Development of Phonological and Orthographic Skill: A 2-Year Longitudinal Study of Dyslexic Children

Article *in* Journal of Experimental Child Psychology · September 1993

DOI: 10.1006/jecp.1993.1026 · Source: PubMed

Franklin R. Manis
University of Southern California

Patricia A Szeszulski
California State University, Fullerton

JOURNAL OF EXPERIMENTAL CHILD PSYCHOLOGY 56, 64–86 (1993)

Development of Phonological and Orthographic Skill: A 2-Year Longitudinal Study of Dyslexic Children

FRANKLIN R. MANIS AND REBECCA CUSTODIO

University of Southern California

AND

PATRICIA A. SZESZULSKI

California State University, Fullerton

Twenty-one dyslexic children, ages 9–15, were administered a battery of tests on two occasions separated by 2 years to assess the development of word recognition and spelling. The majority of the subjects were receiving intensive small-group instruction and one-on-one tutoring in reading and writing. Correlational and regression analyses supported the assumption that phonological and orthographic processing are distinct but reciprocally related components of word recognition and spelling. However, phonological skill appeared to capture most of the unique variance in word identification for dyslexics and younger normal readers matched on word identification skill. Although the dyslexic children made significant gains over 2 years in overall word identification skill and in aspects of phonological and orthographic processing, they failed to show significant "catch-up" in any component skills relative to age- and reading-level-matched normal readers. In addition, dyslexics made little or no progress on a measure of phonemic analysis, on a decoding task requiring processing at the level of the phoneme, and at spelling words with unusual and irregular orthography. The results are consistent with the hypothesis that dyslexic children have primary deficits in phonological processing of speech and print and secondary deficits in orthographic processing.

Portions of these data were presented at the biennial conference of the Society for Research in Child Development, Seattle, April, 1991. The authors thank the principals, staff, and students of Landmark West School, Encino, California, and Fern, Hickory, Madrona, Magruder, and Towers schools, Torrance, California, for their cooperation. We also thank Cathleen Simmons for assistance in testing subjects. Requests for reprints should be sent to Franklin R. Manis, Psychology Department, University of Southern California, Los Angeles, CA 90089-1061.

0022-0965/93 $5.00

There is widespread agreement that word recognition is the primary locus of reading difficulty for individuals with developmental dyslexia (Jorm & Share, 1983; Perfetti, 1985; Stanovich, 1988). Longitudinal studies of children and follow-up studies of adults with a history of dyslexia indicate that dyslexics continue to be poor at decoding unfamiliar words, analyzing speech at the level of the phoneme, rapidly recognizing words in isolation, and spelling words to dictation despite sometimes considerable experience in remedial classes (Aaron & Phillips, 1986; Bruck, 1988, 1990, 1992; Kitz & Tarver, 1989; Pennington, Lefly, Van Orden, Bookman, & Smith, 1987). An oft-mentioned hypothesis is that phonological difficulties leading to a failure to master spelling–sound correspondences are a primary source of both word recognition and spelling problems among dyslexics (Bradley & Bryant, 1985; Bruck, 1990; Jorm & Share, 1983; Kamhi & Catts, 1989; Liberman & Shankweiler, 1985; Olson, Wise, Conners, Rack, & Fulker, 1989; Siegel & Ryan, 1988; Snowling, 1987; Stanovich, 1988; Vellutino & Scanlon, 1987).

Although phonological skills are undoubtedly important to the mastery of both reading and spelling, orthographic processing skills may be an additional source of variance (Cunningham & Stanovich, 1990; Juel, Griffith, & Gough, 1986; Manis, Szeszulski, Holt, & Graves, 1990; Olson, Kliegl, Davidson, & Foltz, 1985; Stanovich & West, 1989). Orthographic processing can be defined as the ability to access visual–orthographic codes for specific words. Cunningham and Stanovich (1990) demonstrated that orthographic processing skill can account for variance in word recognition among a random sample of 3rd and 4th graders even after variance due to phonological processing is partialled out. The unique contribution of orthographic processing appeared to be related in part to children's ability to recognize titles of familiar books, suggesting that orthographic processing ability is partially determined by exposure to print. Stanovich and West (1989) reported similar findings for college students.

Although phonological and orthographic skill are theoretically and empirically separable, it is likely that the two component skills enter into a reciprocal causal relationship with each other (Ehri, 1987; Jorm & Share, 1983). The ability to decode unfamiliar words may increase the number of visual–orthographic codes the child can learn independently, as well as direct the child's attention to the sequence of letter codes in the word (Jorm & Share, 1983). Conversely, the accumulation of information about word spelling may enable the child to induce phonological "rules" or read novel words by analogy (Glushko, 1979; Goswami, 1986). Connectionist models of reading that have become influential recently pose a distinct role for both orthographic and phonological information, but treat both spelling–sound rules and memorized spellings of words as emergent properties of a system in which the reader learns to relate printed letter strings to spoken words on an analogical basis (e.g., Seidenberg & McClelland, 1989).

In previous studies employing a dyslexic sample, orthographic processing skills have been shown to be somewhat independent of phonological skill (Manis *et al.*, 1990; Olson *et al.*, 1985, 1989; Pennington *et al.*, 1987). However, these studies provide a mixed view of the relative importance of phonological and orthographic processing problems in dyslexia. In the studies by Olson and colleagues (Olson *et al.*, 1985, 1989) dyslexics performed more poorly in phonological, but not orthographic, processing than younger normal readers matched on word identification skill. In contrast, Manis *et al.* (1990) found that dyslexics scored at a lower level than reading-level-matched normal readers on more than one measure each of phonological and orthographic processing. Pennington *et al.* (1987) collected cross-sectional data from families participating in a series of genetic linkage studies. They reported that dyslexics showed age-related increases in both phonological and orthographic coding (as reflected in spelling errors). Dyslexics "caught up" with chronological age controls in adulthood in some areas of orthographic processing, but continued to show marked deficits in phonological processing.

Previous studies of component word identification in dyslexic children leave a crucial question unanswered. What is the developmental course of phonological and orthographic skills? We know that dyslexic individuals exhibit serious phonological processing deficits from childhood through adulthood (e.g., Bruck, 1990, 1992; Olson *et al.*, 1989; Pennington *et al.*, 1987), and there is some evidence of serious deficits in orthographic processing skill in adolescence (Manis *et al.*, 1990). However, it is unclear whether orthographic skills improve relative to phonological skills over time. According to Frith (1985), classic developmental dyslexia involves a failure to develop an effective means of spelling–sound translation. Hence, dyslexics can only learn to read more effectively if they bypass phonological codes and build up visual–orthographic codes for individual words (Pennington *et al.*, 1987). These arguments lead to the testable prediction that dyslexics should show greater gains in orthographic than in phonological processing over time.

To examine developmental change in component reading and spelling skills, we gave a battery of tasks to 21 dyslexic children on two occasions separated by 2 years. Scores on all of the measures were collected on a single occasion from normally achieving readers at each of grades 2–8, permitting comparison of the dyslexics' performance to chronological-age- and reading-level-matched groups.

