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Writing Problems in Developmental Dyslexia: Under-Recognized and Under-Treated,^{2,3}

Virginia W. Berninger^a, Kathleen H. Nielsen^a, Robert D. Abbott^a, Ellen Wijsman^{b,c}, and Wendy Raskind^{c,d}

^a Educational Psychology, University of Washington

^b Biostatistics, University of Washington

^c Medicine (Medical Genetics), University of Washington

^d Psychiatry and Behavioral Sciences, University of Washington

Abstract

The International Dyslexia Association defines dyslexia as unexpected problems of neurobiological origin in accuracy and rate of oral reading of single real words, single pseudowords, or text or of written spelling. However, prior research has focused more on the reading than the spelling problems of students with dyslexia. A test battery was administered to 122 children who met inclusion criteria for dyslexia and qualified their families for participation in a family genetics study that has been ongoing for over a decade. Their parents completed the same test battery. Although a past structural equation modeling study of typically developing children identified a significant path from handwriting to composition quality, the current structural equation modeling study identified a significant path from spelling to composition for children and their parents with dyslexia. Grapho-motor planning did not contribute uniquely to their composition, showing that writing is not just a motor skill. Students with dyslexia do have a problem in automatic letter writing and naming, which was related to impaired inhibition and verbal fluency, and may explain their spelling problems. Results are discussed in reference to the importance of providing explicit instruction in the *phonological, orthographic, and morphological processes of spelling* and in composition to students with dyslexia and not only offering accommodation for their writing problems.

Keywords

dyslexia; writing disability; motor skills; automatic handwriting; spelling; written composition

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Correspondence to first author at 322 Miller, Box 353600, University of Washington, Seattle, WA 98195-3600, or vwb@u.washington.edu, or 206-616-6311 (fax).

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Defining Developmental Dyslexia

Dyslexia is a word of Greek origin. It begins with a prefix that means impaired. Its base word means word. Individuals with developmental dyslexia exhibit impairment in word-level processes in written language, that is, in oral reading and written spelling. However, their verbal comprehension or listening comprehension is spared. Once they learn to read words they can usually understand reading material. (See Berninger, 2001a.) More than three decades of research in English speaking countries has identified three marker measures that are not oral reading or written spelling per se but tend to be impaired in dyslexics and explain their problems with learning written words: phonological coding, orthographic coding, and rapid automatic naming (RAN) (Berninger, Abbott, Thomson, & Raskind, 2001).

The current definition of dyslexia recommended by the International Dyslexia Association is unexpectedly low accuracy and/or rate of oral reading or spelling of neurobiological origin (Lyon, Shaywitz, & Shaywitz, 2003). Nevertheless, many diagnosticians and interventionists continue to focus only on the reading and not on the spelling problems of dyslexics. Dyslexia is typically thought to be a reading disorder. The purpose of the research reported here is to increase awareness among school psychologists that students with dyslexia may also have significant problems in writing skills that require assessment and instructional intervention.

Research findings are accumulating that document the writing problems in individuals with dyslexia. For adults with a history of dyslexia, spelling problems persisted through the life span (Bruck, 1993; Lefly & Pennington, 1991), especially in males (Lefly and Pennington, 1991). Connolly et al. (2006) found that college students with dyslexia made more spelling errors than a spelling-matched control. Both children and adults with dyslexia showed almost as many indicators of writing problems as of reading problems when both writing and reading were assessed (Berninger et al., 2001). Follow-up of participants in treatment studies for dyslexia showed that affected students often overcame their reading problems but then faced significant problems in spelling and written composition, but had difficulty finding services for their writing problems once they learned to read (Berninger, 2006).

Not All Reading and Spelling Problems Are Dyslexia

Children may struggle with learning to read and spell for many reasons and the reading and spelling problems are not always unexpected. For example, children with deafness or blindness, primary language disorder or selective language impairment, speech impairment, mental retardation, autism, pervasive developmental disorder other than autism spectrum disorder, specific developmental neurogenetic disorders (e.g., Down, fragile X, or William-Beuren syndromes), biological trauma due to severe prematurity, substance abuse of mother, head injury, or other specific written language learning disabilities (e.g. language learning disability affecting ability to use oral language to learn, Butler & Silliman, 2002; Wallach & Butler, 1994) are likely to have unusual difficulty learning to read and spell too. However, the etiology, most effective treatments, and prognosis may be different than for those with dyslexia (Berninger, 2006). Children with dyslexia and children with language learning disability (also referred to as specific language impairment) share a common phonological core deficit (Bishop & Snowling, 2004), but children with language learning disability also have significant problems in morphology and syntax (Berninger and O'Donnell, 2004). Some children with dysgraphia have problems specific to transcription skills—handwriting and/or spelling—without reading problems, but some children have both dysgraphia and dyslexia (Berninger, 2006). Results of this study generalize only to students with dyslexia as defined in this research and by the International Dyslexia Association.

Typically Developing Writers

Cross-sectional research, based on a recruited sample, representative of the US population in mothers' level of education and child's ethnicity with 50 girls and 50 boys at each grade level from 1st to 6th, identified three separable but interrelated skills in typical writing development: handwriting, spelling, and composition (Abbott & Berninger, 1993). Not only legibility but also automaticity (effortless and fast retrieval and production of legible letters) was shown to be important in handwriting (Berninger, Yates, Cartwright, Rutberg, Remy, & Abbott, 1992). Consistently at each grade level, handwriting automaticity had a significant and sizable pathway to length and quality of written composition but spelling did not (Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). The relationship between handwriting and composing or note taking has been replicated for samples of typically developing students in grades K to 12 (Jones, 2004) and college (Peverly, 2006; Connelly, Campbell, MacLean, & Barnes, 2006).

