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Emotional and Behavioral Correlates of Persisting Specific Learning Disabilities in Written Language during Middle Childhood and Early Adolescence

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Abstract

Parents completed the *Behavior Assessment System for Children-Second Edition Parent Report Scale (BASC2-PRS)* while their children (94 boys, 61 girls; $M=11$ years-11 months) were given tests. Evidence-based profiles of multiple test scores and history (emergence and persistence) were used to assign to groups without specific learning disabilities in written language (SLDs-WL) ($n=42$ control) or with SLDs-WL: ($n=29$ dysgraphia, $n=65$ dyslexia, or $n=19$ oral and written language learning disability [OWL LD]). Parent ratings fell in the clinical or at risk ranges for some individuals in all groups, but mean *BASC2-PRS* ratings showed nine significant main effects for group ($n=4$): Behavioral Symptoms Index, Internalizing Problems Composite, Adaptive Skills Composite, two Clinical Scales (Atypicality and Attention Problems), and four Adaptive Scales (Adaptability, Activities of Daily Living, Leadership, and Functional Communication). Each SLDs-WL group differed significantly from the control group on these nine ratings, except dysgraphia on Atypicality and dyslexia on Adaptive Composite, Adaptability, and Leadership; and each correlated with one or more hallmark impairments associated with a specific SLD-WL. In an fMRI study (without OWL LD), the dysgraphia and dyslexia groups, but not control group, showed connectivity with amygdala; *BASC2 PRS* Internalizing Problems Composite (internal stress) correlated with amygdala connectivity from two cortical regions involved in written word processing and production for all groups ($N=40$). Applications to assessing emotional and behavioral correlates of SLDs-WL for educational services and future research are discussed.

According to the US Department of Education (2015), an estimated 35% of children receiving special education services at school for educationally handicapping conditions qualify under the specific learning disabilities (SLDs) category. Historically, the focus of both eligibility criteria and individual educational planning for the SLD category has been on academic skills. Unless a student has a severe behavioral disability and also qualifies

under the behavioral disability (BD) category, the student's co-occurring emotional and behavioral problems, whether a consequence of or contributing factor to the learning problems, are typically not addressed. Thus, the current study is grounded in a growing body of research, which has documented the co-occurrence of SLDs and emotional and behavioral problems and for which a brief overview is provided. However, most but not all of the research to date on emotional and behavioral correlates of SLDs has focused on reading. In contrast, the overall goal of the current study was to apply a widely available assessment tool in schools for identifying emotional and behavioral functioning to investigating the emotional correlates of not only reading disabilities but also of writing and listening and oral expression disabilities. The current study, which is part of programmatic research over three decades, focused on students who had not responded adequately to their current Tier 3 literacy instruction (special education if in the public schools) or earlier Tier 1 or Tier 2 intervention for prevention.

Both internalizing and externalizing disorders occur with higher incidence in children with SLDs in reading (Morgan et al., 2008) and SLDs in general (Sahoo et al., 2015). In a study of twins with and without reading disabilities, those with a reading disability had higher scores on internalizing and externalizing disorders (Wilcutt & Pennington, 2000). SLDs have also been associated with higher risk of attention, conduct, and anxiety disorders (Maughan, Goodman, & Meltzer, 2005). Young adults and adolescents with poorer reading skills had a higher incidence of Attention Deficit Hyperactivity Disorder (ADHD) and anxiety disorders than those with better reading skills; even when the authors controlled for ADHD, anxiety disorders were still more prevalent in the group who had reading difficulties (Goldston et al., 2007). Compared to typical readers, children with reading disabilities had more depression as well as anxiety (Mammarella et al., 2016). A meta-analysis of studies of children with SLDs found that individuals with SLDs had higher mean scores on measures of anxiety across most studies (Nelson & Harwood, 2011). Some of the emotional problems may also be subtly related to social problem solving, assertiveness, and tolerance (Toro et al, 1990).

Although oral reading plays a fundamentally important role in literacy acquisition in the primary grades, curriculum requirements change in upper elementary and middle school in that the writing requirements increase substantially. Yet, writing disabilities have been relatively neglected (Katusic, Colligan, Weaver, & Barbaresi, 2009). Moreover, not all reading disabilities are the same—some mainly involved oral and written language at the level of the word—learning to decode, identify, and spell single words accurately and automatically and typically are first observed during the transition from preschool to kindergarten and first grade. Other reading disabilities are preceded by struggles in learning to talk and understand heard language which may be observed near the end of the first year of life and even throughout the preschool years in many cases; these often involve oral and written language at the level of multi-word syntactic units or word parts that are affixed to base words to mark or transform their grammatical or semantic features and can affect understanding as well as constructing oral and written language throughout the school years if appropriate instruction is not provided.