METHOD

Subjects

Twenty-one dyslexic children were tested on two occasions separated by approximately 2 years. They were obtained from an original sample

TABLE 1
COMPARISON OF LONGITUDINAL SAMPLE TO ORIGINAL SAMPLE

Variable	Original sample (N = 52)	Longitudinal sample (N = 21)
Estimated WISC-R IQ score		
M	108.2	109.6
SD	10.8	10.1
Woodcock Word Identification Grade Equivalent score		
M	3.9	4.0
SD	0.9	1.0
Woodcock Word Identification percentile score		
M	13.8	11.8
SD	10.2	9.3
Age (in months)		
M	141.0	143.0
SD	16.4	24.0

of 52 dyslexics tested in 1987. At the second testing (1989), an attempt was made to contact all of the original subjects. Eleven had moved out of the area, and of the remaining 41, 21 agreed to participate in the follow-up study. The subsample was very similar to the original sample in IQ, reading achievement, and age. Descriptive information is shown in Table 1. None of the differences between the original and the returning samples were statistically significant.

The 21 subjects participating in both testings came from five public and two private schools in predominantly middle- to upper-middle-class areas of Los Angeles and Orange counties. At the first testing, they were selected for the study if they scored below the 35th percentile on the Woodcock Reading Mastery Test, Word Identification subtest (Woodcock, 1973) and obtained an estimated IQ score of 90 or higher on a reduced version of the Wechsler Intelligence Scale for Children—Revised (WISC-R) (Wechsler, 1974). The Vocabulary, Similarities, Block Design, and Picture Completion subtests were given. According to Sattler (1982), this reduced version of the WISC-R has an expected correlation of .94 with the full-scale WISC-R. Subjects were tested between June and September in both years (1987, 1989), with the exception of three subjects from one family who were not tested until December on both occasions. The average time interval between testings was 24.7 months, with a range of 23 to 27 months.

The normally achieving sample was recruited in 1987 from five public schools in a predominantly middle-class area of Los Angeles county in two steps. First, parents of students scoring at or above grade level in overall reading (composite word recognition and comprehension) on a group achievement test were asked permission to test their child. Second, students whose families assented were given the same two screening tests that the dyslexics were given. Children were placed in the normal reader comparison group if they obtained a Woodcock Word Identification score at the 50th percentile or higher and an estimated WISC-R IQ score of 90 or higher. There were 12 subjects at each grade level from the 2nd through 8th grade, with the exception of the 2nd grade, from which 20 subjects were obtained. All normal readers were tested in the months of March, April, or May 1987.

General Description of Procedures

A battery of tasks designed to measure the component skills of phonological and orthographic processing, as well as aspects of written spelling was given to each subject. Three of the tasks were presented on an Apple IIe computer with a green monochrome monitor. In each task, trials began with a fixation point (a right-pointing arrow) displayed in the center of the screen. It was followed 500 ms later by a warning signal (the standard keyboard bell sound produced by the Apple IIe). The signal was followed 750 ms later by a word or pseudoword stimulus displayed immediately to the right of the fixation arrow. The fixation arrow was taken off the screen immediately prior to onset of the word or pseudoword. The stimulus remained on the screen until the subject pronounced it aloud (in the case of the pseudoword pronunciation task), or until a yes or no button was pushed (in the case of the homonym and orthographic verification tasks).

Voice responses were detected by means of a Gerbrands Model Voice Operated Relay connected to the computer. Pushbutton responses were obtained by means of a metal or wood response panel containing two 1-inch-diameter plastic buttons separated by 4 inches and mounted on a slanted surface. The left button was labeled "NO" and the right button "YES." The buttons were connected to two microswitches, which in turn were connected to the computer. The computer recorded latency from the onset of the stimulus on the screen to the onset of the vocalization or button press to the nearest millisecond. Response accuracy was recorded by keying in a response code to the computer in the case of the pronunciation task, and automatically by the computer in the case of the pushbutton tasks. Subjects were instructed on all three tasks to respond as quickly and accurately as possible. The computer calculated number correct and median latency on correct trials for each of the three tasks. Less than 1% of pronunciation trials was lost due to equipment malfunction, extraneous noise in the test environment, or experimenter error.

Tasks were administered in the order indicated below. These tasks were part of a larger battery. The complete battery was administered in four to five sessions each lasting 35–45 min.

Phonological Processing Measures

Phoneme deletion. In this task, the experimenter pronounced a pseudoword (e.g., "sparf"), the child repeated it to make sure s/he had accurately encoded it, and the child was then asked to pronounce it without one of the phonemes (e.g., "sparf" without the /p/ is "sarf"). The task was designed to tap the ability to analyze the phonemic constituents of spoken words. It is similar to several other tasks purporting to measure phonemic awareness. Of the many tasks of this type, phoneme deletion has been shown to be one of the most reliable among kindergarten subjects (Yopp, 1988). In addition, previous work by the authors has shown it to be free from ceiling effects among older children, adolescents, and adults (Manis *et al.,* 1990; Szeszulski & Manis, 1990).

There was a wide variety of items, including deletion of initial single consonants (e.g., delete /t/ from /tōp/), deletion of a portion of an initial consonant blend (e.g., delete /r/ from /grēb/; delete /s/ from /slōk/), deletion of a final single consonant (e.g., delete /f/ from /blif/), deletion of a portion of a final consonant blend (e.g., delete /l/ from /zelt/), and deletion of a portion of a consonant blend within a two-syllable word (e.g., /l/ from /glimsən/; delete /d/ from /gardēm/). There were four practice trials and 22 experimental trials. Right/wrong feedback was given on the practice trials, but not on the experimental trials. To be scored correct, the subject had to produce the entire response correctly. The split-half reliability (odd/even, Spearman–Brown corrected) of the phoneme deletion task was .85 for the total sample (dyslexics at time 1, CA and reading novel comparison groups combined).

Pseudoword pronunciation. The children were shown a single pseudoword on a computer screen and asked to pronounce it accurately and quickly into a microphone. Three types of pseudowords were included, 16 one-syllable pseudowords with common spelling patterns (e.g., nug, blate, yaid, and neap), 12 one-syllable pseudowords with no close orthographic neighbors ("nonanalog" pseudowords) (e.g., phuve, skoce, shairb) and 8 two-syllable pseudowords with common spelling patterns (e.g., metion, stining), for a total of 36 experimental stimuli. With the exception of the nonanalog pseudowords, all of the stimuli were created by changing one letter of a real word in order to form a nonsense word.

The purpose of the task was to measure the ability to translate an orthographic code into a phonological code. The stimuli without close orthographic neighbors provided a measure of ability to decode from print to sound at the level of individual consonant blends, vowels, and vowel and consonant digraphs.

All pseudowords were presented on the computer screen in oversized lowercase lettering created by a graphics program. The letters were approximately twice the size of the standard lowercase letters on the Apple

IIe. Four practice items were presented, and any errors in pronunciation were corrected by the experimenter. Following the practice, the 36 experimental items were shown. A single random order was used for all subjects, with all three types of pseudoword intermixed. No right/wrong feedback was given on experimental trials. The split-half reliabilities for the total sample for the number correct and reaction time measures, summing across conditions (odd/even, Spearman–Brown corrected), were .91 and .86, respectively.

