The Double-Deficit Hypothesis:  
A Comprehensive Analysis of the Evidence

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Abstract

The double-deficit hypothesis of developmental dyslexia proposes that deficits in phonological processing and naming speed represent independent sources of dysfunction in dyslexia. The present article is a review of the evidence for the double-deficit hypothesis, including a discussion of recent findings related to the hypothesis. Studies in this area have been characterized by variability in methodology—how dyslexia is defined and identified, and how dyslexia subtypes are classified. Such variability sets limitations on the extent to which conclusions may be drawn with respect to the double-deficit hypothesis. Furthermore, the literature is complicated by the persistent finding that measures of phonological processing and naming speed are significantly correlated, resulting in a statistical artifact that makes it difficult to disentangle the influence of naming speed from that of phonological processing. Longitudinal and intervention studies of the double-deficit hypothesis are needed to accumulate evidence that investigates a naming speed deficit that is independent of a phonological deficit for readers with dyslexia. The existing evidence does not support a persistent core deficit in naming speed for readers with dyslexia.

The double-deficit hypothesis of developmental dyslexia implicates naming speed as a second, independent core deficit of dyslexia (Wolf & Bowers, 1999). The development of this hypothesis stemmed from a narrative review of the literature that identified the existence of a group of individuals with dyslexia who showed adequate decoding skills but poor comprehension and for whom phonological processing as an identification and intervention method was not effective. The double-deficit hypothesis of dyslexia categorizes readers according to the presence or absence of two underlying cognitive processes—phonological processing and naming speed—and posits the existence of three subtypes of reading impairment. The phonological-deficit subtype is defined as having a phonological deficit with average naming speed ability. The naming speed–deficit subtype is defined as having a naming speed deficit in the presence of average phonological skills. The double-deficit subtype is defined as having both naming speed and phonological deficits. The double-deficit hypothesis proposes that those readers with a double deficit have the most severe reading impairment, whereas readers with only a phonological deficit have moderate reading impairment, and those with only a naming speed deficit show the least reading impairment (Wolf & Bowers, 1999).

What Is Rapid Naming and How Is It Measured?

The literature on what naming speed represents is less clear than the literature on how to measure naming speed. Naming speed tasks assess the rate at which a verbal label for high-frequency visual stimuli is produced. Naming speed is typically measured using the Rapid Automatized Naming (RAN) task (Denckla & Rudel, 1974) or tasks similar in nature. RAN tasks require individuals to name a series of high-frequency numbers, letters, colors, or objects presented in random order. The primary measure of interest is the time taken to provide a verbal label for all of the stimuli presented. If an individual takes much longer than average to name all the stimuli, that individual is said to have a naming speed deficit. As with any cutoff score used for separating typical from deficient performance on a continuous variable, the decision to identify a naming speed deficit (or a phonological deficit, or dyslexia) is necessarily arbitrary and tends to be sample specific. Within the double-deficit literature, researchers have generally selected a criterion of 1 SD below the mean to indicate a naming speed deficit.

What Do Naming Speed Tasks Index?

In a theoretical article, Bowers and Wolf (1993) stated that “slow naming speed is implicated in failure to learn...
to recognize words quickly” (p. 77), and in a more recent review article, Wolf, Bowers, and Biddle (2000) stated that “naming speed (particularly serial naming speed) provides an early, simpler approximation of the reading process” (p. 393). Together, these statements imply that the experience of rapid naming mimics the reading process, which would make RAN tasks particularly useful for predicting or identifying children at risk for reading difficulties. However, it is less clear what specific characteristics of RAN tasks make naming speed processes important to the development of reading. To date, there is not a single operational definition of rapid naming that is consistently used in the theoretical or empirical literature.

Explanations of the role of rapid naming have varied; these explanations have conceptualized rapid naming as an index of automaticity in lower level processes (Wolf, 1991); as a fluency-related process (Wolf, 1999); and as a set of skills necessary for the rapid retrieval of any automatized, graphological information, as opposed to letter naming, or naming processes in general (Wolf, 1999). Perhaps the most explicit description of naming speed was offered by Wolf, Bowers, and Biddle (2000): “Naming speed is conceptualized as a complex ensemble of attentional, perceptual, conceptual, memory, phonological, semantic, and motoric subprocess that places heavy emphasis on precise timing requirements within each component and across all components” (p. 395). This definition suggests that, in fact, rapid naming is a multicomponential construct that taps many different skills in the context of a timed scenario. However, the lack of an agreed-upon operational definition makes it difficult to evaluate both the diagnostic specificity of RAN tasks and effective intervention for readers with a naming speed deficit. Proponents of the hypothesis have suggested that the underlying processes of rapid naming tasks and their relationship to reading development have yet to be clearly determined (e.g., Wolf, 1999). As such, there is a need for research to address the specificity of rapid naming in the context of dyslexia.

What Do Naming Speed Deficits Represent?

The double-deficit hypothesis of developmental dyslexia proposes two alternative ways in which a deficit in naming speed might have an influence on reading ability. The first postulates naming speed as an index of slow lower level processing that has an impact on reading fluency, particularly with respect to connected text (Wolf, 1999). The second mechanism posits naming speed as both an index of slowing in lower-level processes (as in the first process) and an indicator of a more pervasive processing problem that has an influence on perceptual, lexical, and motoric processes (Wolf, 1999).

In sum, although many theoretical speculations exist that attempt to explain what naming speed is and why it is an important component of the reading process, there has been little empirical work to examine these hypotheses. A recent review of the literature on reading difficulties in children has suggested a lack of specificity of the naming speed deficit and, more globally, a lack of evidence for the double-deficit hypothesis of developmental dyslexia (see McCardle, Scarborough, & Catts, 2001). The purpose of the present review was to examine the evidence related to the double-deficit hypothesis of developmental dyslexia. As such, we examined the extant research, including research that addresses naming speed deficits in dyslexia; naming speed’s contribution of independent variance to reading ability; the debate about naming speed as a phonological process; the nature of the relationship between naming speed and reading development; the existence and characteristics of the three subtypes outlined in the double-deficit hypothesis; and the related findings from intervention studies.

Method

Criteria and Standards for Article Selection

The purpose of the present article was to provide a comprehensive analysis of the evidence for the double-deficit hypothesis. As is customary in a review study, criteria and standards were developed for the selection of articles for review. We adopted the framework used by Wagner and Torgesen (1987) in their review of the nature of the relationship between phonological abilities and the acquisition of reading skills. As outlined by Wagner and Torgesen, to evaluate the relations between a variable and a process, converging evidence must be found from cross-sectional, longitudinal, and intervention studies.

In conducting the review, we used criteria by which studies would be included or excluded. Our initial criteria for selecting articles for the comprehensive review included (a) studies designed to test or investigate the double-deficit hypothesis of developmental dyslexia, (b) empirical studies published in peer-reviewed journals, (c) studies that included measures of both naming speed and phonological processing, and (d) studies that included individuals with dyslexia or reading difficulties in their sample. As we were interested in reviewing the double-deficit literature across development, we did not limit our selected studies based on the age of the participants in the studies. It is of note, however, that only one study in the review included an adult sample; no other studies with adult samples were found based on our search.

As a first step, the search term double-deficit hypothesis was entered into PsycINFO, which resulted in 30 citations. Eighteen of these articles appeared in peer-reviewed journals. Of these 18, 12 were empirical studies and 6 were theoretical discussion papers. Of the 12 empirical studies, only 5 met all of our inclusion criteria. For this reason, we broadened our initial criteria from studies designed to be a direct
test of the double-deficit hypothesis to also include studies that involved an indirect investigation of the double-deficit hypothesis but, at some level, had implications for the double-deficit hypothesis.

Direct studies were defined as studies that were explicit, theory-driven analyses designed to examine the double-deficit hypothesis of dyslexia. Thus, as part of the literature review and research design, these studies explicitly tested the tenets of the double-deficit hypothesis in dyslexia samples. Indirect studies were defined as those studies that did not explicitly test the hypothesis but included measures of naming speed in their analyses and, thus, had implications for the double-deficit hypothesis.

To find additional articles, the following keywords and combinations were entered into PsycInfo: (a) naming speed and dyslexia resulted in 19 empirical studies, 10 of which were not relevant directly or indirectly to the double-deficit hypothesis, 4 of which investigated the role of naming speed in languages other than English (and thus were not included as part of the review), 3 of which were already found in our initial search, and 2 of which were new studies that fit our criteria, and (b) rapid naming and reading development resulted in 10 empirical studies, 7 of which were not relevant to the purposes of our review, 1 of which was in a language other than English, 1 of which had already been located, and 1 of which fit our criteria and was thus included. Furthermore, we obtained those articles that had been cited in previous reviews (e.g., McCardle et al., 2001) but did not come up in our formal search. Our complete search generated 36 articles relevant to the double-deficit hypothesis of developmental dyslexia (8 theoretical articles and 28 empirical studies).

The eight theoretical articles were used in the literature review, and the 28 empirical studies were used in our review of the empirical evidence for the double-deficit hypothesis. Of the 28 empirical articles, 10 were considered direct tests of the double-deficit hypothesis and 18 were considered indirect tests. The findings of the indirect studies as they related to the double-deficit hypothesis were often not the primary findings. However, for the purposes of this review, only those findings that had implications for the double-deficit hypothesis are discussed. Eight studies were longitudinal, 17 were cross-sectional, and 3 were intervention/training studies. For each empirical study, we delineated the study type (direct vs. indirect), the study design (longitudinal, cross-sectional, or intervention), the number of participants and characteristics where provided (e.g., age or grade in school), the classification criteria used for dyslexia, and the findings as they relate to the double-deficit hypothesis of dyslexia. This information is summarized in Table 1.

