Developmental Dyslexia: Related to Specific or General Deficits?

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The present study was designed to examine the question of whether developmental dyslexia in 12-year-old students at the beginning of secondary education in the Netherlands is confined to problems in the domain of reading and spelling or also is related to difficulties in other areas. In particular, hypotheses derived from theories on phonological processing, rapid automatized naming, working memory, and automatization of skills were tested. To overcome the definition and selection problems of many previous studies, we included in our study all students in the first year of secondary special education in a Dutch school district. Participants were classified as either dyslexic, garden-variety, or hyperlexic poor readers, according to the degree of discrepancy between their word recognition and listening comprehension scores. In addition, groups of normal readers were formed, matching the poor readers in either reading age or chronological age. A large test battery was administered to each student, including phonological, naming, working memory, speed of processing, and motor tests. The findings

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indicate that dyslexia is associated with deficits in (1) phonological recoding, word recognition (both in their native Dutch and in English as a second language), and spelling skills; and (2) naming speed for letters and digits. Dyslexia was not associated with deficits in other areas. The results suggest that developmental dyslexia, at the age of 12, might be (or might have become) a difficulty rather isolated from deficiencies in other cognitive and motor skills.

INTRODUCTION

The finding that children with developmental dyslexia perform poorly when reading nonwords has been replicated in many laboratories all over the world, and has been interpreted as a "phonological recoding deficit" (Rack, Snowling, and Olson 1992). When processing time is limited by flashing the nonwords, the dyslexics are at even more of a disadvantage. This suggests that dyslexics may suffer from an "automatic decoding deficit" (Yap and Van der Leij 1993, 1994), which limits their ability to develop fluent and relatively effortless reading skills. However, it is still unclear whether such a deficiency is a symptom of a more general deficit. Although there is a general consensus that reading deficits include impairments in processing phonological aspects of language (Snowling 1987; Stanovich 1988; Stanovich and Siegel 1994), there is disagreement as to whether children with dyslexia suffer from more than phonological problems (e.g., Miles 1983). Recently, Bowers and Wolf (1993) have proposed a double deficit hypothesis, according to which the most severely affected dyslexic children have trouble with rapid automatized naming in addition to, but not separate from, their so-called phonological processing deficit (Wolf, Bowers, and Biddle in press). Alternatively, De Jong (1998) proposes that both phonological and naming speed deficits may be related to a lack of working memory capacity for the concurrent processing and storage of verbal information. Taking a more radical point of view, other authors have argued that children with dyslexia, in addition to many language- and memory-related problems, also may have a more general difficulty automatizing any skill whether phonological, visual, or motor (Nicolson and Fawcett 1990; Fawcett, Nicolson, and Dean 1996).

In this article, we review studies which illustrate the different points of view in the debate, draw attention to possible methodological flaws in relevant studies, and suggest an improved methodology for a study which is aimed at the examination of whether the problems in children with developmental dyslexia are indeed confined to reading and the phonological aspects of language, or whether they extend to deficits outside of these areas. The results of such a study will be presented and discussed.

THE PHONOLOGICAL PROCESSING DEFICIT

Stanovich and Siegel (1994) found the following evidence for the position that dyslexia is to be viewed as a specific deficit: (1) differences between dyslexics and both chronological and reading age-matched controls pertain to phonological skills, and (2) differences between dyslexics and other nondiscrepant poor readers (the so-called garden-variety poor readers) concern general language and memory skills, but not reading and phonological skills. It is for these reasons that their hypothesis is called the Phonological-Core Variable-Difference Model. In their metalinguistic study (Stanovich and Siegel 1994), data from several different studies were aggregated, resulting in a total of 401 good readers, 341 dyslexic readers (poor reading with normal IQ), and 167 poor readers with low IQ (garden-variety poor readers). Because the latter two groups showed similar phonological processing deficits, Stanovich and Siegel (1994) claimed that reading problems are independent from general intelligence.

RAPID NAMING

Denckla and Rudel (1976) and Spring and Capps (1974) were the first to demonstrate that severely disabled readers were slower to name arrays of common stimuli such as letters, digits, objects, and colors than were normal readers. Because this was originally regarded as a name retrieval problem (Ellis 1981) and because it was not clear whether naming problems do co-occur with, cause, or result from reading problems, naming difficulties were seen as part of the phonological processing deficit. However, given recent evidence to show that naming speed correlates only moderately with phonological skills (Wolf et al. in press; De Jong and Van der Leij in press), it has been suggested that deficits in rapid automatized naming constitute a second independent characteristic of reading-impaired children. Nevertheless, phonological and naming skills could share a common base. For the current research, it is important to note Wolf et al.'s (in press) hypothesis that, in the most severe cases of developmental dyslexia, phonological processing deficits go together with naming deficits.

WORKING MEMORY

The role of verbal memory in reading problems has been explored by many authors (for reviews see Elbro 1996 and Brady 1997). Recently, De Jong (1998) has suggested that reading disabled children suffer from a lack of working memory capacity for the concurrent processing and storage of verbal information. According to De Jong, however, the deficit is not restricted to the language domain, but is also manifest in certain numerical tasks.

With respect to phonological decoding, naming speed, and working memory, Ellis and Large (1987, 1988) have confirmed in a longitudinal study that normally intelligent children with a specific reading deficit differ from their better-reading peers on relatively few tasks (phonological segmentation, verbal memory, and rapid automatized naming), whereas children with generalized reading disability (poor reading with low IQ) differ in nearly all respects from their better-reading peers.

In sum, at least three hypotheses of a rather specific and reading-related nature have been supported with empirical evidence: a phonological processing deficit, a double deficit including difficulties with phonological processing and rapid naming, and a deficit in working memory capacity. In each case it has been argued that these deficits do not relate to general cognitive skills.

A PATTERN OF DIFFICULTIES?

Miles (1983, 1998) views dyslexia as a pattern of difficulties, a view based primarily on clinical observations that culminated in the development of a widely used dyslexia screening test, the Bangor Dyslexia Test (Miles 1982). The test items on the Bangor Dyslexia Test concern domains that are not exclusively phonological. For example, they assess left-right confusions over body parts, subtraction tables, knowledge of the sequence of the months both forward and backward, and digit span. The items also include familial incidence of reading and spelling problems, the occurrence of b-d confusions in materials written by the participant, and a memory task that is clearly phonological. That task involves repeating polysyllabic words such as "statistical," and can be considered a nonword repetition task since most of the stimulus words are unrecognizable to low-level readers. Although some empirical support has been found for the utility of these test items in distinguishing between children with dyslexia and children without dyslexia (Miles 1983; Miles and Haslum 1986), a theoretical framework which explains why these test items are indicators of dyslexia has not been developed yet.

DYSLEXIC AUTOMATIZATION DEFICIT (DAD) AND CONSCIOUS COMPENSATION (CC)

In an attempt to provide a theoretical framework for a more general deficit, Nicolson and Fawcett (1990) have proposed that children with dyslexia fail to automatize any skill fully. Their Dyslexic Automatization Deficit (DAD) hypothesis predicts that dyslexics will be unable to acquire fluency in either reading skills or in various skills outside reading and spelling, including phonological, speed, memory, and motor skills. Nicolson and Fawcett claim that "... there is no support ... for any of the theories that attempt to tie dyslexia to one specific modality or type of process" (1994, p. 228). In most of their empirical studies (e.g., Nicholson and Fawcett 1999; Nicolson, Fawcett, and Dean 1996), Nicolson and his colleagues have compared dyslexic readers with normal readers on a series of motor balance tasks. The dyslexic children's performance was at the level of chronological age-matched controls in a simple baseline condition, but tended to deteriorate with increasing complexity of task conditions. For example, differences in speed appeared in a selective choice RT task ("push the button when the tone is low; don't push when it is high"), but not in a simple reaction time (RT) task ("push the button when a tone is heard"). Furthermore, performance on a balance task—a skill which should be fully automatized by the age of 11 years—deteriorated when it was combined with an attention-consuming task such as counting backward from 100 by 3s. To explain the difference in performance in the simple versus complex conditions, Nicolson and Fawcett (1990) supplemented their DAD hypothesis with the Conscious Compensation (CC) hypothesis, stating that dyslexics can mask their automatization deficit in many instances—when not constrained by time or required to divide their attention to perform complex tasks—by committing a considerable part of their attentional resources to the task under study.