Orthographic Processing Measures

Orthographic verification. In this task, children were asked to listen to the experimenter pronounce a word twice. They were then shown a spelling of the word on the computer screen and asked to decide whether it was correct (e.g., "woman"—woman) or not ("street"—streat) and press the appropriate yes or no button.

There were 6 practice and 28 experimental trials. The items used on experimental "yes" trials were: although, leave, machine, travel, woman, beside, sleep, surprise, health, beach, smile, library, police, and stomach. The items used on experimental "no" trials were all phonetic equivalents of a target word (target word in parentheses): amung (among), frend, (friend), leest (least), streat (street), baiby (baby), bizness (business), afrade (afraid), traid (trade), thred (thread), taist (taste), laff (laugh), saifty (safety), cumpleat (complete), throte (throat). The split-half reliabilities (odd/even, Spearman–Brown corrected) for the total sample, for the reaction time and number correct measures, were .84 and .51, respectively.

Homonym verification. This task required subjects to listen to the experimenter read a homonym aloud and use it in a sentence. A printed homonym was displayed on the computer screen. The subject decided whether the homonym on the screen was the correct one (e.g., "week–Monday is the first day of the week." . . . week) or not ("bear—The bear was hungry." . . . bare) and pressed the appropriate yes or no button.

There were 6 practice trials, followed by 28 experimental trials. The items used on experimental yes trials were: piece, whether, seem, week, son, tail, meat, board, raise, deer, flower, weigh, waste, and sale. The items used on experimental no trials (with the actual homonym prompted for in parentheses) were: road (rode), blue (blew), wood (would), sent (scent), pair (pair), weight (wait), hole (whole), break (brake), sell (cell), threw (through), male (mail), bare (bear), pale (pail), role (roll). The split-half reliabilities (odd/even, Spearman–Brown corrected) for the total sample, for the reaction time and number correct measures, were .87 and .66, respectively.

As with measures of orthographic processing used in past studies (Cunningham & Stanovich, 1990; Olson *et al.*, 1985; Stanovich & West, 1989), neither of the two tasks used in the present study can be considered to be a "pure" measure of orthographic processing, as it is possible that subjects phonetically recode the stimuli prior to retrieving and comparing an orthographic representation to the target word. A prediction that follows from this hypothesis is that subjects should make a large number of false positive responses. This prediction will be tested below. Nevertheless, in order to achieve high accuracy on both orthographic processing tasks, subjects must discriminate between correct and phonetically plausible spellings. Hence, they must access an orthographic representation at some point after the word is displayed on the screen.

Experimental Measures of Spelling

The study aims called for a measure of spelling ability. Since existing standardized spelling tests confound the phonological and orthographic aspects of spelling, two experimental tasks were designed to distinguish between the two types of spelling ability.

Pseudoword spelling. Subjects listened to the experimenter pronounce a pseudoword twice. The subject repeated it and any errors were corrected. The subject then spelled the pseudoword on a sheet of paper. Subjects were instructed to spell the nonsense word exactly as they heard it. There were 18 items, administered in the following order for all subjects: /dit/, /səg/, /täb/, /vam/, /fōp/, /jēt/, /vīt/, /glēd/, /chăm/, /səlt/, /blēth/, /thrədvərd/, /traüdəd/, /wifest/, /flīth/, /lōsiskəbəl/. Items were scored correct if the subject gave each phoneme in the item a phonetically plausible spelling. To be scored as phonetically plausible, the spelling of each phoneme had to occur at least once in the corpus of words tabulated by Hanna, Hanna, Hodges & Rudorf (1966). For example, acceptable spellings of /jēt/ included: jeet, jeat, jete, jiet, jeit, geet, geat, gete, giet, and geit. A liberal scoring criterion was adopted in the present study, as in a number of past studies (e.g., Bruck & Waters, 1988, 1990; Moats, 1983), because the intent of the task was to measure whether subjects could track the sounds of the pseudoword successfully and assign a plausible spelling to each sound. The split-half reliability (odd/even, Spearman–Brown corrected) for the total sample was .76.

Irregular word spelling. Subjects listened to the experimenter pronounce a word once, use it in a sentence, and pronounce it again. They were asked to spell each word on a sheet of paper. Each word had an irregular spelling–sound or sound–spelling correspondence or was a member of a homonym pair, thus necessitating the use of word-specific information to spell it. There were 30 items, administered in the following order for all subjects: said, two, your, one, shoe, people, where, their, gone, right, wear, there, sugar, write, enough, weigh, whole, course, eight, beauty, business, foreign, sergeant, schedule, limousine, champagne, psychology, silhouette, ensemble, and jeopardize. Four of the items were eliminated at the second testing to shorten the overall length: right, write, weigh, and eight. To avoid subjecting poor spellers to the entire list, the experimenter administered a minimum of 20 items to each subject and after that stopped whenever a subject had missed five in a row. The maximum score at Time 1 was 30, and the maximum score at Time 2 was 26. The split-half reliability (odd/even, Spearman–Brown corrected) for Time 1 scores for the total sample was .88.

RESULTS

Three sets of analyses are reported below. The first set was concerned with the construct validity of the measures of phonological and orthographic skill. Hierarchical regression analyses within groups were utilized to explore the independence of the two domains of processing. In a second set of analyses, comparisons of dyslexics' performance at each time period (Time 1 or Time 2) to appropriate chronological age (CA)- and reading-level-matched groups were carried out to address the issue of whether dyslexics caught up over the 2-year period to the level attained by normal readers. The third set of analyses concerned changes over the 2-year period in component word identification and spelling skills among dyslexics. Comparisons of means at Time 1 and Time 2 were used to assess developmental change. Correlations of Time 1 and Time 2 scores were used to assess the stability of individual differences in phonological and orthographic skill within the dyslexic sample. Normal readers' development could not be examined directly as this group was tested on only one occasion.

Correlational and Regression Analyses

The correlations among all of the major variables in the study for the Time 1 testing are shown in Table 2 for each group, dyslexics ($N = 21$), CA comparison group (5th-7th grade, $N = 36$), and reading-level (RL) comparison group (2nd-3rd grade, $N = 32$) with age and IQ partialled out. Accuracy scores are based on total percentage correct. Speed scores were calculated for each subject by taking the reciprocal of the median latency on correct trials only. Speed, rather than latency, scores were used in this analysis so that a positive correlation would be associated with better (i.e., more accurate, faster) scores. Table 2 reveals that speed and accuracy tended to be positively correlated for each of the three measures on which both scores were obtained. Hence, no evidence of speed–accuracy trade-offs was obtained. However, the speed–accuracy correlations were not statistically significant for any of the three measures, with the exception of orthographic verification for dyslexic children.