Family Genetics Study of Dyslexia

In a family genetics study, children are identified who meet research criteria for the disorder of interest, in this case, developmental dyslexia. These children are called probands who qualify their nuclear and extended family members for participation in the genetics study. A family genetics study begun over a decade ago included both reading and writing measures to characterize the behavioral expression of dyslexia in children and adults. Reading and writing measures were included that (a) met the definition of dyslexia described in the first section of the introduction, (b) represented variables discussed in the research literature as hallmark features of dyslexia, and (c) were psychometric measures with age norms from national standardization or large research samples representative of the United State population and could be administered across the life span. Although many individuals who initially struggle with reading and writing respond to early intervention, others continue to have persisting difficulty despite appropriate general education and supplementary instruction. Even when these students with persisting difficulties learn to read and spell at age expected levels and are said to be "compensated", they continue to show behavioral (Berninger et al., 2006) and brain (Shaywitz et al., 2003; Stanberry et al., 2006) markers of dyslexia. The behavioral markers have been used in studies around the world to identify the heterogeneous genetic basis of dyslexia. These studies have identified the chromosomes linked to specific behavioral measures of dyslexia. For example, accuracy of real word reading (Chapman et al., 2005), rate of real word reading (Igo et al., 2006), and accuracy of phonological decoding and rate of phonological decoding (Raskind et al., 2005) have shown linkage to different chromosomes.

Research Goals

The main goal of the current research was to determine whether individuals with dyslexia show the same pattern of relationships between transcription and composition as the typically developing writers had in the Graham et al. (1997) study in which handwriting was the unique predictor of composition. It is well known that research results may differ between unreferred and referred samples. The latter are typically biased to specific disorders, for example, a specific kind of learning disability, whereas the former is more likely to include normal variation and representation of a wider range of learners. Berninger et al. (2001, 2006) showed that children with dyslexia scored below the mean for age-peers on standardized measures of writing. The goal of the current research was to go beyond simply comparing affected and unaffected individuals on mean achievement in specific writing skills to employing structural equation modeling to examine patterns of relationships between transcription skills (handwriting and spelling) and written composition to determine if the relationship among the writing skills is different for typically developing writers and children and adults with dyslexia.

A secondary research goal was to dispell the notion that the writing problems of students with dyslexia reflect merely a motor skill. All too often it is mistakenly assumed that writing is

primarily a motor process, but see Abbott & Berninger (1993) for evidence that it is also an orthographic skill. Motor skills may be impaired in dyslexia (Wolff, Cohen, & Drake, 1984; Nicolson, Fawcett, & Dean, 2001), but results supporting an association between motor deficits and reading disabilities are inconsistent (Ramus et al., 2003). Results may depend on which aspect of motor function is studied. Motor skills for serial motor movements have an underlying timing dimension that may be impaired in dyslexia rather than motor skills per se (Wolff et al., 1984). In this research we compared two motor skills relevant to learning written language: grapho-motor planning (assessed by a timed task in which the thumb is touched to each finger in succession) and oral-motor planning (assessed by a timed task in which a set of alternating syllables contrasting in one sound are said repeatedly). Both these grapho-motor planning and oral-motor planning tasks involve timed motor maneuvers but with different end organs—hand or mouth. If dyslexics have a generalized motor impairment in fine motor function, both oral-motor and grapho-motor function should contribute uniquely to both written expression and oral reading. However, if dyslexics have a modality-specific motor impairment, then only one of these is likely to uniquely explain specific writing or reading skills.

We evaluated the role of motor processes in dyslexia within a working memory model, which proved fruitful in a recent family genetics study of dyslexia (Berninger et al., 2006). We used the finger succession task (Berninger & Rutberg, 1992), which uniquely predicted written composition in primary grade children (Berninger et al., 1992) and intermediate grade children (Berninger, Cartwright, Yates, Swanson, & Abbott, 1994), as the indicator of the grapho-motor factor, which may work with the *orthographic loop in working memory* to coordinate word forms and prepare them for written output (spelling) via the hand. We used a test of ability to repeat rapidly three alternating syllables—pa-ta-ka (Fletcher, 1978) as an indicator of the oral-motor planning factor for oral reading, which may work with the *phonological loop in working memory* to coordinate word forms and prepare them for oral output (oral reading) via the mouth.

A third research goal was to identify which processes other than motor skills, might explain the writing problems of students with dyslexia. The rapid automatic *letter naming* (RAN) deficit in dyslexia (Wolf, Bally, & Morris, 1986) has been well documented in research (Wolf & Bowers, 1999). In growth mixture modeling, RAN letters predicted class of response to spelling instruction based on correctly spelled words in composing (Amtmann, Abbott, & Berninger, in press). Rapid automatic *letter writing* is one of the best predictors of reading and writing skills in adults with dyslexia (Connelly, Campbell, MacLean, & Barnes, 2006). Dyslexics may, therefore, have a general deficit in automaticity (Nicolson & Fawcett, 1990), assessed by both rapid automatic naming of letters or rapid automatic writing of letters. Thus, we tested the prediction that a common factor underlies rapid automatic letter naming and rapid automatic writing, which contrast in modality of output (mouth or hand), in the children with dyslexia.