### Results

**Is Dyslexia Characterized by Naming Speed Difficulties?**

Naming speed has been implicated in dyslexia since the research of Denckla and Rudel (Denckla, 1972; Denckla & Rudel, 1976a, 1976b). In a cross-sectional study, Denckla (1972) reported the finding of five boys with “unusual hesitancy” in rapidly naming a series of colors. These boys were selected from a pool of 56 children who had been referred for dyslexia over a period of 2 years. Color naming speed for the dyslexia sample was compared to the mean color naming speed of a control group (154 kindergarten children). Case 1 was a second-grade child who was reading at a 1.3 grade level and had an IQ score of 120. This child was reported to have abnormalities in digit span as well as difficulties in rapid color naming. Case 2 was a third-grade child reading at a first-grade level who had an IQ of 90. Case 2 had difficulties in digit span, word finding, and rapid color naming. Case 3 was a nonreading child repeating the second grade, with an IQ of 108. His difficulties were in visual–motor integration, speech, digit span, word writing, and rapid color naming. Case 4 was a fourth-grade child reading at a 1.9 grade level with an IQ of 122. This child had difficulties in pencil control, digit span, word finding, and rapid color naming. Case 5 had been retained and was repeating first grade, was a nonreader, could not name most of the letters of the alphabet, and had an IQ of 106. Denckla noted that this child could produce the correct phonetic sound for 18 letter names. His difficulties were in articulation, word finding, digit span, visual–motor integration, and rapid color naming. Denckla’s findings showed that, in general, the 5 boys shared the same deficits as the larger pool of 56 children referred for dyslexia, except for rapid color naming, in which the 5 boys showed a color naming speed 1 SD below that of kindergarten children. The five boys also seemed to be characterized by difficulties in short-term memory, as measured by digit span. These results suggested that naming speed characterized only a small sample of children with dyslexia.

In a subsequent cross-sectional study, Denckla and Rudel (1976a) investigated rapid object naming in 10 children with dyslexia, 10 children without dyslexia but with other learning disabilities (LD), and 120 typically achieving children. The participants with LD were selected from a larger pool of children attending a special school for children diagnosed with minimal neurological impairment. Based on performance on measures of reading achievement, reading quotients were calculated (reading age/mental age), and children were classified as either having dyslexia or not. From the larger pool of students with LD, 10 students were identified as not having dyslexia (i.e., reading at chronological age and grade expectations) and 10 students with dyslexia were selected to match this group. The groups were matched on age, sex, Performance IQ on the Wechsler Intelligence Scale for Children (WISC), and vocabulary. The
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<tr>
<td>Badian, 1997</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>n = 90 children ages 6 to 10</td>
<td>Dyslexia defined through discrepancy procedure (standard score $M = 75.3$, $SD = 6.3$)</td>
<td>Dyslexia sample showed most impairment on word reading</td>
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<td>Blachman, 1984</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 34 kindergarten</td>
<td>Sample of kindergarten and Grade 1 children; no specific reading ability criteria</td>
<td>Kindergarten rapid naming related to kindergarten measures of reading and reading readiness</td>
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<td>Bowers &amp; Swanson, 1991</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 43 Grade 2 subgroups: n = 24 dyslexia n = 19 average readers</td>
<td>Dyslexia defined by word reading scores below 25th percentile Average readers defined by word reading scores above the 25th percentile</td>
<td>Naming speed contributed independent variance to second-grade reading skill (reading skill was latency based). Analyses conducted only on the entire group</td>
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<td>Chiappe, Stringer, Siegel, &amp; Stanovich, 2002</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 30 adults with dyslexia n = 32 adult typical readers n = 31 reading-matched controls</td>
<td>Dyslexia defined by word reading scores below 25th percentile Typical readers defined by word reading scores above 29th percentile Reading match defined by word reading scores above 29th percentile</td>
<td>Dyslexia is a phonologically based deficit Independence of rapid naming from phonological processing not supported</td>
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<td>Compton, deFries, &amp; Olson, 2001</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>n = 476</td>
<td>Dyslexia defined as a composite word reading score at least 1.5 $SD$ below age peers and a score of 85 or above on either VIQ or PIQ</td>
<td>RAN deficits primarily affect tasks that require fluent response; phonological deficits primarily affect tasks that require phonological skills</td>
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<td>Deeney, Wolf, &amp; O’Rourke, 2001a</td>
<td>Direct</td>
<td>Intervention</td>
<td>n = 1 (case study)</td>
<td>Dyslexia defined using discrepancy formula</td>
<td>Program that focuses on phonology, automaticity, and fluency can increase reading performance in those with a single naming speed deficit</td>
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<td>Denckla, 1972</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>$n = 5$ boys with dyslexia ages 7.6 through 10.8 years</td>
<td>Dyslexia not defined; boys selected from a pool of 56 children referred for dyslexia who showed “unusual hesitancy” in rapidly naming a series of colors.</td>
<td>Difficulty with color naming implies a discrete dysfunction relevant to dyslexia; trend toward persistence of color naming and severity of dyslexia</td>
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<td>Denckla &amp; Rudel, 1976&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>$n = 140$ ages 8–11 subgroups; $n = 10$ children with dyslexia $n = 10$ children with LD but without dyslexia $n = 120$ typical children</td>
<td>Dyslexia not clearly defined; “on the basis of reading achievement tests, (Gray Oral Reading Test and Peabody Individual Achievement Test of Reading) a clearly dyslexic population was separated from the less numerous, clearly nondyslexic group of students” (p. 3)</td>
<td>Dyslexia group characterized by subtle dysphasia and linguistic retrieval problems</td>
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<td>Denckla &amp; Rudel, 1976&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>$n = 248$ children ages 7–13 subgroups; $n = 72$ children with dyslexia $n = 56$ children with LD but without dyslexia $n = 120$ typical children</td>
<td>Dyslexia defined by a 2-year lag in reading age (oral reading skill) compared to IQ Reading scores not presented</td>
<td>Of 36 children with dyslexia, 2 had no naming speed deficits, 4 were slow on one task, and 30 were slow on two or more RAN tasks Of 31 children with LD but no dyslexia, 7 had no naming speed deficits, 8 were slow on one RAN task, and 16 were slow on two or more RAN tasks</td>
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<td>Fawcett &amp; Nicolson, 1994&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>$n = 77$ children ages 8, 13, and 17</td>
<td>Dyslexia defined as discrepancy of at least 18 months between chronological age and reading age, and IQ of at least 90</td>
<td>Children with dyslexia are characterized by naming speed deficits Typically achieving defined as no discrepancy between chronological age and reading age, and IQ of at least 90</td>
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<td>Felton &amp; Brown, 1990</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>$n = 81$ tracked from kindergarten to Grade 1</td>
<td>sample of kindergarten children identified as at risk at risk: any child who obtained a score of 1 SD below the group mean for the sample, or who was in the bottom 16th percentile on at least three of the research tests administered (phonological awareness, phonological recoding in lexical access, phonetic recoding in working memory) excluded any child rated as above average to superior in potential for success in reading, or who had an IQ below 80</td>
<td>Rapid naming contributed unique variance to Grade 1 reading ability RAN classified as measure of phonological recoding in lexical access</td>
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<tr>
<td>Hammill, Mather, Allen, &amp; Roberts, 2002b</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 200 Grades 1 through 6</td>
<td>Reader subtype classification inconsistent</td>
<td>Phonology and semantics are the best predictors of word reading ability</td>
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<td>Lesaux &amp; Siegel, 2003</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>n = 978 followed kindergarten through Grade 2</td>
<td>Sample of kindergarten children; no specific reading ability criteria</td>
<td>Kindergarten rapid naming ability contributed independent variance to Grade 2 word reading over and above phonological processing</td>
</tr>
<tr>
<td>Levy, Bourassa, &amp; Horn, 1999</td>
<td>Indirect</td>
<td>Intervention</td>
<td>n = 128 children in Grade 2</td>
<td>For dyslexia to be defined, all of the following criteria were necessary:</td>
<td>Fast RAN children required fewer repetitions than slow RAN children in all training conditions (onset–rime, phonemic segmentation, whole word)</td>
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<td>Lovett, Steinbach, &amp; Frijters, 2000a</td>
<td>Direct</td>
<td>Intervention</td>
<td>n = 166 ages 7 to 13</td>
<td>Dyslexia defined as scores below the 20th percentile on four of five standardized reading achievement measures</td>
<td>Naming speed group benefited from intervention programs just as much as other deficit subgroups</td>
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<td>Manis, Doi, &amp; Bhadha, 2000a.b</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>n = 85 Grade 2</td>
<td>Dyslexia not defined and reading skill not used as classification criteria, although DDH subgroups identified</td>
<td>Double-deficit group showed most impairment on word reading ability</td>
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<tr>
<td>Manis, Seidenberg, &amp; Doi, 1999</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>n = 85 Grade 1 followed through Grade 2</td>
<td>Children represented full spectrum of reading abilities</td>
<td>Single-deficit groups only slightly below average</td>
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<td>Naming speed accounts for sizable amount of variance with vocabulary and phonemic awareness controlled</td>
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<td>Grade 1 measures of RAN and phoneme awareness both contributed independently to Grade 2 measures when vocabulary was controlled</td>
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<tr>
<td>McBride-Chang &amp; Manis, 1996</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>n = 125 Grade 3 and Grade 4</td>
<td>Dyslexia defined as pseudoword reading scores below 25th percentile</td>
<td>Phonological awareness related to word reading in both groups</td>
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<td>Subgroups:</td>
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<td>n = 51 with dyslexia</td>
<td>Naming speed related to word reading for dyslexia group only</td>
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<td>n = 74 typical readers</td>
<td>Naming speed appears critical in early elementary stages of word recognition</td>
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<td>Meyer, Wood, Hart, &amp; Felton, 1998</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>Study 1: Children followed from Grade 1 through Grade 8</td>
<td>Dyslexia defined as third-grade word reading scores below the 10th percentile</td>
<td>Phonological skills best predictor of early poor reading, but rapid naming skills best predictor of which reader would improve</td>
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<td>n = 15 with dyslexia</td>
<td>Third-grade naming speed had predictive power for word reading in Grades 5 and 8 for poor but not for typical readers</td>
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<td>n = 139 typical readers</td>
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<td>Study 2: n = 64 with dyslexia in Grade 3 followed through Grade 8</td>
<td>Typical readers defined as third-grade word reading above 10th percentile</td>
<td>No consistent prediction of reading comprehension scores from rapid naming</td>
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<tr>
<td>Morris et al., 1998—a,b</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 376 ages 7.5–9.5</td>
<td>Dyslexia defined as either word or pseudoword reading scores below 25th percentile or a discrepancy of 1.5 standard errors between IQ and reading achievement</td>
<td>7 subtypes of dyslexia identified: 2 global subtypes and 5 specific RD subtypes</td>
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<td>subgroups:</td>
<td>n = 58 with dyslexia</td>
<td>Three of the 5 specific RD subtypes implicated rate deficit</td>
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<td>n = 87 with math disability</td>
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<td>n = 103 with both dyslexia and math disability</td>
<td>Rate deficit subtypes showed impairment on achievement measures only in the presence of concurrent phonological deficits</td>
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<td>n = 55 with ADHD</td>
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<td>n = 17 with IQ score less than 80 (below average group)</td>
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<td>n = 51 with no disability</td>
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<td>Neuhaus &amp; Swank, 2002</td>
<td>Indirect</td>
<td>Cross-sectional</td>
<td>n = 221 Grade 1</td>
<td>Sample selected from general education classrooms; no reading criteria specified.</td>
<td>RAN letter naming found to be a significant predictor of word reading</td>
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<td>Pennington, Cardoso-Martins, Green, &amp; Lefly, 2001</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>Child sample: n = 35 with dyslexia (ages 7.0 to 11.9 years)</td>
<td>Dyslexia defined as history of reading and spelling problems and significant discrepancy between reading or spelling and cognitive abilities</td>
<td>Nine individuals with dyslexia identified without a deficit in phoneme awareness</td>
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<td>Of those 9 participants with dyslexia without phoneme</td>
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<td>Pennington (cont’d)</td>
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<td>n = 25 reading age controls (age $M = 9.04$, $SD = 1.27$)</td>
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<td>awareness deficits, only 2 had naming speed deficits</td>
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<td>n = 21 chronological age controls (age $M = 9.86$, $SD = 1.15$)</td>
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<td>Contribution of naming speed to oral reading rate greater in readers with dyslexia than typical readers</td>
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<td>Adolescent sample:</td>
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<td>n = 36 with dyslexia (ages 12.0 to 18.0)</td>
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<td>n = 31 reading age controls (age $M = 11.32$, $SD = 2.66$)</td>
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<td>n = 20 chronological age controls (age $M = 14.65$, $SD = 1.73$)</td>
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<td>Schatschneider, Carlson, Francis, Foorman, &amp; Fletcher, 2002</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>n = 945 followed from kindergarten through Grade 2</td>
<td>Sample of kindergarten children; no specific reading ability criteria</td>
<td>Analyses called into question the finding that the double-deficit groups had the most reading impairment</td>
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<tr>
<td>Sunseth &amp; Bowers, 2002b</td>
<td>Direct</td>
<td>Cross-sectional</td>
<td>n = 68 Grade 3</td>
<td>Sample of Grade 3 children; no specific reading ability criteria, although DDH groups identified</td>
<td>Identified three dyslexia subtypes within a typical reader sample: phonological only, naming speed only, and double deficit</td>
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<tr>
<td>Torgesen, Wagner, Rashotte, Burgess, &amp; Hecht, 1997</td>
<td>Indirect</td>
<td>Longitudinal</td>
<td>n = ca. 200 Grade 2 followed through Grade 5</td>
<td>Sample of second-grade children; no specific reading ability criteria</td>
<td>Unique contribution of naming speed to word recognition; significant in Grade 2 but lost predictive ability by Grade 4 across the whole sample and within the two poor reader conditions</td>
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<tr>
<td>Vukovic, Lesaux, &amp; Siegel, 2003</td>
<td>Direct</td>
<td>Longitudinal</td>
<td>n = 732 kindergarten followed through Grade 4 subgroup</td>
<td>Sample of kindergarten children; no specific reading ability criteria</td>
<td>Kindergarten performance on rapid naming not significantly correlated with Grade 4 reading</td>
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<td>n = 8 with dyslexia</td>
<td>In subsequent analyses, dyslexia defined as standard score of 85 or less subgroup on word reading measure</td>
<td>Of the 8 poor readers identified, 2 had a deficit in phonological processing only, no children had a naming speed only deficit, and 2 had a double deficit; 4 of the children did not meet the criteria for any of the three reader types</td>
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(table continues)
typically achieving group consisted of 120 children ages 8, 9, 10, and 11, who scored between the 25th and 75th percentiles in academic achievement. The dyslexia group had a median reading quotient of 69 (range 60–79), the other LD group had a median reading quotient of 97 (range 90–110), and the reading quotient of the typically achieving group was not provided. All participants were shown 26 test items consisting of simple drawings of objects occurring with varying frequency. The participants were told to name the object on the page as quickly as possible, and the time taken to name each object was recorded. The results indicated that the LD groups (with and without dyslexia) required more time than typically achieving students to produce object names for the most familiar objects, but only the dyslexia group required significantly more time than the typically achieving group to provide names for less familiar objects. The dyslexia group was significantly slower than the other LD group on high-frequency objects. Moreover, the dyslexia group made significantly more naming errors than the other LD and typically achieving groups, and the other LD group did not differ significantly from the typically achieving group on naming errors. Denckla and Rudel concluded that the dyslexia group was subtly dysphasic and was characterized by linguistic retrieval problems. These findings suggested that naming speed deficits are characteristic of LD populations in general, although dyslexia may involve specific impairment.