Table 2 reveals that Woodcock Word Identification was significantly correlated with pseudoword pronunciation accuracy and speed, and with orthographic verification accuracy and irregular word spelling for dyslexic children, independently of age and IQ. Word identification scores were

TABLE 2
AGE- AND IQ-ADJUSTED CORRELATIONS AMONG VARIABLES FOR DYSLEXICS AT TIME 1, READING LEVEL AND CA COMPARISON GROUPS

Variable	1	2	3	4	5	6	7	8	9	10
(A) Dyslexics (N = 21)										
1. Pseudoword pron. acc.	—	28	45	20	14	12	-30	82	26	57
2. Pseudoword pron. speed		—	23	38	09	03	10	46	09	44
3. Phoneme deletion			—	26	-15	33	-16	51	32	33
4. Ortho. verif. acc.				—	47	44	14	28	60	50
5. Ortho. verif. speed					—	05	48	04	40	30
6. Homonym verif. acc.						—	15	-16	43	09
7. Homonym verif. speed							—	-37	22	33
8. Pseudoword spelling								—	12	57
9. Irreg. word spelling									—	47
10. Woodwock Word Iden.										—
(B) Reading level comparison group (2nd–3rd grades) (N = 32)										
1. Pseudoword pron. acc.	—	08	69	36	22	22	05	65	32	44
2. Pseudoword pron. speed.		—	-06	25	27	-21	37	-10	28	22
3. Phoneme deletion			—	22	43	06	-04	51	06	19
4. Ortho. verif. acc.				—	-05	05	22	17	57	33
5. Ortho. verif. speed					—	07	53	-34	22	22
6. Homonym verif. acc.						—	13	16	34	33
7. Homonym verif. speed							—	-03	26	24
8. Pseudoword spelling								—	19	12
9. Irreg. word spelling									—	45
10. Woodcock Word Iden.										—
(C) CA comparison group (6th–8th grades) (N = 36)										
1. Pseudoword pron. acc.	—	32	31	16	30	04	19	32	43	25
2. Pseudoword pron. speed		—	37	08	18	26	10	06	32	31
3. Phoneme deletion			-	-01	-17	46	-22	65	26	22
4. Ortho. verif. acc.				—	26	25	11	04	38	05
5. Ortho. verif. speed					—	20	83	15	41	56
6. Homonym verif. acc.						—	-16	08	46	-10
7. Homonym verif. speed							—	-31	34	42
8. Pseudoword spelling								—	-02	10
9. Irreg. Word Spelling									—	48
10. Woodcock Word Iden.										—

Note. Correlations were significant at the .05 level (two-tailed) if larger than .43 for Part A, .36 for Part B and .34 for Part C.

significantly associated with pseudoword pronunciation accuracy and irregular word spelling for the RL comparison group, and with orthographic and homonym verification speed and irregular word spelling for the CA comparison group. The pattern of correlations among phonological and orthographic variables indicated some degree of independence of these two aspects of reading and spelling for the dyslexic and RL groups. For example, pseudoword pronunciation accuracy was more strongly related to pseudoword spelling and to phoneme deletion than to orthographic tasks for both the dyslexic and RL groups. The orthographic tasks showed generally weaker relationships with other variables, with the exception of orthographic verification accuracy, which correlated significantly with irregular word spelling, but not with any of the phonological variables for the dyslexic and RL groups. The CA group's pattern differed from the other two groups in that accuracy scores showed weak to nonexistent associations with other measures, phonological variables showed some moderate relationships with orthographic variables (e.g., phoneme deletion and homonym verification accuracy), and orthographic and homonym verification speed were strong predictors of irregular word spelling and word identification.

Thus, although the small sample size and variations in reliabilities of the measures make interpretation of differences in the sizes of correlations difficult, the data for the dyslexic and RL groups are consistent with the view that phonological and orthographic skill are partially independent domains and that both are related to word identification. The different pattern displayed by the CA controls may mean that speed, rather than accuracy, measures are the most important predictors at advanced levels of reading skill.

To further explore the independence of phonological and orthographic skills, hierarchical regression analyses were carried out separately for each group using pseudoword pronunciation accuracy and speed and orthographic verification accuracy and speed as the predictor variables and word identification as the criterion variable. The pseudoword pronunciation and orthographic verification tasks were chosen to represent the phonological and orthographic domains, respectively, as these variables showed higher partial correlations with the word identification variable than either phoneme deletion or homonym verification. The actual order of entry of variables for the first series of regressions was age, estimated WISC-R IQ, pseudoword pronunciation accuracy and speed, and finally orthographic verification accuracy and speed.

The purpose of this analysis was to explore whether orthographic skill accounted for reliable variance in word identification after age, IQ, and phonological skill were partialled out (in the same manner as in Cunningham and Stanovich, 1990). The cumulative R^2 and R^2 change at each step in the regression, as well as significance tests, are shown in Table 3.

TABLE 3

HIERARCHICAL REGRESSIONS PREDICTING WORD IDENTIFICATION SCORES FOR DYSLEXICS, READING LEVEL AND CA COMPARISON GROUPS—PHONOLOGICAL VARIABLES ENTERED BEFORE ORTHOGRAPHIC VARIABLES

Step	Variable	R^2	R^2 Change	*F* to enter
	(A) Dyslexics (*N* = 21)			
1	Age	.68	.68	2.52***
2	WISC	.69	.01	.88
3	Pseudoword pron. accuracy	.79	.10	1.68**
4	Pseudoword pron. speed	.82	.03	1.22
5	Ortho. verif. accuracy	.85	.03	1.77
6	Ortho. verif. speed	.87	.02	1.25
	(B) Reading level comparison group (*N* = 32)			
1	Age	.19	.19	1.62*
2	WISC	.19	.00	.25
3	Pseudoword pron. accuracy	.35	.16	1.61*
4	Pseudoword pron. speed	.37	.02	1.05
5	Ortho. verif. accuracy	.39	.02	.94
6	Ortho. verif. speed	.46	.07	1.33
	(C) CA comparison group (*N* = 36)			
1	Age	.21	.21	1.72**
2	WISC	.31	.10	1.46*
3	Pseudoword pron. accuracy	.35	.04	1.19
4	Pseudoword pron. speed	.39	.04	1.19
5	Ortho. verif. accuracy	.39	.00	.51
6	Ortho. verif. speed	.56	.17	1.81**

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

The second series of analyses (displayed in Table 4) was focused on the issue of whether phonological skill would account for reliable variance when entered after orthographic accuracy and speed.