Because of evidence that dyslexia may be the result of an executive function deficit (Smith-Spark, Fisk, Fawcett, and Nicolson, 2003; Swanson, 1993, 2000) and that individuals with dyslexia are most likely to fall outside the normal range on measures of executive functions (Berninger, Abbott et al., 2006), we also examined whether specific executive functions might be related to automaticity of letter skills. Specifically we were interested in whether ability to inhibit, that is focus on the relevant and ignore the irrelevant, might contribute to development of automatic letter naming or writing. Alternatively, we wondered whether ability to access fluently names that go with letter codes in long-term memory might influence development of automatic letter naming or writing.

To summarize, we tested the hypothesis that handwriting automaticity would have a unique path to written composition in individuals with dyslexia as it has been shown to have in typically developing writers in grades 1 to 6. To rule out the claim that impaired writing in dyslexia

merely reflects a grapho-motor deficit, we tested the hypothesis that the motor problems in dyslexia involve oral motor planning and oral reading rather than grapho-motor planning in composition. Finally, we tested the hypothesis that, because dyslexia is the result of impaired automatic temporal integration of verbal codes and orthographic codes, both rapid automatic naming and rapid automatic letter writing load on the same factor. We then examined whether inhibition or verbal fluency was significantly related to rapid automatic letter naming and rapid automatic letter writing.

Method

Participants

Procedures for recruiting the sample, obtaining informed consent and assent, and ensuring that participants met research inclusion criteria and a complete description of all the measures in the test battery given to children and adults are detailed in Berninger et al. (2001 and 2006). Unexpectedly low word reading and spelling achievement (see introduction) was operationalized in reference to (a) Verbal IQ, an index of verbal comprehension, (b) the population mean (below a standard score of 100 on a scale with an SD of 15), and (c) evidence of failure to respond to supplementary or specialized instruction (based on phone interviews with parents and parent questionnaires with information on educational history). Standardized measures of accuracy and/or rate of oral reading single real words or pseudowords on a list or real words in a passage or of written spelling had to be at least one standard deviation (15 standard score points) below the Verbal IQ.

We used prorated Verbal IQ (information, similarities, vocabulary, and comprehension) rather than Full Scale IQ because research studies have shown it is a better predictor of reading achievement than Nonverbal IQ in referred and unreferred samples (Greenblatt, Mattis, & Trad, 1990; Swanson, Carson, & Sasche-Lee, 1996; Vellutino, Scanlon, & Tanzman, 1991). To qualify for the study, the student's Verbal IQ had to be in the upper 75% of the population because neurogenetic developmental disorders, which could be confounded with dyslexia, fall mostly in the bottom quartile of the intelligence distribution (e.g., Liederman, Kantrowitz, & Flannery, 2005). The same test battery could be given to both children and adults because all measures had age or grade norms. Children identified using this operational definition and their parents showed unexpectedly low reading and spelling achievement on multiple measures based on both absolute criteria (low achievement) and relative criteria (relative to Verbal IQ) and also associated processing deficits in phonological, orthographic, and/or rapid automatic naming skills, with number of such deficits predicting severity of dyslexia (Berninger et al., 2001).

Of the 122 children, 80 were male and 42 were female. Their average age was 138.3 months (SD = 20.6 months). Although the majority were European-American (88.5%). 5.7% were from ethnic minority backgrounds (3.3% Asian-American; 1.6% African-American; 0.8% Native American; and 3.3% other; ethnicity was not reported for 2.5%). Parental level of education (mother's level reported first and then father's) ranged from high school (5.7%; 13.3%) to community college/vocational training (22.1%; 24%) to college (52.1%; 36.7%) to graduate degree (19.8%; 25.8%); this information was missing for 0.8%. Based on the inclusion criteria, less than 5% of the children over the past decade met diagnostic criteria for attention deficit disorder.

Of the 244 biological parents, 115 fathers and 85 mothers (200) met the same inclusion criteria as their children on at least one measure. The adults were not as impaired as their children in mean level of achievement or number of impaired skills. Average age of the adults was 543.2 months (SD = 55.6 months). Their ethnic background differed slightly from the children some of whom were the offspring of ethnically diverse marriages. Most were European-American

(93.5%) and 5.5% were minority (2.5% Asian-American; 1.5% African-American; 0.5% Hispanic; 1.0% Native American); and 1% were other. The parents' level of education ranged from less than high school (1%) to high school (7%), to community college/vocational training (22%), to college (43.5%) to graduate degree (23.5%); no information was available for 3%.

Measures for Assessing Writing and Other Processes in Dyslexia

Verbal reasoning—For individuals 16 years of age or younger, prorated VIQs were based on Information, Similarities, Vocabulary, and Comprehension per the procedures in the manual for the *Wechsler Intelligence Scale for Children-III* (WISC-III; Wechsler, 1991). Reliability coefficients for the Verbal Comprehension Factor range from .91 to .95 for the 6–16 year old age range. For individuals 17 years of age or older, prorated VIQs were based on Information, Similarities, Vocabulary, Comprehension, and Digit Span per the procedures in the manual for the *Wechsler Adult Intelligence Scale-Revised* (WAIS-R; Wechsler, 1981); no reliability is reported for this prorated VIQ.