Fawcett, Nicolson, and Dean (1996) have further speculated that the phonological problems in dyslexia may have a similar cause as deficits traditionally assumed to reflect cerebellar impairment such as balance and time estimation. They suggest that mild cerebellar impairment may limit articulatory control leading to difficulty in building up phonological representations, and also cause problems with most complex motor tasks.

Challenging as the DAD/CC hypotheses may be, attempts to replicate the findings of Nicolson and Fawcett (1990, 1994) have not been entirely successful. For example,Yap and Van der Leij (1994) reported partial support for the automatization deficit, finding deficits in only one of two dual task conditions presented. However, Wimmer, Mayringer, and Landerl (1998), and Stringer and Stanovich (1998) were unable to find any supporting evidence. Therefore, although a general automatization deficit hypothesis is attractive to many clinical workers who are faced with dyslexic persons who present problems outside the domain of reading and spelling, the validity of the DAD/CC hypothesis is still to be assessed.

ON THE METHODOLOGY IN DYSLEXIA RESEARCH

As the studies reviewed are inconclusive concerning the generality of deficits associated with developmental dyslexia, we turn to two methodological concerns with dyslexia research. The first issue deals with the definition of dyslexia, and the second with comorbidity.

A definition of dyslexia must be precise but say nothing about the causes of the disorder because they are yet to be established (Tønnessen 1997). In this respect, the work of Aaron (1991), Siegel (1988, 1989, 1992), and Stanovich (1991) is especially important because it shows that, for example, IQ and reading disability are independent factors which must be separately defined. Thus, it seems worthwhile to start with a rather limited operational definition of dyslexia that refers only to the most obvious and highly quantifiable symptoms (Tønnessen 1997).

Difficulty with the recognition of single words (Lyon 1995), resistant to proper treatment, in combination with normal listening comprehension (Aaron 1991), seem to be good candidates for the components of an ideal operational definition. It is generally agreed that difficulty with word recognition is the main component. Also, in order to be certain that the reading problems are truly resistant to treatment, deficits resulting from poor educational opportunities must be excluded. Finally, studies on the relation of reading and IQ suggest that the IQ criterion should be replaced by listening comprehension, or, to put it in a broader sense, verbal competence. To support this decision, it may be argued that verbal competence is a product of learning actively stimulated by one's environment and is, therefore, more comparable to reading than spatial ability or other aspects of general intelligence. Moreover, verbal competence and reading are both skills in the verbal domain, which makes the discrepancies between them an intriguing issue to be examined. Why is learning the written form of the language so difficult for some students who are able to learn the spoken language? To study this question, the comparison to students who do not show such a discrepancy (chronological and reading age-matched controls) is relevant. We should also include students with the opposite reading profile, hyperlexia, characterized by strong word recognition skill with much weaker listening comprehension. Whatever deficiencies are related to dyslexia should not be detectable in students with hyperlexia. Furthermore, to be able to test the hypothesis that dyslexia (or specific reading disability) is not related to general intelligence (and thus, presumably, unrelated to listening comprehension), it is worthwhile to include a group of garden-variety poor readers who perform poorly at both word recognition and listening comprehension.

Obviously, the operational definition suggested here is quite different from the approach proposed by Miles (1994) who seeks to reconcile within one taxonomy: anatomical findings (that is, structural anomalies in the brain of dyslexic people); impairments in the visual system of persons with dyslexia; genetic aspects of dyslexia; problems in auditory processing; impaired phonological processing; clinically supported pattern of difficulties mentioned earlier. That pattern also gets support from the "that's our Johnnie" effect, by which parents tend not to restrict their reports of difficulties or typical behaviors to only those relevant to reading and spelling. In contrast to the proposed limited operational definition of dyslexia, the co-occurrence of all these phenomena has not yet been established.

In order to establish reliably whether problems in reading and spelling are linked to problems in other domains, we must define the unique characteristics of persons with developmental dyslexia. This is, in essence, a question of comorbidity that can only be answered in a large, randomly selected sample (e.g., Caron and Rutter 1991). Unfortunately, many studies seem to suffer from small sample size because costs are high or from selection bias, perhaps because clinic samples are more easily accessible to researchers. For example, it has been suggested by Wimmer, Mayringer, and Landerl (1998) that the effects found by Nicolson and Fawcett (1990) may be attributed to preselection which has resulted in a high incidence of both dyslexia and attentional disorders among participants. In order to prevent selection bias, we decided to test all students meeting our operational criteria for dyslexia from an entire school district, and to compare them to other relevant groups from that same district.

HYPOTHESES

We reasoned that if developmental dyslexia is related to deficits in phonological processing, naming, working memory, and/or automatization of skills, students with dyslexia would score lower on tasks that require these skills than normal students of the same chronological age (CA controls), and at or below the level of younger students matched for reading age (RA controls).

In addition, by comparing dyslexics to hyperlexics and to garden-variety poor readers, two more hypotheses can be tested. First, if any of the aforementioned deficits is related to poor word recognition only, and not to listening comprehension, it should not affect hyperlexics but should affect both dyslexic and garden-variety poor readers. Second, if the hypothesis of a variable difference outside the domain of reading is correct, dyslexics should outperform both garden-variety poor readers and hyperlexics on tasks that tap general learning abilities.

METHOD

GENERAL DESIGN

In the Dutch school system, children enter secondary schools at age twelve. Classes are tracked according to ability and career goals. Most students receive either low or middle vocational training, or are prepared for tertiary education at various levels. In addition to these main tracks, special schools exist for students with learning disabilities. At secondary level, children whose IQs are within the normal range are routed to schools designed to cope specifically with learning disabilities. Still another type of school exists for children with mild retardation.

We chose to conduct our study at the secondary level in a school district that is representative of an average district in the Netherlands. In particular, only a few nonnative speakers took part. This number would have been much larger had we worked in a large city. In order to keep costs as low as possible, the present study is not longitudinal, but instead focuses on 12-year olds because at that age, reading problems have stabilized (Smart, Sanson, and Prior 1996) and there is little likelihood of misdiagnosis (either false positives or negatives). All 12-year olds who attended the same secondary school for primary learning-disabled children took part in the study so as to represent wide variations on any measure. In fact, we expected our sample to include many dyslexics, nondyslexics, and garden-variety poor readers, all with comparable school careers in special education. We predicted that the dyslexic participants would all have received some form of treatment, but would still need a special school to help compensate for their dyslexia. Our study also included all 12-year olds who attended a secondary school in the same district for children with mild retardation in an effort to find even more garden-variety poor readers and possibly hyperlexics (children who proficiently decode and recognize words, but have trouble understanding what they read). Two CA control groups containing whole classes of 12-year olds were formed: one from a school for low vocational training, and one from a school for middle vocational training. An RA control group was formed by selecting ten fourth graders who read at the same level as the poorest readers in special education, but were two years younger. In addition to normal readers, we expected that classes of 12-year olds from low and middle vocational training would also include a few dyslexics, hyperlexics, and nondiscrepant poor readers.