In another cross-sectional examination of rapid naming, Denckla and Rudel (1976b) investigated naming speed of colors, objects, letters, and numbers in students with dyslexia (n = 72), students with other LD but no dyslexia (n = 56), and typically achieving students (n = 120). The LD sample consisted of 128 children selected from two schools for special education or from a clinical population. To be considered for the LD group, at least one WISC measure (Verbal or Performance IQ) had to be 90 or above. Division of the LD group into participants with (n = 72) and without (n = 56) dyslexia occurred post hoc, using a discrepancy formula. Dyslexia was identified if there was a 2-year lag between reading age and mental age. The reading scores were not presented, so it is not possible to examine the reading levels of the LD groups. All participants completed the RAN tasks (colors, numbers, objects, and letters). As part of their analyses, Denckla and Rudel divided the dyslexia and other LD samples into those without naming speed deficits, those who were slow on one RAN task, and those who were slow on two or more RAN tasks. These analyses were based only on those children 9 years of age and older (Denckla & Rudel, 1976b).
The authors found that of 36 children with dyslexia, 2 were not slow on any RAN task, 4 were slow on at least one RAN task, and 30 were slow on two or more RAN tasks. In the other LD group (n = 31), 7 had no deficit, 8 were slow on one RAN task, and 16 were slow on two or more RAN tasks. These results suggested that naming speed deficits may be characteristic of a broader group of children with LD, in addition to being characteristic of children with dyslexia. However, as reading levels were not presented, it is not possible to determine the reading abilities of the children in the sample with respect to criteria for dyslexia. Denckla and Rudel noted that the diagnostic specificity of RAN was yet unknown.

Since these early studies, research has continued to show that naming speed difficulties, as measured by RAN, appear in some readers with dyslexia. Much of the research in this area is not specific to individuals with dyslexia, and as such, it is difficult to determine the extent to which naming speed deficits characterize dyslexia. For example, Fawcett and Nicolson (1994) investigated three age groups of children (mean ages = 8, 13, and 17 years) with and without dyslexia; using a cross-sectional design, they studied whether naming speed deficits characterized children with dyslexia. The participants in the study were classified according to a discrepancy formula, without the necessary condition of low reading ability, and thus the dyslexia sample was not restricted to poor readers. Specifically, the 17-year-old dyslexia group had reading age scores ranging from 8.2 to 14.6 (the maximum level was 15.0); the 13-year-old dyslexia group had reading age scores ranging from 7.9 to 12.3; and the 8-year-old dyslexia group had scores ranging from 5.5 to 7.9. Although Fawcett and Nicolson found that their dyslexia samples were characterized by naming speed deficits, this interpretation must be made with caution, given the reading abilities of the children included in the study.