Likewise, not all writing disabilities are the same. Dysgraphia involves hallmark impairments in subword letter production without reading impairment (Berninger & Hayes, 2012) but may interfere with other cognitive processes in writing as well (Richards, Abbott, & Berninger, 2016). Dyslexia involves hallmark impairment in word spelling and word decoding or reading without impairment in understanding and constructing oral language at the multi-word level (Richards, Nagy, Abbott, & Berninger, 2016). OWL LD involves understanding heard and written sentences and multi-sentence texts and constructing oral and written sentences and text (Richards et al., 2016; Scott, 2011). There is a sizable body of research published by multiple research groups over the past four decades on the nature of the contrasting reading and writing disabilities and diagnosing specific learning disabilities that vary as to which levels of language (subword, word, syntax) and language systems (by ear, mouth, eye, hand), developmental trajectory (timing of emergence and tendency to persist even with early intervention), and instructional needs; for example, there is substantial evidence that individuals with OWL LD are much more likely to not have a discrepancy between their Verbal Comprehension Index on the Wechsler Scales and literacy achievement than individuals with dyslexia, but may perform comparably or even higher on nonverbal reasoning measures because they are not limited by their disability in oral expression of their thoughts and can instead point to answers or manipulate objects to answer questions. For review of the research see Silliman and Berninger (2011).

More research has focused on identification and instruction for the various SLDs-WL than has focused on emotional and behavioral issues that students with persisting struggles with heard, spoken, read, and/or written language may experience during middle childhood and early adolescence in general and in association with the nature of their specific SLD-WL. To determine whether a prospective participant did not have an SLD-WL or might have dysgraphia (impaired letter production), dyslexia (impaired word reading and spelling), or OWL LD (impaired oral and written language at the syntax level), we used an approach based on three decades of interdisciplinary research on language acquisition (aural, oral, read, and written) from kindergarten to ninth grade (Berninger, 2009). Diagnosis is based on assessing profiles or patterns of multi-leveled language skills in individuals whose ability to translate their cognitions into oral language is at least within the lower limits of the normal range and their developmental and educational histories; family and medical histories are also obtained. Diagnosis is never made on the basis of a single measure or discrepancy between two measures or response to intervention that has not been tailored to an individual's whole learning profile. Much has been learned about the phenotype profiles (behavioral markers shown empirically to be related to underlying genetic and brain variables) that differentiate the diagnostic profiles (Berninger & Richards, 2010).

In this article we report the results of two studies—one at the behavioral level of analysis and one at the brain level of analysis—to add to what is currently understood about the emotional and behavioral correlates of these language learning profiles; we do not address issues related to Verbal Comprehension Index, an indicator of a high level executive function for translating cognitions into oral language or the phenotypes for the language learning system, but see Berninger, Richards, and Abbott (2015) and Sanders, Abbott, and Berninger (in press) for recent validations of inclusion of the Verbal Comprehension Index and the phenotype markers in the language learning system. The shared specific aim of both Study 1

and Study 2 is to demonstrate the importance of assessing social emotional variables in language learners both with and without SLDs-WL and evaluating the hypothesized validity of the *BASC2* parent ratings for doing so.

STUDY 1

Parent Ratings of Emotional and Behavioral Functioning

Rationale and Assessment Tool—Emotional and behavioral functioning can affect a child's ability to engage in learning and benefit from instruction at school and to complete homework assignments and read and write for pleasure outside school. It follows that parents' ratings of emotional and behavioral function at home and outside school are as relevant as educators' ratings at school and normed achievement measures. Therefore, in Study 1 we administered the Parent Rating Scale of The *Behavior Assessment System for Children, Second Edition (BASC2)* (Reynolds & Kamphaus, 2004). This research-supported behavioral checklist with three validity indexes for faking, consistency, and response patterns is widely used in schools and clinics to evaluate emotional and behavioral functioning of children with learning disabilities (Sorenson, 2003, Martinez and Semrud-Clikeman, 2004) as well as other disabilities (Volker et al, 2010).