Handwriting legibility and automaticity—Handwriting was assessed using an alphabet task that requires the examinee to print lowercase manuscript letters from memory in alphabetic order; norms developed from a cross-sectional research program on writing from grades 1 to 9 (e.g., Berninger & Rutberg, 1992) were used. Scoring takes into account legibility and correct order of production within the first 15 seconds. Interrater reliability for this task is .97 (Berninger, Vaughn, Abbott, Rogan, Brooks, & Reed, 1997). See Berninger and Amtmann (2003) for construct validity studies.

Spelling—The *Wide Range Achievement Test-3rd Edition* (WRAT-3; Wilkinson, 1993), which has a reliability coefficient of .96, and the *Wechsler Individual Achievement Test-II* (WIAT-II; The Psychological Corporation, 2002), which has a reliability coefficient of .94, were used to assess the ability to spell dictated single words.

Written expression—Composition was assessed using the Written Expression subtest of the *Wechsler Individual Achievement Test-2nd Edition* (WIAT-II; The Psychological Corporation, 2002), which assesses different levels of language in producing written composition—word fluency, sentence construction, paragraph or essay construction. The Written Expression subtest reliability coefficient is .86.

Accuracy and rate of oral reading of connected text—The *Gray Oral Reading Test-Third Edition* (GORT-3; Wiederholt & Bryant, 1992) was used to assess oral reading of text. Graded passages were read orally by the examinee. Testing continued until basals and ceilings in rate and accuracy were established according to the instructions in the manual. Test-retest reliability is .90 for accuracy of oral reading and .87 for rate of oral reading.

Phonological word form—Three tasks from the *Comprehensive Test of Phonological Processing* (CTOPP; Wagner, Torgesen, & Rashotte, 1999) were given. The Elision subtest (test-retest reliability coefficient = .82) requires the examinee to repeat a word with a phoneme deleted. The Phoneme Reversal subtest (test-retest reliability coefficient = .79) assesses the ability to break words into phonological segments in order to reorder the sounds. The Nonword Memory task from the prepublication version of the CTOPP (Wagner et al., 1999) assesses ability to orally reproduce spoken pseudowords (test retest reliability coefficient = .80).

Orthographic word form—Three measures from the *Process Assessment of the Learner* (PAL; Berninger, 2001b) were given and transformed into z-scores using the mean and SD for each grade. The Receptive Coding subtest requires judgment about the identity and order of

letters in briefly exposed written words that are encoded into temporary memory storage. Internal reliability coefficients for the Receptive Coding subtest range from .61 to .76 for grades 1 through 6. The Expressive Coding subtest measures the ability to code written words into temporary memory and reproduce all or parts of them in writing. Internal reliability coefficients for the Expressive Coding subtest range from .86 to .88 for grades 4 through 6. The Word Choice subtest, which is an adaptation of Olson, Forsberg, Wise, and Rack (1994), assesses speeded access to precise word spellings in order to choose the correctly spelled word among sets of words pronounced the same. Internal reliability coefficients for the Word Choice subtest range from .66 to .89 for grades 1 through 6.

Morphological word form—Morphological processing was assessed using two tasks developed by Carlisle (2000) and two tasks described in Nagy, Berninger, Vaughan, and Vermeulin (2003) and Nagy, Berninger, and Abbott (2006). These tasks were read to the child who responded orally and did not have to read or write to perform the task correctly. Although Carlisle administered her tasks both orally and in writing, impaired spelling of many of the participants made it impossible to give the written version of the task. The Carlisle Decomposition tasks (Carlisle, 2000) assesses ability to decompose words into their component parts (test-retest reliability over a one-year interval, .62). The Carlisle Derivation Task assesses ability to generate new words, using morphemes, from a word base (test-retest reliability over a one-year interval, .61). For both Decomposition and Derivation, the transformed word is created for a specific sentence context. The Morphological Signals task requires the examinee to select one of four morphological word forms that contains an inflectional or derivational suffix that fits a sentence context (test-retest reliability over a one-year period, .71). The Comes From task (reliability studies in progress) requires the examinee to judge whether a word is or is not derived from a base word, that is, whether the target word and base word are semantically related. These measures have construct validity for the assessment of reading and writing skills in elementary school (Nagy et al., 2003) and middle school (Nagy et al., 2006) students.

Rapid automatic naming (RAN) and switching (RAS)—RAN and the RAS (e.g., Wolf, 1986; Wolf et al., 1986; Wolf & Biddle, 1994) were given. The tasks require the oral naming of rows of a constant category (RAN: letters) or switching categories (RAS: letters and numbers or letters, colors and numbers). The RAN/RAS tasks require not only the retrieval of a familiar phonological code for each stimulus but also coordination of phonological and visual (color) or orthographic (alphanumeric) information quickly in time. Test-retest reliability over a nine-month intervention was .65 for RAN and .81 for RAS (Berninger et al., 2001). RAN is thought to assess temporal efficiency of the phonological loop, whereas RAS is thought to assess executive functions for switching mental set rapidly in time during phonological access.