Morris et al. (1998) used a cross-sectional design to conduct a cluster analysis study to identify different dyslexia subtypes. There were 232 participants in the study; 58 were identified as having dyslexia, 106 had both dyslexia and math disability, 17 were identified as a below-average-ability group (IQ scores below 80), and 51 children without disability were identified. Dyslexia (in the presence or absence of a math disability) was defined using either low-achievement or achievement-ability discrepancy definitions. The dyslexia sample had a mean reading standard score of 84.08 (SD = 7.05) and the dyslexia and math disability sample had a mean reading standard score of 81.19 (SD = 9.18). All participants completed a battery of tasks that included measures of phonological awareness, verbal short-term memory (VSTM), rapid naming, lexical vocabulary, visuospatial ability, speed of articulation, and visual attention. The cluster analysis identified seven subtypes of dyslexia: (a) phonology–VSTM–rate deficit; (b) phonology–VSTM–spatial deficit; (c) phonology–VSTM–lexical deficit; (d) phonology–rate deficit; (e) rate deficit; (f) global language deficit; and (g) global deficit. This research is often used to support the position that naming speed is characteristic of dyslexia, as a rate deficit was implicated in three of the five specific dyslexia subtypes. However, a careful examination of the dyslexia profiles reveals that the actual performance on naming speed in these subtypes is not necessarily depressed relative to the overall sample. The global deficit and the phonology–VSTM–rate deficit subtypes clearly revealed deficient naming speed skills (z scores below −0.5). In the other subtypes, the level of impairment was not sufficient to be classified as a deficit relative to the overall sample (z scores greater than −0.5). In fact, in the rate deficit subtype, the mean naming speed score is at a z score of approximately 0. Morris et al. reported that the rate deficit subtype (along with the phonology–VSTM–spatial subtype) was more likely to include children who did not have a disability. Furthermore, naming speed deficits, when present, occurred only in readers with the strongest impairments, which were also characterized by phonological and VSTM deficits.

In a direct test of the double-deficit hypothesis, Badian (1997) employed a cross-sectional sample of 90 children ages 6 to 10 to examine the deficits associated with reading impairment in a group of garden-variety poor readers and children with dyslexia. Dyslexia was defined using a discrepancy formula (mean word reading standard score = 75.3, SD = 6.3), and garden-variety reading impairment was defined as verbal IQ (VIQ) scores below 85 and word reading scores below a standard score of 85 (M = 82.0, SD = 2.4). The dyslexia sample was found to have the most impairment on word reading ability. In the dyslexia sample (n = 28), 14 children were characterized by triple deficits (phonological, naming, and orthographic), 5 by a double deficit in phonological processing and naming speed, and 5 by a double deficit in naming speed and orthographic skill. There were no children with dyslexia who had a singular naming speed deficit. In the garden-variety sample (n = 22), 5 children were identified with a double deficit in phonological processing and naming speed, 4 children were identified with a singular naming speed deficit, and no deficit could be identified in 6 children. These results suggest that naming speed deficits characterized the majority of readers with dyslexia. However, naming speed deficits were unlikely to occur in isolation, particularly in readers with the most severe impairments, which is consistent with the findings of Morris et al. (1998). This finding calls into question the hypothesis that rapid naming is a core source of dysfunction in dyslexia, independent of phonological processing. It is important to note that the sample in this study was not disaggregated by age group; thus, within the group, there were children who ranged in age from 6 to 10 years. Because of the drastic developmental differences in reading ability inherent in children between 6 and 10 years of...
age, it is difficult to determine to what extent we can interpret the findings according to the double-deficit hypothesis and to what extent the findings represent the reader differences inherent in the sample.

Pennington, Cardoso-Martins, Green, and Lefly (2001) conducted a cross-sectional investigation to test the predictions of the phonological and double-deficit hypotheses. Their sample included children ($n = 35$; age range = 7.0–11.9) and adolescents ($n = 36$; age range = 12.0–18.0) with dyslexia, as well as both chronological-age (children, $n = 21$, mean age = 9.86, $SD = 1.15$; adolescents, $n = 20$, mean age = 14.65, $SD = 1.73$) and reading-age (children, $n = 25$, mean age = 9.04, $SD = 1.27$; adolescents, $n = 31$, mean age = 11.32, $SD = 2.66$) controls. Dyslexia classification criteria included a history of reading and spelling problems and a significant discrepancy between reading or spelling and other cognitive abilities. A significant discrepancy was defined as a reading quotient score less than 0.80. Although standardized measures of reading were collected, descriptive characteristics were presented as the proportion of questions answered correctly rather than mean standard scores, so it is difficult to interpret the reading ability of the dyslexia samples. The authors noted that 78% of the dyslexia samples met both achievement and discrepancy definitions. As a test of the double-deficit hypothesis, the authors identified nine individuals in the dyslexia sample who clearly did not have deficits in phoneme awareness. Of these nine individuals with dyslexia without deficits in phoneme awareness, three had difficulty on other measures of phonological processing, four did not present with naming or phonological deficits, and only two had naming speed deficits. Naming speed deficits in this study were not present in the majority of the dyslexia samples, but, when present, they were restricted to readers with the most severe impairments, who also displayed deficits in phonological processing. Pennington et al. concluded that there was clear evidence that the dyslexia samples had a core deficit in phonological awareness; however, deficits in other processes, such as naming speed or visual short-term memory, had no consistent relationship to dyslexia and, when present, occurred only in readers with the most severe impairments. This is consistent with previous research (e.g., Morris et al., 1998; Badian, 1997).

To summarize, research has indicated that there are naming speed deficits in some individuals with dyslexia. On closer examination, however, the question of whether naming speed deficits characterize dyslexia is largely unresolved. The original findings of Denckla (1972) and Denckla and Rudel (1976a, 1976b) suggested that naming speed deficits occurred only in a small portion of dyslexia samples, but also that they were not necessarily restricted to dyslexia samples. Furthermore, based on the results of current research (e.g., Badian, 1997; Morris et al., 1998; Pennington et al., 2001), it is likely that those children with dyslexia in early research studies who were characterized by naming speed deficits were also characterized by phonological processing deficits and perhaps other deficits, such as in orthographic skill. However, it is also of note that many of the individuals identified as having dyslexia in these studies did not exhibit low reading ability. At this time, the research from direct and indirect studies of the double-deficit hypothesis has demonstrated that naming speed difficulties characterize some readers with dyslexia—and likely those readers with the most severe dyslexia, who also have phonological processing deficits. However, there appear to be few or no individuals with dyslexia who have a naming speed deficit but intact phonological skills. Those studies that have examined the nature of naming speed difficulties and are used to support the existence of naming speed deficits have employed cross-sectional designs; it is critical to have evidence from longitudinal research that demonstrates the persistence of naming speed difficulty over time.

**Naming Speed’s Contribution of Independent Variance to Reading Ability**

Research examining the contribution of independent variance by naming speed to reading ability has led to inconclusive results. There is evidence to support the unique contribution of RAN to overall reading ability. For example, in a longitudinal study with 85 first-grade children of varying reading ability, Manis, Seidenberg, and Doi (1999) found that Grade 1 measures of RAN and phoneme awareness both contributed independently to Grade 2 measures of reading when vocabulary was controlled. Bowers and Swanson (1991) found that naming speed contributed independent variance to second-grade reading skills in a cross-sectional sample of 43 second-grade children. However, unlike many other studies, the Bowers and Swanson study defined reading skill as latency rather than accuracy based. Naming speed in this study had a significant relationship with the speed of identifying single words. Using a sample of 34 kindergarten children and 34 Grade 1 children, Blachman (1984) found that kindergarten rapid naming tasks were related to kindergarten measures of reading and reading readiness. Measures of rapid naming administered to the Grade 1 children were related to their performance on Grade 1 measures of reading achievement. In a cross-sectional study with 221 first-grade students in general education classrooms, Neuhaus and Swank (2002) found rapid letter naming to be a significant predictor of word reading.

Hammill, Mather, Allen, and Roberts (2002) conducted a study using a cross-sectional design with 200 children in Grades 1 through 6 to gain insight into (a) how well phonology, rapid naming, semantics, and grammatical composites correlated with word reading ability; (b) how the nature of these abilities affected word identifica-
tion; and (c) how much unique variance these abilities contributed to word identification in below-average and above-average readers. Below- and above-average groups were identified by taking the 100 children who had the lowest and highest word reading scores, respectively. As such, there was no absolute criterion for classification; rather, the cutoff was relative to the sample within the study. The below-average group had mean standard scores ranging from 58 to 103 on measures of reading and, thus, contained children who were reading at average levels. The results of Hammill et al. demonstrated that (a) phonology and semantics composites had the highest correlations with word identification; (a) the rapid processing factor, which included rapid naming, was related somewhat to word identification; (c) rapid naming contributed significant variance to the entire sample and to the below-average sample. However, the phonology composite accounted for the most variance in word identification in the entire sample and in the below-average sample and was the second best predictor (after semantics) for the above-average group. The authors noted that the contribution of rapid naming was modest compared to that of the phonology composite. As the below-average group was not restricted to below-average readers, this limits these findings as they relate to dyslexia.

In their direct study of the double-deficit hypothesis, Pennington et al. (2001) conducted regression analyses to determine the contribution of phonological awareness and naming speed to measures of reading, comprehension, spelling, word attack, and oral reading rate. The authors found that in their sample of children (age range = 7.0–11.9) and adolescents (age range = 12.0–18.0), both phonological awareness and naming speed contributed independent variance to all measures, except that naming speed did not contribute unique variance to spelling. When word reading ability, verbal IQ, and age were entered into the equation, phoneme awareness contributed unique variance to word attack, spelling, and comprehension, and naming speed contributed unique variance only to oral reading rate. The authors found some support for both hypotheses of dyslexia, as both phonological awareness and naming speed contributed unique variance to measures of reading. However, Pennington et al. noted that the contribution of naming speed was “rather modest” (2001, p. 749) compared to the contribution of phoneme awareness and concluded that the phonological hypothesis offered a more parsimonious account of the evidence.