Study 1 was designed to add to the existing research on the *BASC2* by addressing three sets of questions specific to the *BASC2 Parent Rating Scale (PRS)*. First, do students with persisting SLDs-WL in grades 4 and above despite early intervention fall in the clinical range or at risk range on parent ratings? A related question was whether those without SLDs-WL might also fall within the clinical or at risk ranges. Second, if both those with and without SLDs-WL have ratings in the clinical or at risk range, are their parents' mean ratings along the continuous rating scales significantly different for those with and without SLDs—WL? A related question was whether not only main effects across the four diagnostic groups but also significant effects for each diagnostic SLD group compared to the control group would be found. Third, if the *BASC2 PRS* ratings for specific SLD-WL groups differ significantly from those for the control group, are the parental ratings along the distribution for a composite or scale correlated with each hallmark impairment for each of the three SLDs-WL groups? If some ratings for individuals in both the control and SLDs-WL groups fall in the clinical or at-risk range, then these correlations would be based on the total sample for the relevant hallmark impairment. For interpreting the findings for positive versus negative correlations it is important to keep in mind that on the *BASC2 Clinical Scales* a lower score indicates better functioning and higher scores are worse; but on the *Adaptive Scales* a lower score indicates worse functioning and higher scores are better.

Method

Participants

Ascertainment: The sample was ascertained by parents responding to flyers announcing an opportunity to take part in a university study for children in the fourth through ninth grades who have a history of continuing reading and writing difficulties or who have not had any struggles in learning to read and write. An initial interview was conducted over the phone for the purpose of determining if the reading and/or writing difficulties were probably

related to developmental disabilities, brain injury, or other conditions that may be associated with learning problems but not SLDs in otherwise typically developing individuals without acquired disorders or medical conditions; if so no further assessment was done. For those who appeared by history to have an SLD or to be a typical language learner and the parent granted informed consent and the child granted assent per the approved Institutional Review Board protocol where the research was conducted, an assessment was scheduled at the university. That assessment was comprehensive and included multiple cognitive, aural and oral language, reading, and writing, and phenotype measures (behavioral markers of evidence-based brain and/or genetic bases).

Sample characteristics: Altogether 155 children (ages 9 to 15, $M=11$ years, 11 months; 94 boys, 61 girls) completed the assessment and 155 parents (mostly mothers but in rare exceptions fathers) with legal authority for educational decision making completed the *BASC2 PRS*. Parent-reported student ethnicity included European American 70.3%, mixed Ethnicity 19.5%, Asian-American 3.2 %, Hispanic 1.9%, African American 1.3%, Non-European Caucasian 1.3%, and Other/Non-specified 2.5%. Parent education ranged from less than high school (mothers 0.7%, fathers 2.2%) to high school (mothers 2.8%, fathers 2.9%) to more than high school but less than college degree (mothers 5.6%, fathers 10.8%) to college degree (mothers 43.8%, fathers 43.9%) to more than college degree (mothers 47.2%, fathers 40.3%).

Research Parent Questionnaires and *BASC2 PRS* Assessment—Parents completed questionnaires concerning developmental, medical, and family history as well as the *BASC2 PRS*. On *BASC2 PRS* sometimes a parent did not provide a response for a particular item or the response provided was unclear. If complete data were not available for an individual on a specific *BASC2 PRS* Index, Composite, or Scale that individual was not included in the related analysis, which is why n 's and thus df 's vary across some analyses.

The Behavior Assessment System for Children, Parent Rating Scale (BASC2-PRS) yields T -scores for an overall score (Behavioral Symptom Index), three composite scores (Externalizing Problems Composite, Internalizing Problems Composite, and Adaptive Skills Composite), nine clinical scales (Hyperactivity, Aggression, Conduct Problems, Anxiety, Depression, Somatization, Atypicality, Withdrawal, and Attention Problems) and the five adaptive scales (Adaptability, Social Skills, Leadership, Activities of Daily Living, and Functional Communication). Criteria in the manual were used to determine if each T -score fell in clinical range and at risk range for each individual. The norms for both separate and combined genders were used for this purpose; in subsequent analyses, however, because there were more boys than girls in the sample, only the results based on norms for separate genders are reported. However, results for both the separate and combined norms were examined and found to be comparable, varying not in whether an effect was statistically significant but rather the level of statistical significance.

Assessment Battery—The following tests were individually administered.