Results for dyslexics and the RL group were similar and will be considered first. Table 3 reveals that pseudoword pronunciation accuracy accounted for a significant 10% of the variance in Woodcock Word Identification for dyslexics, and 18% for the reading level comparison group, even after age and IQ were partialled out, illustrating the importance of phonological decoding skills for isolated word identification. Pseudoword pronunciation speed and orthographic verification accuracy and speed did not account for significant amounts of variance for either group. Table 4 reveals that pseudoword pronunciation accuracy still accounts for a significant proportion of word identification variance, even when age, IQ, and orthographic verification are entered first. Orthographic verification accuracy accounted for similar amounts of word identification variance

TABLE 4

HIERARCHICAL REGRESSIONS PREDICTING WORD IDENTIFICATION SCORES FOR DYSLEXICS, READING LEVEL AND CA COMPARISON GROUPS—ORTHOGRAPHIC VARIABLES ENTERED BEFORE PHONOLOGICAL VARIABLES

Step	Variable	R^2	R^2 Change	F to enter
	(A) Dyslexics (N = 21)			
1	Age	.68	.68	2.52***
2	WISC	.69	.01	.88
3	Ortho. verif. accuracy	.77	.08	1.55*
4	Ortho. verif. speed	.77	.00	.60
5	Pseudoword pron. accuracy	.85	.08	1.70*
6	Pseudoword pron. speed	.87	.02	1.15
	(B) Reading level comparison group (N = 32)			
1	Age	.19	.19	1.62*
2	WISC	.19	.00	.25
3	Ortho. verif. accuracy	.28	.09	1.37
4	Ortho. verif. speed	.33	.05	1.16
5	Pseudoword pron. accuracy	.46	.13	1.59*
6	Pseudoword pron. speed	.46	.00	.59
	(C) CA comparison group (N = 36)			
1	Age	.21	.21	1.72**
2	WISC	.31	.10	1.46*
3	Ortho. verif. accuracy	.31	.00	.53
4	Ortho. verif. speed	.53	.22	1.93***
5	Pseudoword pron. accuracy	.54	.01	.79
6	Pseudoword rpon. speed	.56	.02	1.10

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

when entered before the phonological variables, but the R^2 change was significant for dyslexics only.

The analyses for the CA group (see Tables 3 and 4) revealed that only orthographic verification speed accounted for a significant proportion of word identification variance (whether entered before or after pseudoword pronunciation).

The correlational analyses indicated that phonological and orthographic skill are somewhat independent components of reading. However, the regression analyses did not provide strong support for the contention in previous studies (e.g., Cunningham & Stanovich, 1990) that orthographic skill accounts for unique variance in word identification after phonological skill is partialled out, with the exception of the CA comparison group, in which only the speed measure was a reliable predictor of word identification. Thus, for dyslexics and normal readers matched on reading level, phonological and orthographic skill appear to measure overlapping domains, and phonological skill appears to be the stronger predictor of word identification.

Comparisons to Grade-Level and Reading-Level Comparison Groups

Whether or not dyslexics "catch up" to the level of performance established by normal readers over a 2-year period can be addressed by comparing the dyslexics' scores at Time 1 and Time 2 with scores provided by good readers at corresponding grade levels at Time 1. Such a comparison tends to favor dyslexics, as they were exposed to the test stimuli twice, whereas the normal readers were only exposed a single time. However, it seems unlikely that practice effects would occur across a 2-year span.

Chronological age-matched comparisons. The dyslexic sample was closely matched in age to the 6th grade normal readers at Time 1 and to the 8th grade normal readers at Time 2. Table 5 lists mean age, estimated WISC-R and Word Identification scores, as well as scores on the experimental tasks. It can be readily seen that not only did dyslexics score far below the normal readers on nearly all measures at Time 1, but they showed no overall signs of catching up at the Time 2 comparison. The overall multivariate analysis of variance was significant for the Time 1–6th grade comparison, $F(13, 16) = 4.80$, $p < .01$, and for the Time 2–8th grade comparison, $F(13, 19) = 6.67$, $p < .001$. The CA comparison groups scored significantly higher than the dyslexics on all univariate tests, with the exception of age and estimated WICS-R IQ.

Reading-level comparisons. A fairly close matching of Woodcock Word Identification scores at Time 1 was obtained by comparing dyslexics to 2nd grade normals and at Time 2 by comparing them to the mean of the 3rd and 4th graders. Mean Woodcock scores, ages, estimated IQs and scores on all experimental tasks are shown in Table 5. Multivariate analyses of variance were significant for the Time 1–2nd grade comparison, $F(13, 23) = 3.66$, $p < .01$, and for the Time 2–3rd/4th grade comparison, $F(13, 31) = 12.86$, $p < .001$. Results of univariate analyses revealed that at Time 1 the dyslexics performed more poorly than the RL group on all accuracy measures except two-syllable pseudoword pronunciation, pseudoword spelling, and homonym verification no-trials. They were somewhat slower at pseudoword pronunciation (significant only in the case of the one-syllable stimuli), but no other RT differences were significant. Similar results were obtained for Time 2. However, the dyslexic–RL control difference was noticeably greater at Time 2 for four measures: nonanalog pseudoword pronunciation accuracy and RT, phoneme deletion, and irregular word spelling.

Comparison of yes and no trial data. The existence of response biases on the orthographic tasks was investigated by comparing time and accuracy on the yes and no trials. Yes trials were generally faster than no trials

TABLE 5
COMPARISON OF DYSLEXIC AND CA AND READING LEVEL COMPARISON GROUP MEANS

Variable	Dyslexic time 1	RL grade 2	CA grade 6	Dyslexic time 2	RL grade 3–4	CA grade 8
Age (in mos.)	143.0[a]	97.0[b]	143.3	167.7[a]	113.9[c]	166.3
	(24.0)	(4.3)	(3.9)	(25.2)	(6.9)	(4.5)
Estimated WISC-R	109.6	106.9	104.4	—	105.4	103.8
	(10.2)	(8.5)	(8.0)		(6.4)	(9.6)
Word indent.	4.0[a]	4.0	9.0	6.2[a]	6.1	11.4
	(1.0)	(0.6)	(1.6)	(1.8)	(1.7)	(1.6)
Pseudoword pron.						
One syll. (%)	69.0[a]	80.9[b]	93.2	77.4[a]	92.6[c]	93.2
	(18.8)	(15.6)	(8.1)	(18.5)	(7.7)	(7.8)
Two syll. (%)	28.0[a]	40.0	52.3	37.5[a]	51.0[c]	56.2
	(21.2)	(18.8)	(14.6)	(23.0)	(16.9)	(18.1)
Non analog (%)	40.1	56.2[b]	68.9	40.5	64.6[c]	70.1
	(24.5)	(21.1)	(11.8)	(24.5)	(15.0)	(19.6)
One syll. RT (ms)	2231	1606[b]	1061	1888	1086[c]	912
	(974)	(769)	(404)	(1115)	(225)	(196)
Two syll. RT (ms)	3797	3184	1825	2644	1898	1579
	(2394)	(1801)	(1177)	(2043)	(812)	(715)
Non analog RT (ms)	3335	3114	1607	2967	1818[c]	1299
	(1526)	(3394)	(812)	(2439)	(806)	(491)
Phon. Del. (%)	56.3	76.8[b]	81.1	59.7	89.6[c]	88.3
	(17.0)	(17.3)	(11.9)	(19.8)	(10.7)	(7.4)
Ortho. Verif. (%)						
Yes	76.9[a]	86.1[b]	95.2	87.1[a]	95.5[c]	96.4
	(12.1)	(8.9)	(6.4)	11.0)	(5.9)	(3.7)
No	67.7[a]	75.0	95.8	79.2[a]	89.0[c]	95.8
	(18.0)	(17.1)	(7.1)	(12.3)	(7.0)	(5.7)
Ortho. Verif. RT						
Yes	1479[a]	1575	860	(1142[a]	1269	740
	(662)	(374)	(175)	(334)	(368)	(164)
No	1472[a]	1685	853	1122[a]	1224	749
	(492)	(376)	(145)	(295)	(271)	(171)
Homonym verif. (%)						
Yes	79.6	87.9[b]	89.9	84.7	89.9	93.4
	(12.0)	(8.7)	(7.7)	(11.8)	(9.9)	(6.4)
No	52.7	70.4[b]	91.1	60.5	82.7[c]	86.3
	(17.6)	(10.4)	(8.7)	(16.2)	(12.4)	(8.3)
Homonym verif. RT						
Yes	1314	1509	768	1111	1263	670
	(517)	(434)	(206)	(456)	(474)	(129)
No	1499	1799	818	1254	1303	740
	(652)	(571)	(170)	(439)	(365)	(168)
Irreg. word spell (%)	33.3	44.8[b]	67.5	39.1	56.7[c]	72.4
	(16.0)	(9.1)	(9.0)	(12.9)	(10.0)	(11.2)
Pseudoword spell (%)	42.6[a]	48.9	58.3	54.8[a]	65.3[c]	69.0
	(20.0)	(17.4)	(17.6)	(19.7)	(12.5)	(10.4)