In addition to the tasks that were used to classify participants (word recognition and listening comprehension), we used a wide range of tasks to test our hypotheses. Reading-related tasks included nonword reading, spelling, and word recognition in English as a second language. Phonological processing tasks involved sound blending, sound analysis, and nonword repetition. Language-related timed tasks included rapid naming and articulation speed. In addition, we presented tasks assessing working memory, speed of processing, and motor skill in both baseline and dual-task conditions. Verbal and nonverbal intelligence tests served as covariates.

The present study was set up to examine as many representative 12-year-old children as possible on a wide range of tests. The purpose of this format was to help us discover characteristics unique to dyslexic students, in comparison to chronological and reading age controls, and to garden-variety and hyperlexic readers.

PARTICIPANTS

All children studied were from the Breda school district in the southern Netherlands. All 73 students from the first classes of a school for learning disabled children were included, along with all 15 children in the first class of a school for children with mild retardation (see Van der Leij 1987 for a detailed description of the special school system in the Netherlands). To avoid selection bias in the CA control group, we included two entire classes from regular schools: 21 children from the first year of a school for low vocational training and 23 from the first year of a school for middle vocational training. Nearly all of these children were 12 years old, although a few were a year older. Finally, ten children in primary education (grade 4) were selected as RA controls for the dyslexic participants. Thus, the total number of participants in our study was 140. In the school for primary learning disabled children, one boy was under psychiatric treatment and one girl suffered from loss of hearing. Both were excluded from the subsequent analyses, reducing the number of evaluable participants to 138.

Among the CA control samples, small subgroups with dyslexic and hyperlexic profiles were found. The first subgroup showed far better listening comprehension than reading skill, although their reading skill still fell within normal limits. The second group showed far better reading than listening skill although, again, the deficient skill was within age-appropriate levels. Despite the fact that both subgroups had very interesting features, it was decided to exclude their results from the analyses in the present research in order to obtain a CA control group which was as homogeneous as possible. This homogeneity was expected to increase the power of the analyses. In Appendix 1, the distribution of the different types of readers over the groups is provided. Thus, our analyses include 118 (138–20) participants.

PROCEDURES

All participants were given all tests described below, either in classes or individually, but always double-blind. Classifications into different types of readers were carried out afterward when all data had been collected. Only the word recognition test of the participants from the school for primary learning disabilities was scored first, in order to select reading-age-matched controls. Due to children's absences, we do not have data for all participants on some tests.

TESTS

Altogether, some 40 different tests and subtests were administered, covering the following domains:

1. Word recognition and listening comprehension (used for classification of the participants).
2. Reading-related measures such as nonword reading, spelling, and word recognition in English as a second language.
3. Tests for the measurement of phonological skills, including sound blending, sound analysis, and nonword repetition.
4. Language-related timed tasks such as rapid naming and articulation speed.
5. Tasks for working memory (Digit Span and the Star Counting Test).
6. Tasks for general speed of processing and motor skill in both baseline and dual-task conditions.
7. Verbal and nonverbal intelligence tests as control measures for general learning ability.
8. Arithmetic and reading comprehension as other academic skills.

Tests for the Classification of Participants. Word recognition was measured by means of the Eén-Minuut Test (One-Minute Test), developed by Brus and Voeten (1973). In this test, the participant is required to read real words aloud as quickly and as accurately as possible. The words (nouns, verbs, and the like) are printed on a card with 116 words arranged in four columns in order of increasing difficulty. The raw score is the number of words correctly read within one minute. Recently, this test has been standardized for the Dutch school population by Van den Bos et al. (1994). Parallel test and test-retest reliabilities were over .80 as reported by Brus and Voeten (1973) and more recently by Van den Bos et al. (1994).

Listening comprehension was assessed by administering the experimental form of the Listening subtest of the BELL 1996 (Van den Bos 1996). For this subtest, the participant selects the one picture out of a group of four that best fits with a spoken sentence. To perform well, the participant should know word meanings and understand syntactic and semantic relations. The test has 34 items of increasing difficulty and has recently been standardized in a large-scale survey (n = 1700) involving first-year students in secondary education (Van Daal and Van der Leij in preparation). Two parallel forms were used, the A and the B forms, which (in the sample of the current study) had homogeneity reliabilities (Cronbach's α) of .63 and .69, respectively.

All participants were classified as either a garden-variety poor reader, a dyslexic reader, a hyperlexic reader, or a normal reader on the basis of the standard scores (*M* = 10; *SD* = 3) obtained on the word recognition test and the listening comprehension test. A dyslexic reader was defined as scoring 7 or less on the reading test and over 7 on the listening comprehension test, with a discrepancy of at least 3 points between the two measures. All participants scoring just over 7 on reading, but having a listening comprehension score of at least 3 points more were also considered dyslexic. In the whole sample of 138, only six such participants could be found. Participants with a listening comprehension score of less than 7 and a reading score at least 3 points higher were treated as hyperlexic readers. Here we had only two participants who scored just over 7 on the listening comprehension test, but had a far better reading score. Finally, the group of garden-variety poor readers included those participants who scored below 7 on both the reading and the listening comprehension tests. Here, no participants with a large discrepancy between reading skill and listening comprehension were encountered.

Reading-related Tests. The first test used to measure reading- and language-related skills was the Klepel (Van den Bos et al. 1994). This test was constructed by changing vowels or consonants in words of the Eén-Minuut Test under the restriction that the pronunciation rules of Dutch were not violated. The score is the number of nonwords correctly read within two minutes. Van den Bos et al. (1994) report reliabilities over .90 for this test.

All participants were also given a standardized spelling test consisting of 135 words of increasing difficulty. The score on this test is the number of correctly spelled words.

As the students in the first year of secondary education also receive formal instruction in the reading and writing of English, an English word recognition test was administered. This test, the English version of the One-Minute Test, consists of words of increasing difficulty which occurred in all commonly used teaching methods in the Netherlands (Van Daal, in preparation). The participant's task is to read aloud the words as quickly and as accurately as he can. The score is the number of words read correctly within one minute. Cronbach's α for this test is .90.

Measures Tapping Phonological Skills. The following three tests were administered with the help of an Apple Macintosh Plus computer on which a program written in AuthorWare was run. In the Auditory Analysis task, the computer presented the spoken form of a nonword (from the parallel version of the aforementioned Klepel) in digitized speech. All speech used was uttered at a rate of one syllable per second by a professional speech trainer, recorded in a studio on DAT tape, and digitized on the computer's hard disk at a sampling rate of 44 kHz. It was the participant's task to say the smallest sounds of the word, as quickly as possible, and in correct order. The experimenters were trained to press the space bar as soon as the participant started speaking so that the latencies of the responses were recorded by the computer. Accuracy in all of these computer-administered tasks was immediately assessed by the experimenter who literally transcribed each error into the system. When the response was scored, the next item was presented. Thus, both the accuracy and the latencies of the responses could be analyzed. The KR-20 reliability of the Auditory Analysis task—which consisted of 20 items—was .87.

For the Sound Blending task, the isolated phonemes of nonwords were presented auditorily by the computer and it was the participant's task to say the whole word as quickly as possible. The KR-20 reliability for this test (20 items) was .69.