Oral language—listening and expressing orally: *Wechsler Intelligence Scale for Children, 4th Edition (WISC IV)* (Wechsler, 2003) *Similarities, Vocabulary, and Comprehension*

subtests were given to compute a *Verbal Comprehension Index* score (test–retest reliability .93 to .95), which is a standard score for age ($M = 100$, $SD = 15$). The Verbal Comprehension Index had to fall at least within the lowest limits of low average range (standard score of 80) in order to qualify for the study. The Index Score is not a pure measure of cognition, but rather of a higher- order executive function for translation of cognitions into oral language using words, phrases, and syntax, which has been shown to contribute significant variance to writing and reading achievement (Niedo, Abbott, & Berninger, 2014). The *Woodcock Johnson Psychoeducational Assessment, Third Edition (WJ III)* (Woodcock, McGrew, & Mather, 2001) *Oral Comprehension subtest*, was given. This aural cloze task (test-retest reliability .88) requires supplying a word orally during a pause in unfolding oral text. It yields a standard score for age ($M = 100$, $SD = 15$). The *Clinical Evaluation of Language Function 4th Edition CELF IV* (Semel, Wiig, & Secord, 2003) *Formulated Sentences* (test-retest reliability .62 to .71) requires constructing an oral sentence from provided words and yields scaled score for age ($M = 10$ and $SD = 3$).

Written language—writing: For *Alphabet 15z*, children are instructed to print the alphabet from memory as quickly as possible in alphabetic order so others can recognize the letters. The score is the number of legible manuscript (unjoined) letters in correct alphabetic order in the first 15 seconds, which is converted to a z score ($M = 0$, $SD = 1$) using research norms for grade (interrater reliability .97). *DASH Detailed Assessment of Speed of Handwriting (DASH)* (Barnett, Henderson, Scheib, Schulz, 2007) requires copying a sentence with all the letters of the alphabet under contrasting instructions: one’s best handwriting or one’s fast writing. Students can choose to use their usual writing format—manuscript (unconnected) or cursive (connected) or a combination. The scaled score for age ($M = 10$, $SD = 3$) for both tasks is based on legibility for single letters within the time limits (interrater reliability .99).

For *WJ III Spell Sounds* (Woodcock et al. 2001) the task is to spell in writing dictated pseudowords based on English phonology and orthography but without semantic meaning (reliability .76). Correct spelling requires application of alphabetic principle in spelling direction (phoneme to grapheme) and orthotactic knowledge of permissible positions within words for certain single letters or letter groups (Treiman & Kessler, 2004). Raw scores are transformed to standard scores for age ($M = 100$, $SD = 15$). The *Wechsler Individual Achievement Test, Third Edition (WIAT III)* (Pearson, 2009) *Spelling* requires spelling dictated words which the examiner first pronounces, then uses in a sentence, and then pronounces again (.92 reliability). Number correct is converted to standard scores for age ($M = 100$, $SD = 15$).

For *WJ III Writing Fluency* (Woodcock et al., 2001) the task (test–retest reliability .88) is to compose a written sentence for each set of three provided words, which are to be used without changing them in any way. There is a 7 minute time limit. The score is a standard score for age ($M = 100$, $SD = 15$). For *WIAT III Sentence Combining* (Pearson, 2009), the task is to combine two provided sentences into one well written sentence that contains all the ideas in the two separate sentences (test-retest reliability .81). The score is a standard score for age ($M = 100$, $SD = 15$).

Written language—reading: *WJ III Word Identification* (Woodcock et al., 2001) assesses accuracy of oral reading of single real words on a list without any sentence context clues (average reliability .97). The score is a standard score for age ($M=100$, $SD=15$). *WJ III Passage Comprehension* (Woodcock et al. 2001) assesses ability to read a passage and supply the missing word that makes sense in the context of the text (reliability coefficient .90). The score is a standard score for age ($M=100$, $SD=15$).