Despite the independent contribution of RAN in the aforementioned studies, it is not possible to make any direct inferences about the role of naming speed in dyslexia, because the samples were not disaggregated by reader type, or, in the case of Hammill et al. (2002), the below-average classification was unsuitable for generalizability or replication. In a study with 81 kindergarten children identified as at risk, Felton and Brown (1990) identified rapid naming as contributing unique variance to their Grade 1 word reading ability. McBride-Chang and Manis (1996) used a cross-sectional design to investigate the role of naming speed in 125 second-semester third-grade and first-semester fourth-grade children. The authors found that for poor readers, as defined by performance below the 25th percentile on Word Attack, both naming speed and phonological awareness were significantly associated with word reading, whereas for good readers, only phonological awareness was significantly associated with reading. Pennington et al. (2001) performed their regression analyses on dyslexia and control samples and found that the contribution of phoneme awareness was not different across reader subtypes, although the contribution of naming speed to oral reading rate was greater for the dyslexia sample.

In a direct test of the double-deficit hypothesis, Wolf et al. (2002) investigated the contribution of phonological processing and naming speed to measures of word reading, decoding, and comprehension in a cross-sectional sample of 144 second- and third-grade children with dyslexia. Dyslexia was defined through either low-achievement criteria (IQ > 70 and reading standard score < 85) or an achievement–ability discrepancy (reading performance approximately 13 points lower than ability). Thirty children fit the low-achievement criteria, 15 children met the discrepancy formula, and 99 children met the criteria for both. Although descriptive statistics were not presented by dyslexia type (low achievement vs. discrepant), the overall group description indicated that the range of standard scores was 49–98 in word reading, 40–94 in decoding, and 26–96 in comprehension; this suggests that the dyslexia sample was not necessarily restricted to poor readers. The results of this study demonstrated that phonological processing and naming speed each contributed independent variance to word reading, decoding, and comprehension; however, phonological processing contributed greater variance to word attack, and naming speed contributed greater variance to word reading. This is in contrast to other studies that have found a greater contribution of phonological processing to word reading (e.g., Hammill et al., 2002; Pennington et al., 2001). Future research is necessary to clarify the contribution of naming speed to reading ability. A further point of interest would be to investigate the role of naming speed in those children who meet criteria for dyslexia through a discrepancy formula, achievement-only formula, or both.

Based on the results of the longitudinal and cross-sectional research in this area, it is difficult to draw any definitive conclusions. Naming speed has been implicated in both typical readers and children with dyslexia, al-
though this finding is inconsistent across studies. Wolf et al. (2002) stated that the fact that some studies do not find a relationship between naming speed and reading might be due to a greater number of nondiscrepant readers in the dyslexia sample; Wolf et al. hypothesized that the greater the number of nondiscrepant participants with dyslexia in the sample, the less predictive naming speed will be—thus suggesting that an ability–achievement discrepancy is a necessary requisite for the viability of the double-deficit hypothesis. However, a large body of research has called into question the validity and utility of IQ scores in the definition and analysis of dyslexia (e.g., Fletcher, 1992; Siegel, 1989, 1992, 1999; Stanovich & Siegel, 1998; Vellutino et al., 1996; Vellutino, Scanlon, & Lyon, 2000), and current conceptualizations of dyslexia do not include the requirement of an ability–achievement discrepancy (e.g., Lyon et al., 2001). Thus, to lend empirical support to the hypothesis, it is first necessary to demonstrate that discrepant readers do in fact have dyslexia.

The inconsistencies of naming speed’s contribution of independent variance to reading ability found in the current review are supported by the findings of a recent review on the relation between phonemic awareness and rapid naming to reading (Allor, 2002). With respect to the evidence for the unique contribution of rapid naming to reading, independent of phonological processing, Allor concluded that the findings were mixed. The findings for the contribution of naming speed were inconsistent, although there was some evidence of naming speed’s unique contribution to word reading, timed word reading, word attack, and comprehension (Allor, 2002). With respect to the double-deficit hypothesis of dyslexia, more research is needed to determine the specific role of naming speed in dyslexia, the prevalence, and the impact of the naming speed deficit on the reading ability of children with dyslexia.

**Should Naming Speed Be Characterized Independently From Phonological Awareness?**

In proposing their double-deficit hypothesis of dyslexia, Wolf and Bowers (1999) argued for the independence of naming speed from the phonological family, based on findings such as those discussed earlier that naming speed contributes unique variance to reading skills independent of phonological awareness. This is consistent with the results from recent cross-sectional studies (Hammill et al., 2002; Wolf et al., 2002), which concluded that the correlation between phonological processing and rapid naming, though significant, was modest (e.g., \( r = .28 \) in Hammill et al., \( r = .28 \) in Wolf et al.), thus suggesting they were independent processes. Wolf and Bowers (1999) stressed that although rapid naming tasks involve many underlying processes, including a phonological *component*, RAN is not a phonological *variable*.

In contrast, other studies have suggested that the relationship between phonological processing and rapid naming should be categorized as a phonological process. For example, in a longitudinal study with 945 children in kindergarten through Grade 2, Schatschneider, Carlson, Francis, Foorman, and Fletcher (2002) found that at the end of Grade 1, naming speed and phonological awareness each uniquely accounted for 13% of the variance in word recognition skills, and their shared variance accounted for 24%. A similar pattern was observed for passage comprehension. In word reading efficiency, naming speed accounted for 22% of the variance, phonological awareness accounted for 11%, and their shared variance accounted for 24% of the total variance. At the end of Grade 2, naming speed accounted for 5% of the total variance in word recognition, phonological awareness accounted for 19%, and their shared variance contributed an additional 10%.

For word reading efficiency, naming speed accounted for 19% of the total variance, phonological awareness accounted for 11%, and their shared variance accounted for an additional 14%. For passage comprehension, phonological awareness accounted for 19% of the variance, and naming speed accounted for 3%. Schatschneider et al. concluded that naming speed was primarily a phonological process, as naming speed and phonological processes were positively correlated and their shared variance was at least as predictive of early reading as each one independently. As Schatschneider et al. noted, the unique role of naming speed in the explanation of reading deficits is unclear.

In a study using a cross-sectional design with 30 adults with dyslexia (mean age 25.23; word reading performance below the 25th percentile) and 32 adult chronological age–matched controls (mean age 25.43), Chiappe, Stringer, Siegel, and Stanovich (2002) found that 75% of the variance accounted for by RAN was shared with measures of phonological processing. They concluded that naming speed deficits might reflect deficits in phonological processing rather than a unique source of reading dysfunction. In the study conducted by Neuhaus and Swank (2002) to investigate the contribution of rapid letter naming to reading, the authors found that RAN was phonologically based and suggested that RAN tasks may be related to phonological memory.

There is some evidence that RAN may be a measure of global processing speed. In a review of the history and significance of RAN, Denckla and Cutting (1999) discussed their preliminary empirical findings of what “goes into” RAN. These preliminary findings suggested that in typical readers, RAN could in large part be accounted for by processing speed. However, Denckla and Cutting were careful to note that RAN could not be fully explained by processing speed. RAN, as a measure of global processing speed, is con-
sistent with the Cattell-Horn-Carroll (CHC) theory of cognitive abilities, one of the most comprehensive and empirically supported frameworks available for understanding the structure of human cognitive abilities (McGrew & Woodcock, 2001). Based on a series of factor analytic studies conducted for the validation of the CHC model, rapid naming was best characterized within the domains of processing speed and long-term retrieval. Consistent with this approach, researchers currently categorize RAN as a measure of the ability to rapidly retrieve phonological codes from long-term memory (Wagner, Torgesen, Laughon, Simmons, & Rashotte, 1993).

In sum, there is evidence that naming speed contributes unique variance to reading ability independent of phonological processing. It is important to note, however, that this unique contribution does not negate the possibility that naming speed is a phonological variable. The results of research from both direct and indirect studies of the double-deficit hypothesis suggest that naming speed is significantly correlated with phonological measures. Findings from indirect studies have indicated that naming speed and phonological processing have a high proportion of shared variance. Other studies have suggested that RAN may be an indicator of global processing speed. However, the global processing speed and phonological hypotheses do not necessarily preclude one another. Specifically, although rapid naming may represent the ability to rapidly retrieve information from long-term memory, its relationship to dyslexia may reside specifically in the ability to rapidly retrieve phonological codes, which would still make it useful to classify RAN as a phonological task (Wagner et al., 1993). To demonstrate the independence of naming speed from phonological processing, future research must provide evidence of an independent contribution of naming speed to reading ability in child, adolescent, and adult samples. Also, research findings would have to demonstrate that phonological training and interventions do not have an impact on naming speed, and that phonologically based reading interventions do not have an impact on the reading ability of individuals with a naming speed deficit subtype of dyslexia.

The Nature of the Relationship Between Naming Speed and Reading Development

If rapid naming is to be considered a core deficit of dyslexia independent of phonological awareness, the persistence of the deficit must be identifiable in individuals over time. The research findings are mixed, and the majority of findings have indicated that although rapid naming has predictive power in the early reading years, it loses its predictive power for reading ability after the early years.

Wolf, Bally, and Morris (1986) found that within a group of 83 Grade 2 children followed since kindergarten, RAN lost its predictive power by Grade 2. They concluded that as RAN ability becomes more automatic, it differentiates children with dyslexia from typical readers but does not have predictive power. In this study, children with dyslexia were reported to have been identified based on a cutoff score of 1.5 grade levels below the norm on one of two measures of reading comprehension, and based on teacher recommendation. However, when examining the descriptive characteristics presented in the article, it appears that the participants with dyslexia were reading at grade level.