A nonword repetition test also was administered with the help of the computer. Here participants were again instructed to respond as quickly as they could after the computer had said the nonword. Subsequent items increased in number of syllables, from one, KES, to four, WAPELBROEGER. The KR-20 reliability for this test (20 items) was .55.

Language-related Timed Tasks. The rapid naming test comprised six subtests, each of which contained 50 items printed on a card. The participants were asked to name the items on each card as quickly as they could without hesitations or errors. Mean total naming times per card were computed for alphanumeric stimuli (digits [0-9], capital letters [A-Z], and a mix of digits and capital letters) and objects and colors (one card with five different familiar objects, and one card with five different colors). The sixth subtest consisted of a mix of letters, digits, and colors for which the total naming time was also recorded by the experimenter in an individual testing situation. Errors were not analyzed as they rarely occurred.

Articulation time was measured with an identical procedure in each of two trials. In the first trial, the participant was asked to repeat ZUS AAPJE BOTERVLOOT (sister monkey butterdish) five times, as quickly as possible and without errors. In the second trial, JAS AUTO KIPPENHOK (coat car chickenhutch) was repeated. Word combinations were taken from a standard list used by speech trainers to assess speech problems in Dutch, and were pronounced by the experimenter at a rate of about one syllable per second. Articulation speed was timed only after the participant was able to repeat the target phrase once without errors. The number of trials to achieve accuracy was also recorded by the experimenter.

Working Memory. Digit Span (WISC-R) was administered in the classrooms. To avoid cheating (writing the numbers down then reversing them) only forward items were used. Three trials at each string length were used to increase the reliability of the test. The total number of items correctly recalled was scored.

The Star Counting test was originally developed by De Jong and Das-Smaal (1995) and has 22 items on which the participant is allowed to work for a total of 30 minutes. The score is number of items correctly solved. A single item of the Star Counting test consists of a 5 x 5 array of stars (*), plus signs (+), and minus signs (–). A value is given to start with, say 25, and instruction is provided on how many to add (2) and to subtract (3). Thus, if the first row of the array is +**–*, the result would be 25 + 2 + 2 = 29 – 3 = 26. According to the memory model by Baddeley (1986), this task can be perceived as a task for dual processing because a slave system simply has to count, while an executive master system looks for whether addition or subtraction is required.

Measures of General Speed of Processing and of Motor Skill. As a baseline measure of Simple Reaction Time (RT), participants were asked to press the space bar as soon as possible after hearing a tone. A visual signal warned the participant that the next stimulus was about to come with a random latency of 0.5 second (sec) to 1.5 sec after the visual signal. Mean RTs were computed.

In the selective choice RT task, participants were asked to press the space bar as quickly as possible when a high tone was presented, but to refrain from pressing when a low tone was presented. For this task, RTs for hits and false alarms were recorded, as were numbers of hits, misses, correct rejections, and false alarms. A measure of *d*-prime (*d'*) was also computed (McNicol 1972).

Two balance and motor tests were also presented, using a dual task paradigm. The Two Board Balance task (after Henderson and Sugden 1992) requires the child to balance with one foot in front of the other on a narrow board which is positioned like a seesaw on top of a second board. The experimenter can hear a click whenever a child loses balance, causing the two boards to collide. We measured how much time had passed before the participant caused the boards to click. There were two baseline conditions: one with the dominant foot in front of the other foot, the other with the dominant foot at the rear of the board. On two additional trials, participants were blindfolded, and on another two trials they counted backward from 30 by ones, while balancing. Each type of trial was done once with the dominant foot in front of the other foot, then repeated with the dominant foot at the rear of the board. Participants were allowed to practice for 10 seconds before each trial.

The other motor balance task was Walking Backwards (original version by Henderson and Sugden 1992). Participants were required to walk backward over a line, 3 cm wide, touching toe to heel at each step. We measured how many steps each child could make (with a maximum of 15) while properly touching toe to heel and without going off the line with more than half of the foot. The test was repeated with the added task of counting backward from 30 by 1s. Two test trials were run before scoring in order to verify that the instructions were understood.

It must be noted that the procedures for scoring the balance and motor tasks in this study were more objective than the methods used by Nicolson and Fawcett (1990) who measured the degrees of swaying and the waving of the arms, as recorded on video tapes.

Intelligence. For some of the participants, intelligence test scores had been used for school entrance decisions in special education, so were available for use in our study. Results from both a test for verbal intelligence, the OTIS (Dutch version by Maussen 1971), and one for nonverbal intelligence, the Raven's Progressive Matrices (Raven, Court, and Raven 1979) were gathered from the school files of all children who had been assessed on these measures within the last two years.

Other Academic Achievement Tests. Reading comprehension was measured by means of the Reading subtest of the BELL 1996 (Van den Bos 1996). To complete this task, participants first read a sentence, then turn over the page and select the picture that best corresponds to that sentence. The test consists of 34 items of increasing difficulty and its format largely parallels that of the listening comprehension test. Here again, both A and B forms were used, and had reliabilities (Cronbach's α) of .74 and .81, respectively.

Arithmetic speed was measured by means of the Tempo Test Rekenen (Speeded Test of Arithmetic, De Vos 1992) which consists of five subtests. For this measure, participants are instructed to solve as many simple calculations as they can using paper and pencil within one minute. The subtests are divided into measures of addition, subtraction, multiplication, division, and a mixture of all four operations.

RESULTS

Multiple regression analyses were carried out using a regression-based variable for decoding/listening comprehension as the dependent variable, and all tests entered as independent variables. Fifty-six percent of the total variance could be explained, F (26, 79) = 3.94, $p < .001$. Significant predictors included rapid naming of alphanumeric items and nonword reading. No other variable explained additional variance in the regression-based variable for decoding/listening comprehension. For the sake of simplicity, analyses of differences between discrete groups on individual measures are presented below in detail. Analyses of variance were conducted with Bonferroni tests to assess the significance of pairwise comparisons.

GROUP DIFFERENCES IN CLASSIFICATION VARIABLES

The means and standard deviations for both classification variables (listening comprehension and word recognition) are presented in Table I. Differences between groups were significant on word recognition. Garden-variety poor readers read fewer words per minute than any other group, and both dyslexics and RA controls read fewer words than either hyperlexics or CA controls.

Between-group differences were also found on the listening comprehension test. In this case, CA controls and dyslexics were better at listening comprehension than were the garden-variety poor readers, hyperlexics, or RA controls. Therefore, we can say that the classification of the participants was generally successful, although the garden-variety poor readers were less competent at word recognition than the dyslexic readers. Also, the listening comprehension test (which had been designed for 12-year olds) proved too hard for the younger, RA-matched controls.

GROUP DIFFERENCES ON READING-RELATED TESTS

As seen in table I, group differences were also found on all three reading-related tests. On nonword reading, garden-variety and

Table I. Mean scores (and *SDs*) of reading groups on classification and reading-related variables.