Note. Standard deviations in parentheses. All differences between columns 1 and 3 were significant except for age, WISC-R, and word identification; all differences between columns 4 and 6 were significant except for age and WISC-R.

[a] Significant difference between columns 1 and 4.
[b] Significant difference between columns 1 and 2.
[c] Significant difference between columns 4 and 5.

across groups, but differences were not significant for any group. All groups were significantly more accurate (p values less than .05) on yes than on no trials with the exception of the CA-matched groups at both grade levels (6th and 8th) on the orthographic verification task and the CA-matched group at the 6th grade level on the homonym verification task. The yes–no difference was particularly large on the homonym verification task for dyslexics at Time 1 and Time 2 and for the 2nd grade reading level comparison group, suggesting that younger and poorer readers were more susceptible to a yes response bias than older and better readers.

One interpretation of these findings is based on the assumption that a yes trial bias is due to a tendency to generate phonological codes for the letter strings. In this view, younger and poorer readers are more dependent on (or more prone to utilize) phonological strategies on the orthographic and homonym verification tasks. This interpretation is consistent with Bruck's reports that dyslexic children (Bruck, 1988) and adults (Bruck, 1990) are more susceptible than all but the youngest normal readers to spelling–sound regularity effects in word identification tasks. However, since the pseudohomophone and homophone spellings of the stimuli are orthographically similar to the correct spellings, a yes bias could also arise from a tendency to base responses on global visual similarity to the target word's spelling.

Change Over Time within the Dyslexic Sample

To evaluate the significance of changes within the dyslexic group over the 2-year interval, a repeated measures multivariate analysis of variance was conducted using all of the variables in Table 5. The overall F-test for the Time 1 vs. Time 2 comparisons was significant, $F(13, 5) = 8.50$, $p < .025$. Univariate analyses revealed significant improvements on the Woodcock Word Identification test over the 2-year period, $t(20 = 7.35$, $p < .0001$, as well as on two measures of phonological accuracy, one-syllable pseudoword pronunciation, $t(20) = 2.75$, $p < .05$, two-syllable pseudoword pronunciation, $t(20) = 2.54$, $p < .05$, and all four measures of orthographic verification, yes trial accuracy, $t(20) = 2.17$, $p < .05$, no trial accuracy, $t(20) = 3.40$, $p < .001$, yes trial RT, $t(20) = 2.40$, $p < .05$, and no trial RT, $t(20) = 3.98$, $p < .01$. In addition, a significant improvement was observed for pseudoword spelling, $t(20) = 3.30$, $p < .01$, but not for irregular word spelling.

Although there was no overall improvement on the irregular word spelling task, the significant improvement on the pseudoword spelling task suggested that the dyslexics might have made advances in the phonological accuracy of their spelling. Spelling errors on the irregular word spelling task were coded as phonologically appropriate or inappropriate using the same criteria employed in the scoring of the pseudoword spelling responses (i.e., any sound–spelling correspondence found in at least one English word was coded as phonologically appropriate). At Time 1, 51.6% of the dyslexic children's spelling errors were phonologically appropriate. This figure increased slightly to 57.3% at Time 2, but the change was not significant ($p > .11$). Variability was extremely high for both testing times (range: 18.8 to 73.3% at Time 1, and 23.1 to 87.5% at Time 2).

To summarize, dyslexic children were able to master new spelling–sound correspondences as well as to develop increased facility on one measure of ability to access orthographic codes in memory. Perhaps because of advances in these two related skills, they also showed a sizeable improvement on a standardized measure of word identification. However, they showed little progress on tasks for which it was essential to focus at the phonemic level (phoneme deletion, pronunciation of pseudowords with no neighbors). With regard to spelling, the dyslexics appeared to increase their knowledge of sound-to-spelling correspondences (pseudoword spelling) but did not advance significantly in the ability to spell irregular real words.

A somewhat different issue concerns the stability over time of individual differences among dyslexics in component reading and spelling skills. Table 6 shows correlations of all variables from Time 1 to Time 2. Age and estimated IQ at Time 1 were not significantly related to Time 2 scores, with the exception of the Time 1 age and Time 2 Woodcock scores. Values on the diagonal indicate the stability of each measure. Measures found to be stable were the phonological accuracy variables, orthographic verification time, irregular word spelling and Woodcock Word Identification. Looking only at the accuracy data, pseudoword pronunciation and phoneme deletion were more stable than either of the orthographic variables. When the stability values are corrected for attenuation due to unreliability, all of the tasks showed high stability (e.g., values above .75), with the exception of homonym verification. Both phonological and orthographic variables were effective predictors of Time 2 Woodcock scores, with pseudoword pronunciation and spelling showing the highest values. Again, when corrections for unreliability were made, all of the tasks except homonym verification showed moderate to high correlations with word identification. In general, speed measures were less stable and less predictive of Woodcock scores than accuracy measures.