In a longitudinal study, Torgesen, Wagner, Rashotte, Burgess, and Hecht (1997) investigated the contributions of naming speed and phonological processing to reading development in a sample of approximately 200 children across the spectrum of reading ability. The authors found that both naming speed and phonological measures contributed significantly to reading development over time. However, when prior reading experience was controlled, the unique contribution of naming speed to word recognition was significant in Grade 2 but lost its predictive ability by Grade 4. The pattern of results was similar when the sample was divided into children with word recognition scores at the bottom 20th percentile and the bottom 10th percentile; rapid naming lost its predictive ability over time when reading ability was controlled. The results of this study demonstrated that when prior reading experience is considered, phonological processing continues to have an influence on reading development, whereas the unique contribution of naming speed is lost. This is similar to the findings of Pennington et al. (2001), who found that naming speed in a cross-sectional sample did not contribute significantly to measures of reading when reading and vocabulary were controlled. In contrast, Meyer, Wood, Hart, and Felton (1998) found that in a longitudinal study with 64 children with dyslexia and a random control sample of 154 students, third-grade naming speed had predictive power for single-word reading in fifth and eighth grade for poor readers (classified as below 10th percentile on word recognition) but not for average readers. These findings that RAN loses its predictive power over time are consistent with those of a recent longitudinal study (see Chiappe, Siegel, & Wade-Woolley, 2002; Lesaux & Siegel, 2003; Vukovic, Lesaux, & Siegel, 2003). This study was designed to examine the reading development of a cohort of children from kindergarten to Grade 4. The sample consisted of all the children who entered kindergarten in one district. The children were assessed annually on a battery of reading, phonological processing, rapid naming, working memory, and spelling tasks. At the end of Grade 2, we found that rapid naming contributed independent variance over and above the variance in word reading accounted for by letter identification and phonological processing (Lesaux & Siegel, 2003). At the end of Grade 4 ($n = 732$), we examined the relationship between kindergarten phonological processing (as measured
by syllable identification), naming speed (as measured by rapid picture naming), and Grade 4 word reading ability. Within the sample of children with a standard score of 85 or less on a word recognition measure at the end of Grade 4 \( (n = 8) \), we found that kindergarten performance on syllable identification (a phonological task) was significantly correlated with fourth-grade word reading ability, although rapid naming ability was not (Vukovic et al., 2003). However, given the small size of the dyslexia sample, these results must be interpreted with caution.

In sum, the literature is not consistent in documenting a relationship between naming speed and reading development, and the majority of studies have indicated that naming speed loses its predictive ability over time. The developmental course of dyslexia should continue to be investigated. For validation of the double-deficit hypothesis, more research is needed, using a design and rationale similar to that of Torgesen et al. (1997). Specifically, in studying whether rapid naming is a core deficit of dyslexia, it is crucial to consider the confound of slow RAN and poor reading by controlling for reading ability to understand whether RAN causes slow growth in reading or whether these initial difficulties (often correlated with RAN) are responsible for the lack of growth in reading over time.

**What Does the Extant Research Conclude About the Three Subtypes?**

Manis, Doi, and Bhadha (2000) found support for the double-deficit hypothesis; they classified a cross-sectional sample of 85 second-grade children into those with phonological deficits only, naming speed deficits only, and a double-deficit group. However, their double-deficit group had word recognition reading scores ranging from below the 25th percentile to the 48th percentile, and thus was not restricted to children with reading impairment. Similarly, Sunseth and Bowers (2002) found the existence of three reading impairment subtypes in their cross-sectional sample of 68 third-grade children. As Sunseth and Bowers noted, however, reading ability was not used as a classification criterion. Instead, irrespective of reading ability, the authors selected those children that were below average in naming speed and phonological processing to form their groups. Their double-deficit groups, therefore, had an average standard score of 100 on a standardized measure of reading ability.

In their study with children in Grades 1 through 6, Hammill et al. (2002) did not find support for the double-deficit paradigm as a means of subtyping individuals with dyslexia and cautioned against using the double-deficit hypothesis as the basis for identifying at-risk children. However, as noted, their criterion for dyslexia was questionable. In the Pennington et al. (2001) study discussed previously, when the authors examined their dyslexia samples, they identified nine individuals who clearly did not have deficits in phoneme awareness. Of these nine individuals with dyslexia without deficits in phoneme awareness, three had difficulty on other measures of phonological processing, four did not have deficits in either naming speed or phonological processing, and only two had naming speed deficits. Pennington et al. interpreted this as evidence against the double-deficit hypothesis, stating that “one of the greatest strengths of the double deficit hypothesis—relative to the phonological hypothesis—would seem to be its potential to account for the small number of dyslexics without a phonological deficit” (p. 748). If that were the case, they would have expected nine children with independent naming speed deficits.

Schatschneider et al. (2002) subdivided their sample \( (n = 945) \) into those with a phonological deficit \( (n = 33) \), a rate deficit \( (n = 56) \), or a double deficit \( (n = 30) \). Reading ability was not used as a classification criterion. The rate-deficit group had mean reading standard scores within the average range (Letter–Word Identification, \( M = 96.4, \ SD = 12.5 \); Passage Comprehension, \( M = 97.4, SD = 13.7 \)). The phonological-deficit group had slightly more depressed scores, although still within the average range (Letter–Word Identification, \( M = 93.4, \ SD = 10.6 \); Passage Comprehension, \( M = 96.1, SD = 10.1 \)). The double-deficit group had the lowest mean reading standard scores (Letter–Word Identification, \( M = 78.2, \ SD = 14.7 \); Passage Comprehension, \( M = 80.1, SD = 14.4 \)). Although these results support the hypothesis that the double-deficit group shows the most severe impairment on measures of reading, these results must be interpreted with caution, as many of the children did not have any reading problems. Furthermore, Schatschneider et al. demonstrated that the greater severity of the double-deficit group is likely a statistical artifact that results from creating groups using arbitrary cutoffs of continuous variables that are significantly correlated.

In their study, Schatschneider et al. (2002) showed (a) that rapid naming and phonological processes were correlated; (b) that the double-deficit group had lower phonological awareness skills than the group identified with only a phonological deficit; and (c) that the greater the severity of phonological deficits, the greater were the impairments in reading. Thus, the greater impairment in the double-deficit group might be due to the group’s greater impairment in phonological processing, as opposed to the combined influence of phonological processing and naming speed deficits (Schatschneider et al., 2002). Such a statistical artifact has serious implications for the double-deficit hypothesis (for a discussion, see Schatschneider et al., 2002).
deficit group to show the most impairment. Dyslexia was defined as a score at least 1.5 SD below that of age peers on a composite measure of word reading, and a score of 85 or above on either the Verbal or the Performance IQ scale of the WISC. Compton et al. were able to categorize their sample into the hypothesized subgroups, although their results were not necessarily consistent with the double-deficit hypothesis. In a series of analyses, the authors found a number of statistical problems associated with creating discrete groups based on continuous variables. They found that categorizing children into subtypes based on arbitrary cutoffs of continuous variables resulted in groups that differed in their level of phonological impairment. As Schatschneider et al. (2002) noted, such an artifact limits our ability to draw definitive conclusions. Furthermore, Compton et al. found that when the groups were matched on phonological and naming speed processes (i.e., the double-deficit group and the naming speed deficit group were matched on naming speed, and the double-deficit group and the phonological deficit group were matched on phonological skills), many of the differences in reading skill disappeared, contrary to the double-deficit hypothesis. Compton et al. did find additive effects of naming speed and phonological processes, but only in a regression model that did not categorize children into the double-deficit subtypes. They concluded that deficits in naming speed seem to affect tasks that require fluent responses, whereas deficits in phonological awareness are implicated in tasks that require phonological skills.

In a study defining dyslexia as scoring below the 20th percentile on four of five standardized reading achievement measures, including word recognition and decoding measures, Lovett, Steinbach, and Frijters (2000) subdivided 166 children with dyslexia (age range = 7–13 years) into the three hypothesized reading impairment groups. The double-deficit sample included 76 children; the phonological-deficit group (defined by a mean score on three standardized phonological measures at least 1 SD below age norm expectations) included 31 children; and the naming speed–deficit group included 33 children. The authors found support for the double-deficit hypothesis, as they were able to identify the three impairment groups. A careful examination of the double-deficit group, however, revealed that the deficits exhibited by the naming speed–deficit group were not restricted to naming speed. As a group, they were able to identify, on average, only 29 of 37 letter sounds and 10.8 of 30 letter cluster sounds (mean age = 9.7 years). Moreover, the group had a mean standard score of 73 on a measure of decoding ability, which is significantly below average. These depressed scores do not appear to be reflective of a group that has average phonological ability.

Lovett et al. (2000) also found support for the double-deficit hypothesis in that the double-deficit group showed the most severe impairment on measures of reading, spelling, and arithmetic, followed by the phonological-deficit group, and then the naming speed–deficit group. However, as mentioned previously, Schatschneider et al. (2002) noted that this could be due to classifying children based on variables that are correlated with each other. Until there is a robust body of research that demonstrates similar levels of impairment in phonological and naming speed processes across subtypes, the claim that the double deficit is the most severe type of reading impairment must be interpreted with caution.