	Poor Readers			Control Groups		
	Garden-variety	Dyslexic	Hyperlexic	CA Match	RA Match	F-Value
n	13	41	16	34	10	
Classification Variables						
Word Recognition:						
Words read in one minute	42.7^a (15.8)	58.0^b (9.3)	81.0^c (10.3)	79.0^c (10.7)	68.5^b (7.1)	43.69^{***} *df* (4,113)
Listening Comprehension:						
Number correct (max = 34)	16.5^a (2.8)	27.0^b (2.8)	17.8^a (3.4)	25.8^b (2.8)	18.4^a (2.4)	67.15^{***} *df* (4,113)
Reading Related Tests						
Nonword reading:						
Words read within 2 minutes	27.6^a (13.7)	35.6^a (11.0)	74.8^b 15.8)	68.5^b (17.1)	64.0^b (9.2)	50.80^{***} *df* (4,113)
Words correctly spelled	73.1^a (26.3)	106.3^b (13.8)	120.4^c (9.7)	122.1^c (8.0)	98.9^b (10.1)	34.80^{***} *df* (4,112)
Foreign language:						
English words read in one minute	32.8^a (1.9)	32.6^a (8.4)	53.5^b (19.6)	55.6^b (17.6)	— —	19.36^{***} *df* (4,88)

Note: Results of post-hoc comparisons indicated by superscripts; different superscripts in a given row indicate those comparisons that are significantly different. CA match = chronological age match; RA match = reading age match.

$^{***}p < .001$

dyslexic poor readers decoded fewer nonwords than RA controls, CA controls, or hyperlexics.

On spelling, garden-variety poor readers spelled fewer words correctly than any other group, and both RA controls and dyslexics spelled fewer words correctly than hyperlexics or CA controls. On English word recognition, hyperlexics and CA controls successfully read more English words than dyslexics or garden-variety poor readers. Therefore, we can say that the classification of the subjects is supported by the results on the reading-related tasks.

PHONOLOGICAL SKILLS

In table II, statistics are presented for the phonological tasks of auditory analysis, auditory synthesis, and nonword repetition.

Although no significant differences were found on the latency measures, groups did differ in their accuracy on each measure. Garden-variety readers were less accurate than CA controls on both nonword repetition and auditory synthesis tasks, and less accurate than RA controls on auditory analysis. Interestingly, only on nonword repetition were the dyslexic readers more accurate than the garden-variety readers.

Thus, on the phonological processing tests, we failed to find the differences that would be predicted by the Phonological-Core Variable-Difference Model.

Table II Mean accuracy and latency scores (and *SD*s) of reader groups on phonological processing tests.

	Poor Readers			Control Groups		
	Garden-variety	Dys-lexic	Hyper-lexic	CA Match	RA Match	ANOVA F-Value
n	13	41	16	34	10	
Auditory Analysis						
Percentage correct	51^{a} (33)	62^{a} (25)	51^{a} (31)	61^{b} (29)	89^{b} (11)	2.99^{*} *df* (4,97)
Latency (seconds)	.87 (.25)	1.04 (.34)	1.14 (.37)	1.13 (.45)	1.31 (.28)	1.84, *ns* *df* (4,97)
Auditory Synthesis						
Percentage correct	69^{a} (17)	86^{b} (16)	79^{a} (19)	86^{b} (12)	86^{a} (6)	3.30^{**} *df* (4,97)
Latency (seconds)	.44 (.12)	.36 (.11)	.40 (.10)	.34 (.08)	.34 (.15)	2.15^{ns} *df* (4,94)
Nonword Repetition						
Percentage correct	86^{a} (16)	96^{b} (6)	90^{a} (8)	96^{c} (6)	92^{c} (7)	4.36^{**} *df* (4,97)
Latency (seconds)	.26 (.07)	.25 (.07)	.26 (.06)	.23 (.07)	.26 (.04)	< 1, *ns* *df* (4,97)

Note: $^{*}p < .05$; $^{**}p < .01$

Results of post-hoc comparisons indicated by superscripts; different superscripts in a given row indicate those comparisons that are significantly different. CA match = chronological age match; RA match = reading age match.

LANGUAGE-RELATED TIMED TASKS

Group performances on timed language tasks are presented in table III. On the rapid naming of alphanumeric items, significant group differences were found such that garden-variety poor readers were slower than all other groups except the RA controls, and dyslexics were slower than hyperlexics and CA controls. Although there was an overall group effect on the rapid naming of symbols and colors, no pairwise comparison reached significance.

On the first wordstring of the articulation test, RA controls needed more trials than the CA controls, hyperlexics, and dyslexics, but there were no differences on the second wordstring. Garden-variety poor readers were slower in articulating

Table III Mean scores (and *SD*s) of reader groups on language-related timed tasks.

	Poor Readers			Control Groups		
	Garden-variety	Dys-lexic	Hyper-lexic	CA Match	RA Match	ANOVA *F*-Value
n	13	41	16	34	10	
Rapid Naming Measures						
Number of seconds to	32.4^{a}	27.8^{b}	21.8^{c}	23.2^{c}	26.0^{a}	13.04***
name letters/digits	(9.1)	(4.5)	(3.5)	(3.9)	(3.7)	*df* (4,111)
Number of seconds to	46.4	42.0	38.4	39.4	44.5	3.07, *ns*
name objects/colors	(7.8)	(7.7)	(5.5)	(9.0)	(5.1)	*df* (4,112)
"Zus aapje botervloot"						
Trials to articulate	1.6^{a}	1.4^{b}	1.3^{b}	1.2^{b}	2.8^{a}	4.18**
	(.9)	(.7)	(.5)	(.5)	(3.3)	*df* (4,112)
Seconds to articulate	9.6^{a}	7.0^{b}	7.7^{a}	6.9^{b}	8.2^{a}	3.90***
five times	(3.3)	(2.3)	(2.6)	(1.5)	(2.3)	*df* (4,112)
"Jas auto kippenhok"						
Trials to articulate	1.4	1.2	1.3	1.0	1.3	1.40, *ns*
	(.7)	(.5)	(.8)	(.2)	(.7)	*df* (4,112)
Seconds to articulate	8.4^{a}	6.3^{b}	6.9^{a}	6.2^{b}	8.1^{a}	4.70*
five times	(2.4)	(2.3)	(1.5)	(1.3)	(1.6)	*df* (4,112)

Note: $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$

Results of post-hoc comparisons indicated by superscripts; different superscripts in a given row indicate those comparisons that are significantly different. CA match = chronological age match; RA match = reading age match.

than dyslexics and chronological age controls, both on the first and second wordstrings.

In general, our results agreed with what would be predicted by the naming deficit hypothesis. We should, however, cite three points of diversion from expected results:

1. Garden-variety readers were slower than dyslexics.
2. The naming deficit did not generalize to nonalphanumeric stimuli.
3. Naming deficits tended to go along with articulation problems.

WORKING MEMORY

As shown in Table IV, garden-variety poor readers remembered fewer digits than all other groups on the WISC Digit Span subtest. They also made fewer correct calculations on the Star Counting Test than any other group.

On working memory tests, therefore, garden-variety readers performed less well than the other groups.

Table IV Mean scores (and *SD*s) of reader groups on memory measures.

	Poor Readers			Control Groups		
	Garden-variety	Dys-lexic	Hyper-lexic	CA Match	RA Match	ANOVA *F*-Value
n	13	41	16	34	10	
Digit Span						
Number of items recalled	4.1^a	4.8^b	4.7^b	5.0^b	4.5^b	3.16*
	(1.1)	(.7)	(1.1)	(.7)	(.5)	*df* (4,112)
Star Counting Test						
Number of items correct	6.2^a	12.8^b	13.6^b	13.4^b	13.6^b	6.23***
	(6.3)	(4.1)	(4.5)	(4.8)	(4.5)	*df* (4,112)

Note: $^*p < .05$; $^{***}p < .001$

Results of post-hoc comparisons indicated by superscripts; different superscripts in a given row indicate those comparisons that are significantly differ-

TESTS FOR GENERAL SPEED OF PROCESSING AND MOTOR SKILL IN BASELINE AND DUAL-TASK CONDITIONS

On the simple reaction time task, CA controls were faster than RA controls (see table V). On the choice reaction task, however, no differences at all were found for *d*-prime or for latencies for hits. Only on latencies for false alarms were the reading age controls slower than the chronological age controls. The differences found can be explained easily by maturation effects.