Color word-form and verbal fluency measures—Three subtests of the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001) were given because they have been shown to have construct validity for clinically assessing dyslexia (Berninger & O'Donnell, 2004): Color Word-Form Inhibition and Inhibition/Switching and Verbal Fluency Letters. The first two are thought to assess executive functions for language, whereas the last is thought to assess the time sensitive phonological loop. Test-retest reliability coefficients for the D-KEFS Color-Word Form subtests range from .62 to .76. The Inhibition subtest measures the time required to rapidly name the ink color of color words written in a different color of ink; this score reflects the ability to suppress irrelevant information (name of color word) and attend to relevant information (color of ink). The Inhibition/Switching subtest measures ability to switch attention rapidly between two changing tasks with minimal interference between the two tasks—naming ink color (when word is not in a box) and naming words (when they are in a box). The Verbal Fluency subtest of the D-KEFS (Delis et al., 2001) has test-retest reliability coefficients that range from .36 to .80.

Grapho-motor and oral-motor planning—Grapho-motor planning was assessed using the PAL (Berninger, 2001b) timed Finger Succession subtest (test-retest reliability coefficients range from .87 to .89) that requires touching the thumb to each finger in sequence while hands are held in air out of sight. Oral-motor planning was assessed using a timed task that required repetition of the oral sequence PaTaKa on the Time-by-Count Test Measurement of Diadochokinetic Syllable Rate (Fletcher, 1978); no test-retest reliability reported.

Data Analyses

Structural equation modeling—EQS 6.1 (Bentler & Wu, 2006) was used for (a) confirmatory factor analyses to evaluate the measurement model (see Berninger, Abbott et al., 2006), (b) structural modeling to evaluate which paths from the predictor factors to the writing or oral reading outcomes are statistically significant and account for unique variance in the outcome; and (c) hierarchical structural equation modeling to evaluate how much additional variance in the outcome was explained by systematically adding additional predictor variables. Confirmatory factor analysis has the advantage that latent factors extracted for multiple indicators may provide more reliable measurement of the constructs in the models than do single observable measures alone. Structural equation modeling has the advantage that the structural relationships among predictor factors and the outcome factors can be analyzed to identify the statistically significant paths—those that account for unique variance in the outcome beyond the shared covariance among predictor factors. Hierarchical structural equation modeling has the advantage that the contribution of each component to explaining the total variance accounted for by the model can be systematically evaluated as specific components are added to others. In some instances, fitting the structural models required (a) extraction of a second order factor based on the first order factors, or (b) a new factor that combined two or more predictor factors. For example, for children the phonological loop and executive function factors could be modeled as separate factors within a working memory architecture, but for adults, they were highly correlated and were modeled as a combined factor.

We also applied structural equation modeling to a set of factors selected to represent the three components of working memory (word form storage, time-sensitive phonological loop, and executive functions supporting language) as in a prior study (Berninger, Abbott et al., 2006). Composing places enormous demands on the limited resources of working memory, which uniquely predicts written composition in typically developing writers (e.g., Swanson & Berninger, 1995). The concept of working memory has evolved since first described on the basis of three components: phonological or visual-spatial storage unit, an articulatory loop for maintaining information in the temporary storage unit, and a central executive (e.g., Baddeley, 1986; Hitch & Baddeley, 1976). Current models allow for other kinds of storage, for example, an episodic buffer for storing novel stimuli (e.g., Baddeley, 2002) and three word forms—phonological, orthographic, and morphological (Berninger, Abbott et al., 2006; Richards et al., 2006). The articulatory loop that maintains information in temporary memory through speech rehearsal has been reconceptualized as the time-sensitive *phonological loop*, which guides the learning of new words through overt naming (e.g., Baddeley, Gathercole, & Papagno, 1998). The central executive, which has not only capacity but also attention resource limitations, is not a single function but more likely a set of independent and interrelated functions. Recent research has shown that two executive functions—inhibition and verbal fluency—are particularly important (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000).

We used a second order factor underlying phonological, orthographic, and morphological word forms based on Berninger et al. (2006), which uniquely predicted spelling in children with dyslexia. To conserve journal space, we provide an overview of the themes in the results of the data analyses, but more complete data analyses, including correlations, standard deviations,

and model fit parameters, which were excellent, and the results are available from the third author.

Results

Written and Oral Language Skills in Children and Adults with Dyslexia

Children's language profiles—Children with dyslexia were impaired in handwriting (1.1 standard deviations below the mean), spelling (1.03 standard deviations below the mean), and written composition (slightly more than one standard deviation below the mean). The children did not have, on average, related oral language problems as assessed with behavioral tests (e.g., in morphological and/or syntactic awareness) or histories of significant language delay or oral language problems during the preschool years. Such children exist in school, clinical, and research populations but were not the ones identified using the inclusion criteria for this research.

Adults' language profiles—Adults with dyslexia markers were less impaired than their children in handwriting (about $-1/3$ SD below the mean) and spelling and composing (at or near the population mean). The notable persisting oral language weakness in affected adults was in repetition of nonwords on the CTOPP ($M=7.09$, $SD=1.93$), which fell in the low average range. Their CTOPP elision ($M=9.03$, $SD=2.72$) and phoneme reversal ($M=9.35$, $SD=3.23$) were closer to the population mean. All their morphological skills (based on z-scores for large, unrefereed, representative research samples) were near and above the population mean.