DISCUSSION

The most important findings of the study concerned changes over time in the dyslexics' performance. Over the 2-year period, dyslexics gained 2.2 grade levels on the Woodcock Word Identification test. Since word identification skills are thought to be dependent on both phonological decoding and orthographic knowledge, this would imply that gains in these component skills occurred as well. Indeed, dyslexics made significant prog-

TABLE 6

INTERCORRELATIONS AMONG VARIABLES FROM TIME 1 TO TIME 2 FOR DYSLEXIC CHILDREN

	Time 2											
Variable	1	2	3	4	5	6	7	8	9	10	11	12
Time 1												
1. Age	98	—	25	12	27	07	29	11	24	16	30	48
2. Estimated WISC-R	24	—	−22	−29	00	−32	−38	09	−12	−14	−29	09
3. Pseudoword pron. acc.	58	—	77	27	73	07	50	02	57	41	48	65
4. Pseudoword pron. speed	09	—	48	13	04	09	33	00	06	31	37	31
5. Phoneme deletion	38	—	60	−18	74	21	18	03	21	53	27	44
6. Ortho. verif. acc.	20	—	31	02	24	38	47	43	06	68	84	43
7. Ortho. verif. speed	44	—	00	35	17	10	48	33	37	37	47	39
8. Homonym verif. acc	54	—	22	−27	40	05	28	18	14	23	52	20
9. Homonym verif. speed	34	—	−13	09	−08	19	38	32	21	05	30	21
10. Pseudoword spelling	47	—	74	25	60	−05	31	03	42	64	34	69
11. Irreg. word spelling	57	—	27	23	49	20	66	31	52	42	84	41
12. Woodcock Word Iden.	86	—	55	27	52	08	45	13	32	36	49	68

Note. Decimals are omitted. Values on the diagonal are time 1 to time 2 correlations for each variable (stability scores). Correlations were based on an N of 21, and were significant at the .05 level (two-tailed) if larger than .43.

ress on several measures of phonological processing and orthographic knowledge. However, they showed little or no progress on a measure of phonemic analysis, a decoding task requiring processing at the level of the phoneme, and a test of the ability to spell words with irregular spelling–sound (and sound–spelling) correspondences.

Comparisons of dyslexics to CA- and reading-level-matched groups suggested that dyslexics failed to catch up with these groups on any of the component skills and actually fell further behind on the three measures discussed above (pronunciation of nonsense words with no neighbors, phoneme deletion and irregular word spelling).

Previous studies have provided evidence that phonological awareness is strongly related to reading progress, although there is undoubtedly a bidirectional relationship between phonological awareness and learning to read (Bradley & Bryant, 1985; Ehri, 1987; Jorm & Share, 1983). What the results of the present study suggest is that dyslexics' phonological awareness lags behind their reading. Although the direction of causality cannot be inferred from essentially correlational data, the results are consistent with the hypothesis that causality in dyslexia is stronger from phonological awareness to reading than the reverse direction. The finding that irregular word spelling showed little improvement is at first glance hard to reconcile with the phonological deficit hypothesis. However, it is reasonable that difficult or unusual orthographic codes (as in the irregular word stimuli) may be more difficult to consolidate in memory for individuals who experience repeated failures at decoding the same words (Jorm & Share, 1983). Due to the greater need for precision in the orthographic representation for spelling tasks, as compared to that for reading tasks, it makes sense that irregular word spelling may be more "affected" by phonological deficits than orthographic verification and homonym verification. Further research utilizing training paradigms would be of value in testing this hypothesis.

The study also provided information on the stability of individual differences among the dyslexic sample. Pseudoword pronunciation, phoneme deletion, pseudoword spelling, irregular word spelling, and Woodcock Word Identification were somewhat more stable than the two orthographic recognition tasks. Higher stability of phonological measures is consistent with the view that phonological processing is a central difficulty in dyslexia that is established relatively early and persists over time. The relatively lower stability of the orthographic tasks is consistent with arguments (e.g., Cunningham & Stanovich, 1990; Olson *et al.*, 1989) that orthographic knowledge is partially related to experiential variables, such as exposure to print, and hence is a less stable trait. Unfortunately, no measure of exposure to print was given in the current study, so the hypothesis cannot be tested directly. Additional possibilities that cannot be ruled out at present are that stability was lower for the orthographic tasks owing to lower task reliability, or to age- and ability-related differences in the strategies subjects utilize on these tasks. Some evidence that subjects may shift away from phonological strategies as their overall skill in word identification increases was provided by the examination of yes–no trial differences.

In conclusion, the findings are broadly consistent with the prevailing view that problems in processing speech at the level of the phoneme and difficulties in mastering spelling–sound correspondences are central to the reading and spelling problems of dyslexic children (e.g., Jorm & Share, 1983; Siegel & Ryan, 1988; Stanovich, 1988). The present study offers the following additional clarifying points.

First, despite gains in phonological decoding over time, differences in relative phonological ability among dyslexics remain fairly stable. It would be of interest to determine how malleable this skill is by means of systematic training programs conducted with older dyslexic children (typically such programs are offered to elementary school age children).

Second, orthographic skill and certain aspects of phonological skill (e.g., knowledge of commonly occurring spelling–sound correspondences) improve over time, and these improvements may underlie fairly impressive improvements in overall word identification skill over the 2-year period studied.

Third, while orthographic skill may be partially independent of phonological skill, phonological skill may be the more important predictor of word identification for dyslexics and young normal readers. The present study failed to replicate earlier demonstrations that orthographic skill accounted for independent variance in word identification when phonological decoding was partialled out (Cunningham & Stanovich, 1990; Stanovich & West, 1989). A possible source of these interstudy differences was that measures of accuracy and speed were combined in the previous studies and kept separate in the present study. We found that speed of orthographic verification was a strong independent predictor of word identification for older normal readers. The independence of phonological and orthographic skill in the earlier studies may have been due largely to the speed measures. Future studies separating speed and accuracy will be necessary to evaluate this explanation.

Fourth, one reason why phonological and orthographic skill may be difficult to separate is that most measures of orthographic skill are contaminated by phonological processing. One source of contamination is a developmental one: individuals who are strong in phonological decoding will have more successful identifications of unfamiliar words and hence build up orthographic codes in memory more rapidly (Jorm & Share, 1983). An additional source of contamination is that subjects may find it difficult to avoid utilizing a phonological decoding strategy on the orthographic tasks. Our evidence indicates that older and better readers are less prone to the latter problem. Bruck (1990) obtained similar results in a comparison of adults with a history of dyslexia to younger good readers. The dyslexic adults showed large effects of spelling–sound regularity on word pronunciation for words with both high and low frequency of occurrence in print, whereas normal readers showed regularity effects only for low-frequency words. Bruck (1990) argued that normal readers decrease their reliance on phonological decoding with development, whereas dyslexic readers continue to use the "less mature" strategy, despite deficits in spelling–sound knowledge.

A final issue bearing on the interpretation of results concerns the differential effectiveness of the two measures of orthographic skill. Of the two, homonym verification had slightly higher split-half reliability, but was less consistently related to other orthographic variables and to word identification and less stable over time within the dyslexic sample. On the fact of it, both tasks appear to tap the subject's knowledge of the exact spelling of a word. Hence, there is no a priori reason why the homonym task would have performed more poorly as a measure of orthographic processing. One can speculate that homonyms were more similar orthographically than the words and pseudohomophones used as stimuli in the orthographic verification task. If this were the case, subjects might be more likely to respond "yes" due to visual similarity or to rely on a phonological recoding strategy. Both possibilities (higher visual similarity and greater reliance on phonological strategy) are consistent with the lower overall accuracy scores and the higher yes-trial bias for the homonym task noted above (see Table 5).