As seen in table V, on none of the motor and balance tasks were differences between any two groups found. Therefore, no support for the DAD/CC hypothesis was found.

VERBAL AND NONVERBAL INTELLIGENCE

In table VI, scores for nonverbal and verbal intelligence are presented. As mentioned previously, these measures were available only for students attending the school for primary learning disabled. Among these children, hyperlexics scored lower on average than dyslexics on the Raven's test ($F[3,53] = 3.87$, $p = .014$), whereas the garden-variety poor readers performed less well than the dyslexics and CA controls on the OTIS ($F[3,54] = 4.79$, $p = .005$).

Thus, as in other language-related tasks, garden-variety poor readers performed less well on verbal intelligence and on nonverbal intelligence.

OTHER ACADEMIC ACHIEVEMENT TESTS

Scores on reading comprehension and speeded arithmetic are presented in table VI. Significant group differences were found on reading comprehension, with garden-variety poor readers scoring lower than hyperlexics, dyslexics, and CA controls. Reading-age controls scored lower than dyslexics and CA controls. On the speeded arithmetic test, the garden-variety poor readers were less competent than all other groups except the reading-age controls.

DOUBLE DEFICIT

As discussed earlier, a double deficit involving both nonword reading and letter naming speed may characterize a subgroup of dyslexics; such students should have the most severe reading impairments. However, it should be noted that the correlation between nonword reading and naming speed was rather high in the whole group ($r = .68$), probably because the nonword reading task involved speed as well. Interestingly, this correlation dropped to .35 when only dyslexics were taken into account.

Table V. Mean scores (and SDs) on baseline and dual-task measures of general speed of processing and of motor skill.

	Poor Readers			Control Groups		
	Garden-variety	Dyslexic	Hyperlexic	CA Match	RA Match	ANOVA F-Value
Speed of Processing						
Simple RT (secs)	.80^{a,b}	.76^{a,b}	.86^{a,b}	.68^{b}	1.00^{a}	3.75***
(baseline condition)	(.22)	(.22)	(.24)	(.20)	(.30)	*df* (4,97)
Choice reaction: *d'* (dual-task condition)	1.43	1.34	2.01	1.57	1.47	1.66,*ns*
	(1.02)	(.69)	(1.49)	(.68)	(.41)	*df* (4,97)
Choice reaction:	1.7	1.9	1.8	1.6	1.9	1.78*ns*
latency of hits (secs)	(.5)	(.5)	(.6)	(.4)	(.2)	*df* (4,97)
Choice reaction: false alarm	1.1^{a,b}	1.2^{a,b}	1.0^{a,b}	.9^{b}	1.6^{a}	2.69*
latency (secs)	(.5)	(.6)	(.4)	(.3)	(.9)	*df* (4,97)
Two-Board Balance						
Secs in balance	2.8	4.8	5.8	3.9	4.1	*ns*
preferred foot in front	(1.6)	(5.2)	(6.0)	(3.0)	(3.6)	*df* (4,97)
Secs blindfolded	3.1	4.6	5.1	3.9	4.8	*ns*
preferred foot behind	(2.1)	(4.3)	(5.2)	(3.4)	(4.9)	*df* (4,97)
Secs blindfolded	1.3	1.8	2.1	1.7	1.8	*ns*
preferred foot in front	(.9)	(1.1)	(1.5)	(1.3)	(.9)	*df* (4,97)
Secs in balance	1.5	2.0	1.6	1.7	1.6	*ns*
preferred foot behind	(1.3)	(1.9)	(1.1)	(1.3)	(.5)	*df* (4,97)
Secs counting backward	1.0	3.5	4.9	3.2	2.9	*ns*
preferred foot in front	(1.3)	(3.6)	(4.9)	(2.9)	(2.6)	*df* (4,97)
Secs counting backward	1.4	4.7	3.2	3.1	3.4	*ns*
preferred foot behind	(2.2)	(5.2)	(2.8)	(2.6)	(4.0)	*df* (4,97)
Walking Backward						
Number of steps	8.2	9.4	7.2	10.2	12.3	ns
	(6.3)	(5.2)	(5.4)	(5.7)	(3.6)	*df* (4,97)
Number of steps while counting	5.7	8.6	6.8	8.4	9.5	*ns*
backward	(4.5)	(5.8)	(5.8)	(5.6)	(6.1)	*df* (4,97)

Note: $^{*}p < .05$; $^{***}p < .001$

Results of post-hoc comparisons indicated by superscripts; different superscripts in a given row indicate those comparisons that are significantly different. CA match = chronological age match; RA match = reading age match.

Table VI. Mean scores (and *SD*s) on tests of intelligence and academic achievement tests. (Raven's and OTIS scores available only students from school for primary learning disabled).

	Poor Readers			Control Groups		
	Garden-variety	Dys-lexic	Hyper-lexic	CA Match	RA Match	ANOVA *F*-Value
Intelligence Measures	$n = 5$	$n = 30^{\#}$	$n = 6$	$n = 17$		
Raven's (nonverbal)	$105.2^{a,b}$	113.7^{b}	102.2^{a}	$109.8^{a,b}$		3.87^{*}
IQ Points	(4.0)	(8.7)	(9.9)	(8.9)		*df* (3,53)
OTIS (verbal)	87.4^{a}	100.5^{b}	$91.0^{a,b}$	101.6^{b}		4.79^{**}
IQ points	(6.7)	(8.7)	(8.6)	(10.9)		*df* (3,54)
Achievement Measures	$n = 13$	$n = 41$	$n = 16$	$n = 34$	$n = 10$	
Reading comprehension:	15.6^{a}	24.5^{c}	$22.5^{b,c}$	26.0^{c}	$19.0^{a,b}$	18.50^{***}
no. correct	(5.3)	(3.8)	(4.7)	(3.8)	(4.2)	*df* (4,112)
Speeded arithmetic: no. correct	74.4^{a}	111.8^{b}	115.6^{b}	123.8^{b}	$96.3^{a,b}$	7.46^{***}
in five mins	(35.5)	(25.3)	(33.7)	(28.8)	(18.2)	*df* (4,112)

$^{\#}$Note: In Dyslexic group, $n = 29$ for the OTIS measure.

Within this group, we found eight students who had neither deficit, nine who had both deficits (scoring 1 *SD* below the general mean on both variables), and 26 students with a single deficit. Those with only one deficit always had a decoding problem (scoring 1 *SD* below the general mean). In a secondary analysis, we compared the group with the double deficit to the group with the single nonword reading deficit. Differences were found only on naming speed measures themselves, including the naming of both alphanumeric stimuli, $F(1,22) = 31.12$, $p < .001$ and nonalphanumeric items, $F(1,22) = 10.36$, $p = .004$. No significant difference was found on any other variable.