Relationship of Transcription to Composition in Dyslexia

Spelling, a genetically based deficit in dyslexia (Wijsman et al., 2000), was the unique predictor of written composition in children and adults with dyslexia (Table 1). These results differ from those for typically developing children (Graham et al., 1997). They also differ from those for young adults, for whom, letter writing automaticity explained note taking, which in turn explained test performance (Peverley, 2006). However, for a sample of college students with self-reported history (rather than clinical diagnosis) of dyslexia, who may also have had dysgraphia, both spelling and handwriting automaticity contributed uniquely to quality of composing (Connolly et al., 2006).

Motor Deficits in Dyslexia

Grapho-motor planning—Grapho-motor planning did not contribute uniquely to written expression in either the children (Table 2) or adults (available upon request) with dyslexia. For children with dyslexia, grapho-motor planning was significantly correlated only with word form and not with phonological loop, executive support, or written expression. Only the word form factor contributed uniquely to written expression (Table 2). For adults with dyslexia markers, grapho-motor planning was significantly correlated with the word form factor and the combined phonological loop and executive factor, but, as in the children, only the word form factor contributed uniquely to written composition. Hierarchical structural equation modeling showed that grapho-motor planning explained no additional variance beyond that explained by the other components in the model for children (40%) and only an additional 2% beyond that explained by the other components in the model for adults (50%). Thus, grapho-motor planning does not appear to be as direct an influence on composition as is spelling in children with dyslexia. However, grapho-motor planning may contribute indirectly to composition through the orthographic word form in children and adults with dyslexia.

Oral-motor planning—The structural modeling showed that for children with dyslexia (Table 3), only the word form factor contributed uniquely to their *oral reading accuracy*, whereas for adults with dyslexia markers (results available upon request), each working

memory component--word form, combined phonological loop/executive support, and oral-motor skill--contributed uniquely to *oral reading accuracy*. However, hierarchical structural equation modeling showed that in children the oral-motor factor only added 2% variance to the total variance (58%) already explained by the set of the other factors; and in adults it added only 1% more variance than the total variance (78%) already explained by the set of the other factors.

For children, all the single components in the model were significantly correlated except oral-motor planning and *reading rate*. Yet, the results of the structural equation modeling showed that the oral-motor factor, along with the working memory components in the model, contributed uniquely to *oral reading rate* (Table 3), suggesting that the contribution of oral-motor planning is only evident in children with dyslexia when it has to be orchestrated with other working memory components for the purposes of fluent reading. In contrast, for the adults with dyslexia markers (available upon request), the working memory components but not oral-motor planning contributed uniquely to *oral reading rate*. As was the case with oral reading accuracy, hierarchical structural equation modeling showed that the oral-motor planning factor added little to explaining individual differences in oral reading rate--3% to the 50% already explained by all the other factors in the children and 1% to the 75% accounted for by all the other factors in adults.

Summary—Taken together the results for grapho-motor planning and for oral-motor planning are consistent with the conclusion that dyslexia is not characterized by a generalized fine motor planning deficit across modalities, even when the task is constant—timed sequential motor movements. Grapho-motor planning did not contribute uniquely to written composition, but oral motor planning did to oral reading—to its fluency in children with dyslexia and to its accuracy in adults with dyslexia.

Automatic Letter Processing

For children with dyslexia average performance on both RAN for letters and alphabet writing was more than one standard deviation below the mean (Berninger et al., 2006). Principal component analysis showed that for children with dyslexia automatic letter naming and writing loaded on the same component. Loadings were RAN letter .687, automatic letter writing -.872, and total time letter writing .768. For adults, principal components analyses also showed that the same measures loaded on the same component; loadings were RAN letter .721, automatic letter writing -.864, and letter writing total time .900.

Predictors of Automatic Letter Skills

Multiple regression was used to identify which specific executive functions might contribute uniquely to automatic letter processing, as a function of whether the mouth or hand was involved. Results in parentheses indicate the standardized beta weights, *t*-values, and *p*-values, respectively. For children, D-KEFS Verbal Fluency Letter ($\beta = -.184$, $t(117) = -2.174$, $p = .032$) and D-KEFS Inhibition ($\beta = -.385$, $t(117) = -4.554$, $p < .001$) contributed uniquely to *rapid naming of letters* (total variance accounted for was 20.9%, $F[2,117] = 15.16$, $p < .001$); and D-KEFS Verbal Fluency Letter ($\beta = .218$, $t(118) = 2.604$, $p = .01$) and D-KEFS Inhibition/Switching ($\beta = .361$, $t(118) = 4.307$, $p < .001$) contributed uniquely to *automatic letter writing* (total variance accounted for was 19.3%, $F[2,118] = 13.89$, $p < .001$). For adults, D-KEFS Verbal Fluency Letter ($\beta = -.206$, $t(198) = -3.312$, $p = .001$), D-KEFS Inhibition ($\beta = -.277$, $t(198) = -3.665$, $p < .001$), and D-KEFS Inhibition/Switching ($\beta = -.275$, $t(198) = -3.696$, $p = .001$) contributed uniquely to *rapid naming of letters* (total variance accounted for 37.7%, $F[3,198] = 49.27$, $p < .001$); and D-KEFS Verbal Fluency Letters ($\beta = .339$, $t(195) = 5.024$, $p < .001$) contributed uniquely to *automatic letter writing* (total variance accounted for 11.5%, $F[1,195] = 25.24$, $p < .001$). Thus, individual differences in inhibition or fluency may influence automatic letter naming (output

through the mouth) or automatic letter writing (output through the hand), in children and adults with dyslexia.