Wolf et al. (2002) divided their sample of 144 children with dyslexia into the three hypothesized subtypes of readers: 19% of the sample was characterized by phonological deficits, 15% had naming speed deficits, 60% were double-deficit readers, and 6% could not be classified. The reading, phonological, and naming speed means for each subgroup were not presented; thus, it is difficult to evaluate the validity of the samples. Badian (1997) found that of the 28 children with dyslexia identified using a discrepancy criterion, 14 had triple deficits (phonological, naming speed, and orthographic), 5 had a double deficit in phonological processing and naming speed, and 5 had a double deficit in naming speed and orthographic skills. There were no children with dyslexia who had a singular naming speed deficit. In the nondiscrepancy sample (n = 22), 5 children had a double deficit in phonological processing and naming speed, and 4 children were identified with a singular naming speed deficit. These results contradict the hypothesis presented earlier that naming speed deficits are associated with discrepant dyslexia.

In our longitudinal study previously discussed, we examined the predictions of the double-deficit hypothesis by examining the characteristics of the dyslexia sample at the end of Grade 4 (Vukovic et al., 2003). The participants in this study included the 732 native English speakers in the entire district who had been part of the longitudinal study since their kindergarten year. The sample was divided into dyslexia and typical reader groups based on the children’s performance on the Reading subtest of the Wide Range Achievement Test—Third Edition (WRAT-3; Wilkinson, 1993). Children were classified as having dyslexia if their score on the WRAT-3 was below a standard score of 85. Children were classified as typical readers if their score on the WRAT-3 was above a standard score of 90. Of 732 children, 708 were classified as typical readers and 8 were identified as having dyslexia.

The dyslexia group was disaggregated to examine the existence of the three hypothesized reading impairment groups. Within the dyslexia sample (n = 8), we found that two of these children had a deficit in phonological processing (as measured by the Rosner Auditory Analysis Test; Rosner & Simon, 1971) without rapid naming difficulties. No children with a naming speed–only deficit could be identified. There were two children who met the criteria for the double-deficit subtype. Four chil-
It is important to examine the characteristics of the role of naming speed in reading. Deficit, although that is not their only deficit. These results are inconsistent with the double-deficit hypothesis, as we were unable to find the three subtypes of dyslexia in a sample of 732 children. These findings are similar to those of Pennington et al. (2001), who found that the double-deficit hypothesis was not able to account for those poor readers without phonological deficits.

In conclusion, there is little evidence that children with dyslexia can reliably be classified into the reading impairment groups hypothesized in the double-deficit hypothesis, although there is some evidence that readers with a double deficit have the most severe impairment, consistent with the double-deficit hypothesis. However, as noted, Schatschneider et al. (2002) postulated that the greater impairment in groups identified as having a double deficit could be due in part to a statistical artifact and concluded that this makes it difficult to determine the impact of naming speed on reading ability independent of phonological awareness. Further research using stringent classification criteria is necessary to determine the utility of the double-deficit hypothesis in dyslexia samples. Also, more research using double-deficit groups that have similar degrees of impairment on measures of naming speed and phonological processing is needed to investigate the prediction that the double-deficit group is the dyslexia subtype with the most severe impairment.

**Who Is Slow on RAN?**

Despite the limited support for the existence of the reading impairment subtypes proposed by the double-deficit hypothesis of developmental dyslexia, there is research to support the position that some children with dyslexia are characterized by a naming speed deficit, although that is not their only deficit. To gain a better understanding of the role of naming speed in reading, it is important to examine the characteristics of the children with low naming speed.

Morris et al. (1998) identified seven subtypes of dyslexia based on a cluster analysis of 232 children with either dyslexia, dyslexia and math disability, below-average ability, or no disability. The global subtypes and the phonology–VSTM–rate subtype were found to show the most impairment on all measures of achievement. The three subtypes that included a rate deficit showed clear impairment on achievement measures only in the presence of concurrent phonological deficits. The rate-deficit subtype, in contrast, showed achievement scores within the average range (mean reading, spelling, and comprehension standard scores of 99.3, 99.8 and 93.5, respectively), indicating that they did not have dyslexia. Morris et al. also found that this group (along with the phonology–VSTM–spatial group) was more likely to include children who did not have reading disabilities. This finding suggests that those children with a singular deficit in naming speed show no deficit on measures of reading achievement. Furthermore, the finding that rate deficits were associated with below-average achievement only in conjunction with low phonological skills suggests that it is the impairment of phonological skills and not of naming skills that contributes to the below-average performance. This conclusion is consistent with previous research (e.g., Pennington et al., 2001; Schatschneider et al., 2002).

To determine the characteristics of the group of children scoring low in naming speed in our longitudinal study, we examined those children characterized by a naming speed deficit independent of reading ability (Vukovic et al., 2003). Table 2 shows that on the average, children low in naming speed were not low in reading, decoding, reading comprehension, spelling, or arithmetic. If slow naming speed is a deficit, it is difficult to argue that it has a significant effect on reading ability in particular or on academic achievement in general. This finding further challenges the specific role of naming speed in reading.

**Intervention Studies**

The double-deficit hypothesis of developmental dyslexia was developed to account for those children who have adequate decoding and phonological skills but poor reading comprehension—that is, children who are not properly identified or served using phonologically based methods (Wolf & Bowers, 1999). According to the double-deficit hypothesis, children with dys-

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Mean Percentile Scores on Academic Skills of Children with Low Naming Speed</th>
</tr>
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<tbody>
<tr>
<td><strong>Academic Skill</strong></td>
<td><strong>Percentile Score</strong></td>
</tr>
<tr>
<td>WRAT-3</td>
<td></td>
</tr>
<tr>
<td>Reading</td>
<td>56.14</td>
</tr>
<tr>
<td>Spelling</td>
<td>48.77</td>
</tr>
<tr>
<td>Arithmetic</td>
<td>40.88</td>
</tr>
<tr>
<td>WJ-R</td>
<td></td>
</tr>
<tr>
<td>Word Identification</td>
<td>58.16</td>
</tr>
<tr>
<td>Word Attack</td>
<td>58.71</td>
</tr>
<tr>
<td>Stanford</td>
<td></td>
</tr>
<tr>
<td>Reading Comprehension</td>
<td>43.30</td>
</tr>
</tbody>
</table>

**Note.** WRAT-3 = Wide Range Achievement Test, 3rd ed. (Wilkinson, 1993); WJ-R = Woodcock-Johnson Tests of Achievement–Revised (Woodcock & Johnson, 1989); Stanford = Reading Comprehension subtest of the Stanford Diagnostic Reading Test (Karlsen & Gardner, 1994).
lexia who have naming speed or double deficits do not benefit from traditional phonological interventions, as naming speed deficits are hypothesized to be an independent source of reading dysfunction. To validate the double-deficit hypothesis of dyslexia, findings from intervention or training studies are thus necessary. Although few such studies exist, we will review one case study that used the RAVE-O (Retrieval, Automaticity, Vocabulary, Elaboration, Orthography; Wolf, Miller, & Donnelly, 2000) intervention program, and another study that investigated the effects of phonological and metacognitive intervention compared to a no intervention condition. Also, the instructional context of our own longitudinal study will be discussed.

The RAVE-O (Wolf, Miller, & Donnelly, 2000) reading intervention program is designed for and used with children with naming speed or double deficits to develop fluency and automaticity. The program also has a heavy emphasis on developing phonological skills and, as suggested in a theoretical description of the program (Wolf, Miller, & Donnelly, 2000), is designed to accompany a phonological program. Given the emphasis on phonological skills in the program, it may be problematic to conduct intervention studies designed to examine an independent naming speed deficit.

In a case study of one student with a profound naming speed deficit, Deeney, Wolf, and O’Rourke (2001) described the response to intervention of a child with dyslexia who had a naming speed deficit. Reading disability was defined using a discrepancy formula (preintervention reading standard score of 86 and postintervention reading standard score of 90). A deficit was defined as performance at least 1 SD below the mean. For the purposes of classification, naming speed was assessed using the Letters subtest of the RAN. Phonological skills were assessed using the Blending Words and Elision tasks of the Comprehensive Test of Phonological Processing (Wagner, Torgesen, & Rashotte, 1999). According to Deeney et al., this child had the most severe naming speed deficit the authors had ever investigated. The child’s phonological skills were reported as intact (standard score = 99 on phonological processing). Moreover, the child demonstrated a global processing speed deficit (at or below the 16th percentile on the Visual Matching test of the Woodcock-Johnson Tests of Achievement). The child was first identified at the end of Grade 1, and a 70-hr intervention program began in October of Grade 2. The intervention program combined RAVE-O with a phonological analysis and blending program. Postintervention measures were taken at the end of the intervention and again 1 year later as a follow-up. The follow-up results were not presented or analyzed. Although the authors described this child as having a naming speed deficit only, a closer examination of this case study reveals that the child had significant impairments in measures of phonological processing: At the end of Grade 1, the child could identify only 10 of 25 rhyme patterns, could not associate sounds with complex vowel combinations, could not identify any initial consonant blends, and only knew 29 of 37 letter sounds (Deeney et al., 2001). The child thus did not meet the criterion imposed by the double-deficit hypothesis that individuals with a naming speed deficit have adequate phonological and decoding skills (Wolf & Bowers, 1999).