DISCUSSION

The outcomes of the current study are straightforward. The dyslexic group differed from the CA-matched control group in two respects only: they had extreme difficulties with single-word measures including nonword reading and recognition of high-frequency words in a foreign language (English); and with spelling. Of course, these difficulties come as no surprise. The analyses revealed that dyslexic students were below RA level when reading nonwords and at RA level in word recognition (due to our matching procedure). Because the two tasks, Klepel for nonword reading and EMT for word recognition, are equivalent except for the semantic element, the hypothesis of a phonological recoding deficit (Rack, Snowling, and Olson 1992) is supported by our findings. Because dyslexic students also did poorly on recognizing foreign words which they had practiced, and because all three reading tasks involved speed, the results are consistent with the automatic decoding deficit hypothesis as well (Yap and Van der Leij 1993). According to this hypothesis, it is the automatization of reading skill that is deficient; therefore, the reading of overlearned or very familiar words remains slow, even when a high level of accuracy is attained. Moreover, reading performance will break down when task demands are increased by presenting, for example, less frequent words, nonwords, longer real words, or words with complex orthographic structures. Another way to increase the task demands is to emphasize speed of response (for more details, see Van der Leij and Van Daal 1999). In addition, because automatization of reading is deficient, no robust orthographic representations (Share 1996, 1998) are built up, a fact reflected in dyslexic students' performance in spelling.

The second and only significant finding outside the area of reading and spelling concerns a naming deficit. The fact that this deficit only appeared when letters and/or digits had to be named and not with symbol/color naming, favors the idea that an automatic decoding deficit (in the sense of an impaired retrieval speed for letter names) exists as well. Our data do not, however, support the position of a more general naming deficit. Much to our surprise, we were not able to find any other significant difference between dyslexic and normal readers, whether matched on CA or RA. The hypotheses of a general phonological processing deficit, of a general naming deficit, of a general deficit in working memory, and of a more general automatization deficit were all unsupported by our findings.

In contrast, garden-variety poor readers differed from dyslexic readers and the CA and RA control groups on a variety of tasks that assessed phonological skills (analysis, blending, nonword repetition), rapid naming (letters and digits), articulation speed, and working memory (Digit Span, Star Counting Test). The garden-variety poor readers seemed to match the cognitive profiles predicted by the aforementioned hypotheses better than the dyslexics. The only profile that the garden-variety poor readers did not match was that predicted by the general automatization deficit: they did not differ from other groups on the reaction tasks or on the motor tasks. Consistent with their weaker verbal intelligence, garden-variety poor readers scored lower on both reading comprehension and speeded arithmetic. However, it should be noted that the garden-variety group in the current study, with an average nonverbal IQ of 105 and verbal IQ of 87, were of low-average intelligence and could easily have been placed in the dyslexic group in other studies. If this is in fact the case, our findings strongly suggest that the hypothesized deficits may not appear in dyslexics across the intelligence continuum. This casts doubt not only on the validity of the various hypotheses regarding deficits outside the area of reading, but also on the independence of developmental dyslexia from general learning disabilities.

In line with our predictions, the hyperlexic readers were better than dyslexic readers at phonological recoding, English word recognition, spelling, and rapid naming (letters and digits), but scored lower on nonverbal intelligence. Differences in verbal intelligence and reading comprehension were in the expected direction, but were not significant.

Now we will discuss our findings with regard to the different hypotheses in more detail. Regarding the phonological processing deficit hypothesis, no differences between the dyslexics and CA control groups were found on three phonological processing tasks (synthesis, analysis, and nonword repetition), although nonword reading was certainly impaired in the dyslexics. It should be noted that the mean accuracy percentages on blending and analysis do not indicate a ceiling effect. It may be that at this age, a phonological processing deficit is no longer characteristic of dyslexics. A phonological processing deficit may be bound to a younger age, and, more important, a lower reading age (the mean score of the dyslexics on the classification variable EMT—58.0 words correctly read per minute—equalled a reading age at the end of grade 3). Support for this view may be found in a longitudinal study that showed that, in Dutch, phonological skills and word reading are correlated only in the first stages of reading development (De Jong and Van der Leij 1999). As we will discuss later, the emerging picture seems to be that young dyslexics who perform poorly on a variety of tasks may, over time, move into the normal range on some of these tasks. In fact, in 12-year olds, we found little support for the part of the Phonological-Core Variable-Difference Model that relates to pure phonological processing. Moreover, our findings did not reveal total independence of the phonological core from general intelligence because the garden-variety students performed less well than the dyslexic students on all phonological processing tasks (blending, analysis, and nonword repetition).

The naming deficit hypothesis as a more general deficit was also not supported by our findings because our dyslexics were not impaired on all naming tasks: the twelve-year-olds in this study were normally proficient at the naming of objects and colors. However, as suggested by other authors such as Wolf et al. (in press), a double deficit may be characteristic of a subgroup of dyslexics; that is, the most severely dyslexic subgroup may show all the predicted differences in comparison to a dyslexic subgroup that is less affected. In a secondary analysis, we were able to classify participants into two groups based on whether they had an additional naming deficit apart from their nonword reading deficit. The only difference in performance between these two groups concerned the rapid naming of symbols and colors. Therefore, we can conclude that the most severely affected group has a general naming problem. It may make sense to differentiate subtypes based on these two measures but this topic requires more thorough investigation, especially because we found a relation with articulation speed in the whole group.

We were not able to find support for the hypothesis of a general deficit in working memory. Our findings are more directly comparable with the work of our Dutch colleague and coworker De Jong (1998) than with studies from other countries. Whereas the dyslexic students in De Jong's study also were selected from special schools for primary learning disabled children, they were two to three years younger (10 instead of 12.5 years) than the participants in the current study, and their reading age (on the same word recognition test) was about one year lower (end grade 4 instead of end grade 5). Across these studies, a comparison of the results on the Star Counting Test suggests that the dyslexic students tend to catch up when they grow older, whereas the scores of the CA controls tend to level off with age. This phenomenon also has been noticed by Nicolson and Fawcett (1994) who compared dyslexic groups at the ages of 8, 13, and 17 years, and found "a heartening developmental trend" (p. 224). They mean by this that differences between CA-matched groups tended to decrease over time, on measures for memory, articulation, and processing speed. Of course, only a longitudinal study (which, to our knowledge, has never been done for children aged twelve and over), could provide an answer. Note, however, that Nicolson and Fawcett

(1994) also suggested that the developmental trend toward normal performance may not appear for all skills. In their research, even the 17 year olds with dyslexia still performed poorly on various tests of phonological skill, naming speed, and motor skills, with particular deficits evident in the one-foot-balance and blindfold-balance tasks. In their view, these deficits, when found at an older age, can be interpreted as a more general automatization deficit.

This portion of Nicolson and Fawcett's (1994) results was not confirmed by our findings. We found no differences on tests for speed of processing (simple/choice reaction), or on a motor task (in simple and dual conditions). Although the performance of the dyslexic students on the motor tasks (walking backward and two-board balance) decreased in the dual-task condition (counting backward), the same was true for all other groups as well. We suggest three possible reasons for the discrepancy in findings: differences in the selection of participants, task demands, and the classification of participants.

With respect to selection of the participants, most of the studies mentioned have been carried out in countries where English is the native language. It is known that English orthography is more difficult than Dutch because it has more irregular spelling-sound correspondences. As a consequence, it could well be that participants in our study were less severely reading impaired in an absolute sense. Nonetheless, our participants did meet the traditional criteria for dyslexia, with mean IQs of 113.7 (nonverbal) and 100.5 (verbal), and mean reading delay of about 3.5 years at the age of 12 to 13. In addition, they showed the reading profile that is predicted by the hypotheses of both a phonological recoding deficit (Rack, Snowling, and Olson 1992), and of an automatic decoding deficit (Yap and Van der Leij 1994), a strong discrepancy in word-nonword reading, and a low retrieval speed for overlearned orthographic stimuli like letters and (English) words. Moreover, our participants represented the most severe cases of an entire school district (with a population of about 60,000). To support our claim that our participants accurately represented the dyslexics in our country and that their dyslexia was the most severe we could find, it is important to note that the participants of our study and in the study of De Jong (1998) are very much alike. If you divide reading age according to years of instruction and practice in reading, both groups progressed at about half the normal rate of development.