Discussion

Relationship between Transcription and Composition

The first and main hypothesis was not confirmed. Dyslexics did not show the same relationship between automatic letter writing and written composition as typically developing writers did during the school years (Graham et al., 1997) or between handwriting and note-taking as typically developing writers during the college years (Peverly, 2006). Word spelling, rather than automatic letter writing, contributed uniquely to the written composition of both children with dyslexia and adults with markers of dyslexia. This finding is consistent with the hallmark feature of dyslexia—it is disorder characterized by impairment in learning to read and spell written *words*. However, some college students may have both dyslexia and dysgraphia in which case both handwriting automaticity and spelling may contribute to the quality of their composing (see Connolly et al., 2006). Later in the discussion we discuss how letter writing, which has direct links to composition in typically developing students, may influence written spelling in individuals with dyslexia, which in turn exerts direct influences on composition in individuals affected with this specific learning disability. However, we first rule out grapho-motor skills as the major source of difficulties in the written composition of students with dyslexia, despite a widely held belief that writing is primarily a motor skill.

Grapho-Motor Skills and Writing Problems in Dyslexia

Grapho-motor planning did not contribute uniquely to written composition in children with dyslexia or adults with dyslexia markers. In contrast, multiple regressions showed that grapho-motor planning did contribute uniquely to the composition of typically developing primary (Berninger et al., 1992) and intermediate grade (Berninger et al., 1994) students. However, even in typically developing students orthographic word form coding, but not grapho-motor planning, contributed uniquely to handwriting (Abbott & Berninger, 1993).

For the children with dyslexia, the word-form factor was a unique contributor to composition when grapho-motor planning and other working memory components were included in the structural model (Table 2). However, grapho-motor planning was significantly correlated with the word form factor. An *orthographic loop in working memory may link orthographic word forms and the hand*, just as the phonological loop in working memory links phonological word forms and the mouth. Other research studies are currently exploring this hypothesis. The finding most relevant to understanding the writing problems in dyslexia is that it is the relationship between the grapho-motor planning and the word form factor that is more important than grapho-motor planning alone in predicting written composition. This finding is consistent with the fact that dyslexia is primarily a disorder in word-level written language processing.

Automatic Letter Skills and Spelling Problems in Dyslexia

Rapid automatic naming and rapid automatic letter writing loaded on the same factor. Rapid automatic naming has been shown to be a predictor of classes of responding to spelling instruction (Amtmann et al., in press). Although rapid automatic letter writing did not contribute uniquely to written composition in children with dyslexia, a general automaticity factor, indexed by rapid automatic naming and rapid automatic writing, may exert some influence on the spelling skills of children and adults with dyslexia. Those spelling skills do contribute uniquely to the composition of individuals with dyslexia. Thus, automatic letter writing may be a distal influence on spelling, which is a proximal influence on written composition.

Predictors of Automatic Letter Skills

Executive functions, such as inhibition and verbal fluency, did not uniquely directly predict written composition of children with dyslexia (Table 2) as they did for typically developing writers (Altemeier, Jones, Abbott, & Berninger, 2006). Yet, inhibition and verbal fluency influenced automatic letter skills in children with dyslexia. Letter naming or letter writing skills may not automatize normally unless children can inhibit what is irrelevant and focus on what is relevant or can access verbal information fluently in long-term memory. Hooper, Wakely, de Kruif, & Schwartz (2006) have shown the benefits of training executive functions on spelling. Further research is needed on effective executive function instruction for helping individuals with dyslexia develop automatic letter skills.

Educational Applications

Prevention and persistence—Early intervention can prevent writing problems (Berninger, Rutberg et al., 2006). However, some students have biologically based specific learning disabilities that influence the ease with which they learn and use written language throughout schooling. These individuals may require ongoing treatment throughout schooling (Berninger, 2006). Even though the problems are persisting, specialized instruction has been shown to be effective in improving the writing skills of students with dyslexia in grades 4 to 9 (Berninger et al., in press).

Diagnosis—At a time in education when the importance of science supported instructional practices is being emphasized, school psychologists have an important role to play in implementing science supported diagnostic practices for differential diagnosis of specific learning disabilities. Although special education law does not specify criteria for defining dyslexia, research has identified criteria for doing so (Berninger, 2001a, Berninger et al., 2001, 2006; Lyon et al., 2003). Research is also identifying criteria for language learning disability, in which verbal comprehension is not always spared because of associated impairments in morphological and syntactic awareness in addition to the phonological awareness impairment (Berninger & O'Donnell, 2004). Further research is needed on which transcription and other oral language skills uniquely predict the composition of students with language learning disability. Future research should also address differential diagnosis of written language disabilities because there may be treatment implications.

Dyslexics whose verbal comprehension is spared may *benefit from* specialized instruction in phonological awareness and its links to spelling, whereas those with language learning disability, whose verbal comprehension is typically not spared due to morphological and syntactic awareness problems, may require specialized instruction in morphological and syntactic awareness in addition to phonological awareness and their links to spelling. All students with dyslexia will probably benefit from explicit instruction in phonological, orthographic, and morphological awareness for spelling, but those with language learning disability may require greater intensity and duration in such instruction. Schools psychologists can play an important role in helping to disseminate the growing body of research about students who have oral language as well as written language impairment (Catts, & Kamhi, 2005), which is different from dyslexia that is not associated with selective oral language impairment other than phonological processing. Dyslexia exists, dyslexia is diagnosable, but not all reading disabilities are dyslexia.