Some tentative recommendations for educational practices can be offered. First, since dyslexics made their smallest gains on measures of phoneme-level processing, it would seem useful to add such measures to batteries of diagnostic tests. This would be beneficial at both younger age levels, when intervention could be targeted at improving phonological awareness, and at older age levels, when there may be a problem in diagnosing a reading difficulty in an individual who has had considerable remediation. In support of the latter point, Bruck (1992) found deficits in phonological analysis among a subgroup of adults with a history of reading disability who had normal standardized reading scores. Second, and more important, the fact that gains in phonological awareness lag behind gains in reading suggests that intervention to improve phonological awareness may benefit reading. We are not aware of any intervention studies targeting phonological awareness in an older dyslexic sample, but such a study seems in order. Third, since the data indicate that dyslexics make progress in decoding during the early part of adolescence, reading curricula for older dyslexic students should continue to focus in part on enhancing decoding skills, rather than shifting entirely to the training of comprehension skills after the child attains a minimal level of decoding skill.

REFERENCES

Aaron, P. G., & Phillips, S. (1986). A decade of research with dyslexic college students. *Annals of Dyslexia,* **36,** 44–68.

Bradley, L., & Bryant, P. E. (1985). *Rhyme and reason in reading and spelling* (IARLD Monographs, No. 1). Ann Arbor: Univ. of Michigan Press.

Bruck, M. (1988). The word recognition and spelling of dyslexic children. *Reading Research Quarterly,* **23,** 51–68.

Bruck, M. (1990). Word-recognition skills of adults with childhood diagnoses of dyslexia. *Developmental Psychology,* **26,** 439–454.

Bruck, M. (1992). Persistence of dyslexics' phonological awareness deficits. *Developmental Psychology,* **28,** 874–886.

Bruck, M., & Waters, G. (1988). An analysis of the spelling errors of children who differ in their reading and spelling skills. *Applied Psycholinguistics,* **9,** 77–92.

Bruck, M., & Waters, G. (1990). Effects of reading skill on component spelling skills. *Applied Psycholinguistics,* **11,** 425–437.

Cunningham, A. E., & Stanovich, K. E. (1990). Assessing print exposure and orthographic processing skill in children: A quick measure of reading experience. *Journal of Educational Psychology,* **82,** 733–740.

Ehri, L. C. (1987). Learning to read and spell words. *Journal of Reading Behavior,* **19,** 5–31.

Frith, U. (1985). Beneath the surface of developmental dyslexia. In K. Patterson, J. Marshall, & M. Coltheart (Eds.), *Surface dyslexia* (pp. 301–330). London: Erlbaum.

Glushko, R. J. (1979). The organization and activation of orthographic knowledge in reading aloud. *Journal of Experimental Psychology: Human Perception and Performance,* **5,** 674–691.

Goswami, U. (1986). Children's use of analogy in learning to read: A developmental study. *Journal of Experimental Child Psychology,* **42,** 73–83.

Hanna, P. R., Hanna, J. S., Hodges, R. E., & Rudorf, E. H. (1966). *Phoneme–grapheme correspondences as cues to spelling improvement.* Washington, DC: U.S. Government Printing Office.

Jorm, A. F., & Share, D. (1983). Phonological recoding and reading acquisition. *Applied Psycholinguistics,* **4,** 103–147.

Juel, C., Griffith, P., & Gough, P. (1986). Acquisition of literacy: A longitudinal study of children in first and second grade. *Journal of Educational Psychology,* **78,** 243–255.

Kamhi, A., & Catts, H. (1989). *Reading disabilities: A developmental language perspective.* Boston: College-Hill Press.

Kitz, W. R., & Tarver, S. G. (1989). Comparison of dyslexic and non-dyslexic adults on decoding and phonemic awareness tasks. *Annals of Dyslexia,* **39,** 196–205.

Liberman, I. Y., & Shankweiler, D. (1985). Phonology and the problems of learning to read and write. *Remedial and Special Education,* **6,** 8–17.

Manis, F. R., Szeszulski, P. A., Holt, L. K., & Graves, K. (1990). Variation in component word recognition and spelling skills among dyslexic children and normal readers. In T. Carr & B. A. Levy (Eds.), *Reading and its development: Component skills approaches* (pp. 207–259). New York: Academic Press.

Moats, L. C. (1983). A comparison of the spelling errors of older dyslexic and second-grade normal readers. *Annals of Dyslexia,* **33,** 121–140.

Olson, R. K., Kliegl, R., Davidson, B. J., & Foltz, G. (1985). Individual and developmental differences in reading disability. In G. E. MacKinnon & T. G. Waller (Eds.), *Reading research: Advances in theory and practice* (Vol. 4, pp. 1–64). Orlando, FL: Academic Press.

Olson, R. K., Wise, B., Conners, F., Rack, J., & Fulker, D. (1989). Specific deficits in component reading and language skills: Genetic and environmental influences. *Journal of Learning Disabilities*, **22**, 339–348.

Pennington, B. F., Lefly, D. L., Van Orden, G. C., Bookman, M. O., & Smith, S. D. (1987). Is phonology bypassed in normal or dyslexic development? *Annals of Dyslexia*, **37**, 62–89.

Perfetti, C. A. (1985). *Reading ability*. New York: Oxford Univ. Press.

Sattler, J. (1982). *Assessment of children's intelligence and special abilities*, 2nd ed. Boston: Allyn & Bacon.

Seidenberg, M. S., & McClelland, J. L. (1989). A distributed, developmental model of word recognition and naming. *Psychological Review*, **96**, 523–568.

Siegel, L. S., & Ryan, E. B. (1988). Development of grammatical sensitivity, phonological, and short-term memory skills in normally achieving and learning disabled children. *Developmental Psychology*, **24**, 28–37.

Snowling, M. J. (1987). *Dyslexia: A cognitive developmental perspective*. New York: Basil Blackwell.

Stanovich, K. E. (1988). The right and wrong places to look for the cognitive locus of reading disability. *Annals of Dyslexia*, **38**, 154–177.

Stanovich, K. E., & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly*, **24**, 402–433.

Szeszulski, P. A., & Manis, F. R. (1990). An examination of familial resemblance among subgroups of dyslexics. *Annals of Dyslexia*, **40**, 180–191.

Treiman, R., Goswami, U., & Bruck, M. (1990). Not all nonwords are alike: Implications for reading development and theory. *Memory & Cognition*, **18**, 559–567.

Vellutino, F., & Scanlon, D. (1987). Phonological coding, phonological awareness and reading ability: Evidence from a longitudinal and experimental study. *Merril-Palmer Quarterly*, **33**, 321–363.

Wechsler, D. (1974). *Wechsler Intelligence Scale for Children—Revised*. New York: Psychological Corporation.

Woodcock, R. W. (1973). *Woodcock reading mastery tests*. Circle Pines, MN: American Guidance Service.

Yopp, H. K. (1988). The validity and reliability of phonemic awareness tests. *Reading Research Quarterly*, **23**, 159–177.

RECEIVED: October 11, 1991; REVISED: December 7, 1992