With respect to the tasks we used in the current study, they were certainly neither too easy nor too difficult, as no ceiling or floor effects were found. Instead, there was wide variation in performance in all groups. The difficulty of the task demands could, however, still be decisive. Returning to the issue of comparisons of studies across orthographies, a study of Landerl, Wimmer, and Frith (1997) is relevant because the Dutch orthography resembles the German orthography more than it does the English. Landerl, Wimmer, and Frith (1997) compared 12-year old dyslexic students in Austria (German orthography) and the United Kingdom (English orthography) with CA- and RA-groups on equivalent tasks in their own language, and concluded that dyslexics from both countries suffered from the same phonological processing deficit. The task they used in that study—which required children to exchange the consonant onsets of two words (boat-fish becomes foat-bish)—was far more complex than the phonological blending, analysis, and nonword repetition tasks that we used. It is possible that dyslexic students in our sample may have been trained in the kind of tasks we presented because practicing the phonological route has become part of the curriculum in the special schools. One possible way to test the phonological processing deficit hypothesis at the age of 12 and over is through a task that taps analysis, blending, and phonological working memory all at once, as in the task of Landerl, Wimmer, and Frith (1997). Although our tasks may not have been demanding enough to reveal a phonological processing deficit, our other tasks seem to have been designed or selected properly. They indicated the expected effects of maturation (RA students showed slower speed in rapid naming, articulation, and simple and choice reaction), general learning abilities (garden-variety students performed more poorly at reading comprehension, working memory tasks, and arithmetic), and educational experience (RA students were at reading level at spelling, reading comprehension, and arithmetic). However, a direct comparison between findings across countries (and orthographies) may be possible only when the tasks used are exactly equivalent. Alternatively, if these cannot be constructed, the structures of covariances between tasks must be analyzed. Thus, the time has come to execute a large-scale international study on the characteristics of developmental dyslexia.

The validity of our classification, based on word recognition and listening comprehension, is supported by the findings that the dyslexic and garden-variety groups performed equally (at or below RA level) on the other reading tasks and spelling, but differed in scores on reading comprehension and verbal IQ (garden-variety below and dyslexics equal to CA level). The hyperlexic group performed slightly better than expected on tasks related to listening comprehension, but otherwise met expectations. That is, they matched the CA group in reading and spelling, and their reading comprehension skill and verbal intelligence was somewhat lower than CA level. To conclude, although the classification into dyslexic and garden-variety groups was confirmed by other findings, the hyperlexic classification was only partially confirmed. However, we suggest that it still may be worthwhile to differentiate hyperlexic readers from the other groups, in light of the fact that the verbal IQ (91) for the hyperlexic group nearly matched the garden-variety level (87) and was much lower than the dyslexic level (101). To support this idea further, it should be noted that the hyperlexic students performed at the expected CA level on all tasks that tap speed, working memory, and automatization.

Two issues remain to be discussed: (1)why did our findings not support most of the hypotheses that relate dyslexia to other variables of cognitive functioning and information processing? and (2) why do our findings differ from the general automatization deficit hypothesis? With regard to the hypotheses within the language domain (phonological processing, naming speed, working memory), we draw the tentative conclusion that, at this age, most differences with chronological peers tend to disappear by means of the combined mechanisms of levelling off in normal performance, and catching up in dyslexic performance. Of course, this hypothesis should be tested in a proper, longitudinal design. In such a study, the way to operationalize the phonological tasks should be reconsidered as well. A phonological processing deficit still may appear at this age when task demands require complex phonological processing, as evidenced by data from the students in the study of Landerl, Wimmer, and Frith (1997), who were only slightly younger.

Regarding the hypothesis of a more general automatization deficit, our interpretation is less straightforward. We failed to find any association between group membership (dyslexics/CA/RA) and performance on general speed and motor tasks in either simple or dual conditions. Moreover, two recent studies also failed to replicate the results obtained by Nicolson and Fawcett (1994) and Fawcett, Nicolson, and Dean (1996). Wimmer, Mayringer, and Landerl (1998) report that all differences between dyslexics and control participants on various balance tasks disappeared when participants with ADHD were removed from their (Austrian) sample (see also Wimmer, Mayringer, and Raberger 1999). And Stringer and Stanovich

(1998) failed to replicate Nicolson and Fawcett's (1994) findings on a duration estimation task. Weak performance by dyslexics on this task is thought to be critical for the cerebellum hypothesis, which states that both the motor problems and the reading problems in dyslexics stem from improper functioning of the cerebellum. Stringer and Stanovich (1998) found that time duration accounted for no unique variance in reading performance once age and intelligence were controlled for. The only recent study that replicated part of the original findings of Nicolson and Fawcett (1990, 1994) was carried out in our own lab (Yap and Van der Leij 1994), and included a clinical sample of dyslexics. This means that, unless we go back to the files, we cannot rule out that some students may have suffered from ADHD as well. Thus, it could be that the relatively small groups of participants in the Nicolson and Fawcett studies were preselected in some way that influenced their results. In the present research, where we have tried to avoid such selection problems, we were not able to find support for the DAD/CC hypotheses. We concede that there is always the possibility that our motor tasks—walking backward and two-board balance, with and without counting backward and with and without being blindfolded—did not conform to the dual-task paradigm. Perhaps, for example, the single task of walking backward, meant to tap automatic processing, required too much attention because it is such an unusual motor activity. On the other hand, in our measures of speed of processing within the same paradigm, we did not find the expected interaction between group (dyslexics/CA/RA) and condition (simple/choice reaction) either, although the dyslexic, CA, and RA students performed equally well in the simple condition.

To conclude, the findings of our study confirm that dyslexia at the age of twelve to thirteen is related to problems in phonological recoding, in speed of word recognition, and in rapid naming of letters and digits. Thus, our results support the hypothesis of a very specific automatic decoding deficit (Yap and Van der Leij 1993; Van der Leij and Van Daal 1999). Furthermore, our findings suggest that, at least at this age, dyslexic students do not suffer significantly from more general deficits in the domains of phonological processing, naming speed, working memory, and automatization. In our sample, it was the performance of the garden-variety students, rather than that of the dyslexics, that seemed more in line with the predicted characteristics. This finding suggests that, in order for such deficits to be present at this age, pure dyslexia must be surrounded by a more general learning

APPENDIX 1 Distribution of different types of readers across schools. Percentage is based on total study sample.

	Poor Readers			Chronological Age Controls			Reading	
	Garden-variety	Dyslexic	Hyperlexic	Normal Profile	Dyslexic Profile	Hyperlexic Profile	Age Controls	Total
Special Education:	8	1	5	1				15
Retarded Children	5.8%	0.7%	3.6%	0.7%				
Regular Education:		8	4	3	1	5		21
Low Vocational Training		5.8%	2.9%	2.2%	.7%	3.6%		
Regular Education:		3	3	12	3	2		23
Middle Vocational Training		2.2%	2.2%	8.7%	2.2%	1.4%		
Special Education:	5	32	6	17	8	1		69
Primary Learning Disabled	3.6%	23.2%	4.3%	12.3%	5.8%	0.7%		
Primary Education:							10	10
Grade 4							7.2%	
All Schools Included	13	44	18	33	12	8	10	138

disability such as specific language impairment or lower intelligence. These tantalizing conclusions should be regarded as tentative, and we eagerly await further investigation on this subject.

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