Accommodation plus explicit instruction rather than accommodation only—

Children with dyslexia should be screened for writing disabilities and if at risk given early intervention and monitored for writing progress. They should continue to receive specialized intervention until all their writing as well as reading skills reach expected level based on verbal comprehension. Given the importance of the third to fourth grade transition when writing

expectations increase and of integrating writing-reading connections in grade 3 and beyond (Altemeier et al., 2006), it is important to screen for and provide instructional intervention for writing throughout the elementary school years. Once dyslexics respond to instructional intervention for their reading problems, they should not be dismissed from special services without consideration of whether they need ongoing, explicit instruction in writing (handwriting, spelling, and/or composing) throughout the upper elementary and middle school and possibly high school years. Accommodations may be necessary but are seldom sufficient. If their writing problems are untreated, students with dyslexia are often unable to complete written assignments successfully and pass high stakes tests, both of which are necessary to graduate from high school with a diploma and succeed in most jobs.

Teaching spelling—The current research results point to the importance of a link between spelling and written composition. Many participants in our research studies lament that they cannot write compositions that express their ideas without limiting those ideas to the words they think they can spell without embarrassment. One of the outcomes of the whole language movement was that schools not only minimized the importance of decoding instruction in reading but also dropped spelling programs altogether or deemphasized spelling instruction (Dreyer, Luke, & Melican, 1995). Not only students with dyslexia but also typically developing writers may not get sufficient systematic instruction and practice in spelling. The myth that spelling instruction is not important in an era of computers when users can rely on spell check, though unfounded, persists. Spell checkers provide a way to self-monitor typos but only if the user can recognize the correct spelling; spell checkers do not help poor spellers generate correct spellings.

The spelling program for students with dyslexia should include explicit instruction in phonological, orthographic, and morphological awareness of word forms, their parts, and their interrelationships. Research supported instructional approaches for this goal are widely available (e.g., Bear, Iverson, Templeton, & Johnson, 2000; Dixon & Englemann, 2001; Fry, 1996; Henry, 2003; Masterson, Apel, Wasowicz, 2002) but not yet widely implemented in individual educational programs for students with dyslexia in upper elementary, middle school and high school. Likewise, there are programs for teaching strategies for self-regulation of composition (Carlisle, 1996; Graham & Harris, 2005).

Conclusions

An appropriate education for students with dyslexia includes explicit, systematic instruction for *both* writing and reading until they can perform at grade level or above in *both* writing and reading. Such instruction should focus on spelling, including awareness and coordination of phonological, orthographic, and morphological word forms and their parts, and composition. Dyslexics should not be dismissed from special education until their writing as well as reading problems resolve. They may need ongoing *explicit instruction in writing and not just accommodations*.

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Table 1

Paths (Standardized) and Z Statistics from Structural Equation Models for Handwriting and Spelling Predictor Factors and WIAT II Written Expression Outcome for 122 Children with Dyslexia and 200 Affected Adults with Dyslexia Markers

	Handwriting^a		Spelling^b	
	Path	Z	Path	Z
Children's Written Expression	-.22	1.79	.46	4.15 ***
Adult's Written Expression	.05	0.66	.68	8.04 ***

*
p<.05

**
p<.01

p<.001

^a Indicators: UW Alphabet Task (accuracy in the first 15 seconds and total time);

^b WRAT3 Spelling and WIAT-II Spelling

Table 2
Paths (Standardized) and Z Statistics from Structural Equation Models for Working Memory and Grapho-Motor Planning Predictor Factors and WIAT II Written Expression Outcome for 122 Children with Dyslexia

Predictor Factors for Written Expression Outcome					
2 nd Order Word Form ^a		Phonological Loop ^b		Executive Support for Language ^c	
Path	Z	Path	Z	Path	Z
	3.80 ***	.30	.93	-.03	-.09
				-.01	-.13

p<.001

^aIndicators: Based on phonological, orthographic, and morphological word forms

^bBased on RAN-letters and D-KEFS Verbal Fluency—Letters

^cBased on RAS-Letters and Numbers, RAS-Letters, Numbers, and Colors, D-KEFS Inhibition and Inhibition/Switching

^dBased on Grapho-Motor Planning (dominant and non-dominant hands)

Table 3
Paths (Standardized) and Z Statistics from Structural Equation Models for Working Memory Component and Oral-Motor Planning Predictor Factors and GORT Oral Reading Accuracy and Rate Outcomes for 122 Children with Dyslexia

Predictor Factors for Oral Reading Outcomes					
2 nd Order Word Form ^a		Phonological Loop ^b		Executive Support for Language ^c	
Path	Z	Path	Z	Path	Z
Accuracy					
.73	5.33***	-.38	-.98	.56	1.60
Rate					
.52	2.32*	-.28	-.87	.70	4.36**
				.16	2.01*

* p<.05
** p<.01
*** p<.001
^aIndicators: Latent Factor based on phonological, orthographic, and morphological word forms
^bLatent Factor based on RAN-letters and D-KEFS Verbal Fluency—Letters
^cLatent Factor based on RAS-Letters and Numbers, RAS-Letters, Numbers, and Colors, D-KEFS Inhibition and Inhibition/Switching
^dBased on Pa-Ta-Ka