adults with RD and average reading comprehension scores and those without RD with below-average comprehension scores. Specifically, it would be of interest to determine whether an RD group with average comprehension scores is distinguishable from a normative sample, and whether a normative group with below-average comprehension scores is distinguishable from an RD group. Such research would contribute to the definition and delineation of adults with RD.

Summary

The findings of the present study offer mixed results with respect to the double-deficit hypothesis. The present study demonstrated the persistent nature of both phonological processing and naming speed deficits in a sample of adults with RD, which is consistent with the double-deficit model. Regression analyses revealed that phonological processing was unimportant to comprehension and naming speed was the most important. This supports the role of naming speed in RD. However, in a regression model including reading rate, the influence of naming speed became unimportant, and reading rate accounted for a large majority of the variance. This finding challenges the core deficit explanation of naming speed, as reading rate seemed to provide a better index of fluency and offered a better model of reading comprehension. Finally, although the deficit groups hypothesized by Wolf and Bowers (1999, 2000) were identifiable, these groups did not display the expected characteristics hypothesized by the double-deficit model.

Although RAN tasks have been shown to have predictive ability in the early school years (Torgesen et al., 1997; Wolf et al., 1986), this predictive ability seems to lessen with time (Torgesen et al., 1997), and, in the present study, did not provide additional information about comprehension ability over and above reading rate and
vocabulary. The results of the present study suggest that measures of phonological processing and naming speed may be useful in identifying adults with RD, although the inclusion of measures of naming speed does not provide additional diagnostic information independently of reading rate and vocabulary. The results of the present study are mixed at best and are consistent with the conclusions of McCandless et al. (2001) that support for the double-deficit hypothesis of dyslexia remains limited.

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NOTE
Meyer et al. (1998a) found that naming speed latency approached asymptote by adolescence. As such, a comparison between Grade 8 students and an adult sample seems appropriate to gain insight into the severity of the naming speed deficit.

REFERENCES