After the 70-hr intervention (details not provided), Deeney et al. (2001) reported an increase in the child’s naming speed skills—a finding they attributed primarily to the intervention. It is important to note that marked improvement in phonological awareness was also observed. Specifically, at the end of the intervention, the child knew 37 of 37 letter sounds, could identify 14 of 30 sound combinations, could identify 15 of 15 onsets, and could identify 21 of 25 rimes. These gains in phonological processing likely reflected the phonological processing component of the intervention. Because the child did not have a deficit only in naming speed, and the intervention did not target naming speed processes specifically, it is not possible to determine which elements of the intervention were responsible for the child’s gains in naming speed. Furthermore, although gains in naming speed were observed, it is not clear whether these gains were reflected in the subsequent gain in reading or if the gains in both naming speed and reading were due to the phonologically based reading intervention or to some other unobserved influence. The 1-year follow-up results were not presented, so the long-term impact of the intervention cannot be evaluated.

In the Lovett et al. (2000) study previously discussed, the authors classified 166 children with dyslexia into the three hypothesized reading impairment groups to investigate their response to intervention. The sample with a double deficit included 76 children, the phonological-deficit group included 31 children, and the naming speed–deficit group included 33 children. As noted previously, the naming speed group seemed to be characterized by some deficits in decoding and, thus, might have been more appropriately classified in the double-deficit group.

The children were randomly assigned to either a phonological, metacognitive, or control intervention program. The phonological intervention (the same one that was used to supplement RAVE-O in Deeney et al.’s 2001 study) used direct, systematic instruction to remediate basic phonological analysis and blending deficits (Lovett et al., 2000). The “metacognitive phonics” program taught strategies to aid children in their decoding skills. These strategies were (a) identifying words by analogy; (b) seeking the part of the word that you know; (c) attempting variable vowel pronunciations; and (d) removing prefixes and suffixes in multisyllabic words (Lovett et al., 2000). In the control condition, children were taught organizational strategies, academic problem solving, study skills, and self-help skills. Literacy training
was not provided in the control condition. All participants received 35 hr of their respective intervention programs. The results revealed that children in all groups (double-deficit and both single-deficit groups) made treatment gains in phonological skills, but not in rapid naming. Also, moderate gains in standardized measures of reading were observed. Overall, the metacognitive program was associated with greater gains in real word reading, and the phonological program was associated with greater gains in the phonological processing domain. There were no differences between the three deficit groups in their response to the intervention programs.

The findings of the Lovett et al. (2000) study are inconsistent with the double-deficit hypothesis, as children in the naming speed and double-deficit groups did make gains in reading and phonological skills as a result of phonological interventions. As stated in the criteria for the evaluation of the relation between rapid naming and reading skill, one approach is to examine the findings of training studies that attempt to remediate difficulties in the target skill. Lovett et al. did not isolate rapid naming as a skill, nor did they attempt to remediate naming speed deficits. Furthermore, as noted, the classification of the naming speed-deficit group is in question. However, it is noteworthy that children with dyslexia who had naming speed deficits (with concurrent phonological deficits) made gains in phonological, word reading, and decoding skills. This study is important in demonstrating that naming speed processes targeted for intervention; it is not possible to determine to what extent a naming speed–deficit group would have benefited from phonological interventions, or what effects on reading a naming speed intervention would produce. Further research in these areas is needed.

In our longitudinal study previously discussed, we examined a model of early identification for the prevention of reading difficulties (see Chiappe, Siegel, & Wade-Woolley, 2002; Lesaux & Siegel, 2003). In this study, kindergarten children were screened with a battery that included measures of phonological processing, rapid naming, and working memory. Children were identified as at risk for reading difficulties if they performed at least 1 SD below average on the WRAT-3 Reading subtests. During kindergarten, all children received systematic phonological awareness instruction, and children identified as at risk received targeted intervention in phonological awareness. During Grade 1, reading instruction involved systematic instruc-
tion in phonics in the context of a balanced literacy program. For those with difficulty, this instruction continued in a resource room setting. In kindergarten, 120 children were identified as at risk.

The children were tested annually through fourth grade on measures of reading, including the Rosner Auditory Analysis Test (RAAT; Rosner & Simon, 1971) as a measure of phonological processing and rapid number naming as a measure of RAN. By the end of fourth grade, eight children could be classified as having dyslexia, as indicated by their performance at least 1 SD below the mean on WRAT-3 Reading (Vukovic et al., 2003). Of the eight children who were identified as having dyslexia, two had a phonological deficit, as measured by the RAAT; no children had naming speed deficits, as measured by rapid number naming; two had a double deficit; and four children had neither deficit when measured using the RAAT and rapid number naming. It is important to note that at the end of Grade 4, some of the children with dyslexia continued to be characterized by phonological difficulties, despite ongoing intervention that began in kindergarten. The fact that there were no poor readers who had a naming speed only deficit is consistent with the double-deficit hypothesis. Given that the intervention was targeted strictly at phonological awareness and that according to the double-deficit hypothesis, naming speed represents a second source of reading dysfunction independent of phonological processing, it would be expected that by the end of Grade 4 there would be a subsample of children with dyslexia who had deficits in naming speed with average levels of phonological awareness and decoding. This result was not found. Our results suggest that early identification and intervention that targets phonological processing are successful in preventing reading failure in the vast majority of children. For those children whose difficulties persisted despite the intervention, naming speed was not implicated.

In conclusion, the results from intervention studies demonstrate that it is difficult to find children with naming speed deficits without concurrent phonological deficits, and also that naming speed deficits do not seem to interfere with the ability to benefit from phonological interventions. However, it remains unclear what type of intervention (i.e., phonological, rapid naming, or a combination) individuals with naming speed deficits (with or without concurrent phonological deficits) best respond to. Intervention studies targeting naming speed processes may be limited because it is not yet clear what level an intervention should focus on with a child with a naming speed deficit. Specifically, the lack of an operational definition hinders our ability to provide effective intervention: Should the child be taught to name objects more quickly or decode more quickly, or should intervention focus on the yet undefined attentional, perceptual, conceptual, memory, phonological, semantic, and motoric processes involved in naming speed? At the present time, there are no data on this issue. Until the literature thoroughly addresses the level at which breakdown occurs for children with naming speed deficits, intervention studies may continue to yield inconclusive results for the double-deficit hypothesis. Future research is necessary to determine the underlying deficits these children exhibit, and how to identify and remediate these deficits in young children.

**Discussion**

We conducted this review to evaluate the evidence for the double-deficit hypothesis of developmental dyslexia. In doing so, we identified major issues involving the research conducted to test the hypothesis, as well as issues that influence the interpretability of the extant research. The results of this review shed light on the current evidence for the double-deficit hypothesis, identified gaps in our understanding of the hypothesis, and identified outstanding issues yet to be resolved.

Consistent with the conclusions of a prior review (McCardle et al., 2001), the findings from this review suggest that evidence in support of the double-deficit hypothesis of developmental dyslexia remains limited. One could make the argument that low naming speed is characteristic of some readers with dyslexia, who are also characterized by phonological deficits, but the evidence does not support a persistent core deficit in naming speed across individuals with dyslexia. There is some evidence that the double-deficit group has the most impairments of all readers with dyslexia, although this may be due in part to a statistical artifact. There is a lack of evidence to support the hypothesis that
deficits in naming speed skills are independently related to reading impairment. Research that has examined the independence of naming speed from phonological awareness has demonstrated inconsistent findings, with most studies supporting naming speed as a phonological variable. Finally, the hypothesis that children with a naming speed deficit would not benefit from phonological interventions is not supported.

In conducting this review, it was difficult to explicate common theoretical, methodological, and psychometric criteria and standards used in double-deficit and naming speed studies. Most problematic for drawing conclusions about the hypothesis and integrating the findings was the tremendous variability surrounding sample characteristics and the identification of reader types. Further complicating a synthesis of the literature is the persistent finding that measures of phonological processing and naming speed are significantly correlated, resulting in a statistical artifact that makes it difficult to disentangle the influence of naming speed independently of phonological processing. It is of note that much of the research cited in support of the double-deficit hypothesis of dyslexia was not actually designed with this hypothesis in mind, and there appear to be just as many theoretical as empirical studies of the double-deficit hypothesis. More empirical research is needed.

A significant gap in the double-deficit literature is the lack of properly designed intervention studies. As Wagner and Torgesen (1987) outlined, to evaluate the relations between a variable and a process, converging evidence must be found from cross-sectional, longitudinal, and intervention studies. With respect to the double-deficit hypothesis, the majority of the research has employed cross-sectional designs, and evidence from longitudinal studies remains sparse. Intervention studies designed to remediate dyslexia by targeting naming speed processes are particularly important to properly investigate the double-deficit hypothesis. Despite the robust evidence for phonologically based interventions for children with dyslexia, there remain children who do not benefit from such methods. Thus, training studies to examine the double-deficit hypothesis may contribute significantly to our understanding of dyslexia, its core deficits, and effective interventions.

Specifically, what is necessary is research on intervention programs that are designed to remediate slow retrieval processes while teaching reading. As a specific example, a study that would contribute to our understanding of the double-deficit hypothesis would match groups of children with dyslexia who have similar phonemic awareness skills but differ significantly in RAN performance. These groups would then be randomly assigned to a phonologically based reading program and a control group, and a subtype-by-treatment interaction could be examined, also referred to as an attribute-by-treatment interaction (ATI). For example, if found in the appropriate direction, this interaction would suggest that a RAN deficit does affect responsiveness to a validated treatment, and that RAN is an important variable to consider when conceptualizing dyslexia. If no ATI were present, there would be no evidence in support of the double-deficit hypothesis (see Note). Finally, it is important to continue to investigate the underlying deficits of dyslexia. At this time, the variation in reading ability and definitions of dyslexia employed in the double-deficit literature and the yet undefined relationship of RAN to a particular aspect of the reading process have resulted in a lack of clarity about slow naming and its specific role in reading ability.

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