Assignment to Diagnostic Groups—Based on procedures described and validated in Berninger, Richards, and Abbott (2015) and Sanders et al. (in press) and prior programmatic research over two decades by one research group (see Berninger, 2009; Berninger & Richards, 2010) and other research groups as well (see Silliman & Berninger, 2010), participants were assigned to diagnostic groups according to these evidence-based criteria for learning profiles based on patterns on multiple test scores and developmental and educational history past (developmental onset) and current (had to be persisting despite intervention):

- a. **dysgraphia** if scored below $-2/3$ SD (25th %ile) on two or more handwriting measures and had parent reported past and current history of struggles with handwriting despite intervention, no history or evidence on tests of reading problems, and no history of oral language problems during preschool years;
- b. **dyslexia** if scored below the population mean and at least one standard deviation below Verbal Comprehension Index (a measure of their ability to translate cognitions into oral language, that is, oral expression of ideas) on word reading or decoding or spelling measures, scored at or above $-2/3$ SD in listening comprehension and oral expression, and had parent reported history of past and current struggles with word reading and spelling despite intervention but no history of oral language problems during preschool years or current listening comprehension or oral expression problems;
- c. **OWL LD** if they scored below $-2/3$ SD on at least two measures of listening comprehension, oral expression, reading comprehension, and/or sentence written expression and had parent reported history of oral language problems during the preschool years and past and current struggles with oral language, reading, and writing despite intervention; or
- d. **typical language learner (control)** if they scored at or above $-2/3$ SD on all oral language, writing, and reading measures and parent reported no struggles in learning oral language during the preschool years and no current or past struggles with writing or reading during the school years.

Importantly, all participants who completed assessment were readily assigned to a diagnostic group because test scores and parent reported developmental and educational history converged with normed measures.

Data Analyses—A multi-step approach to data analyses was employed. For the first research question descriptive statistics were used to identify the frequency in the whole sample with and without SLDs-WL of those falling in the clinical range or at-risk range for

each *BASC2 PRS* Index, Composite, or Scale. For the second research question, inferential statistics (between groups one-way ANOVAs) were used to identify significant main effects for group on the *BASC2 PRS* Index, Composites, or Scales in which groups were control, dysgraphia, dyslexia, and OWL LD. For *BASC2 PRS* measures that showed a significant main effect for group, then posthoc tests evaluated whether each diagnostic group was significantly different from the control group. For the third research question, Pearson product moment correlations were computed between *BASC2 PRS* ratings showing significant differences between a diagnostic group and the control group and the achievement measures for the hallmark impairments in diagnosing that SLD-WL. Of interest was whether emotional and behavioral indicators that differed along the continuum of ratings for the diagnostic and control groups were significantly correlated with the specific language skills with which the students showed impairment by history and current test results.

Results

Assignment to diagnostic groups—As shown in Table 1, overall the mean scores were higher in the control group than in the dysgraphia group for handwriting, in the control group than in the dyslexia group for spelling and word reading, and in the control group than in the OWL LD group for listening comprehension, oral expression, reading comprehension, and sentence composition. Keep in mind, however, consistent with the cascading levels of language diagnostic framework (Berninger et al., 2015), students may show signs of impairment at a lower level but not higher level of language than the level of their primary impairment (e.g. handwriting in dyslexia, or handwriting and word reading and spelling in OWL LD). So group means are not as clinically meaningful as the individual learning profiles for each assessed student.

First research question—As shown in the Table 2, of the 155 students, some with persisting SLDs-WL (outside the parentheses) and some without SLDs-WL (inside the parentheses) had *BASC2 PRS* ratings that fell in the clinical range or at-risk range.

Second research question—Because more students with SLDs-WL than without SLDs-WL fell in clinical or at-risk ranges, the mean differences between them on the *BASC2 PRS* ratings that fell along a distribution were also compared. As shown in Table 3, across all the ratings, seven main effects for comparison across all four groups were statistically significant at $p < .001$ (Behavioral Symptoms Index, Adaptive Skills Composite, Atypicality, and Attention Problems on the Clinical Scales, and Adaptability, Activities of Daily Living, and Functional Communication on the Adaptive Scales) and two at $p < .01$ (Internalizing Problems Composite and Leadership). Also displayed in Table 3 are the results of the posthoc comparisons of each diagnostic group with the control group with Bonferroni correction for multiple comparisons set at $p < .0125$. Each of the three SLD-WL groups was statistically different from the control group in mean parental ratings except for the control group and dyslexia group on Adaptive Composite, Adaptability, and Leadership and for the control group and the dysgraphia group on Atypicality.

Third research question—Correlations were computed between the parent ratings shown to have a statistically significant main effect for all four groups and the posthoc comparisons of each SLD-WL group with the control group (second research question) and the oral and written language achievement measures for hallmark impairments for each SLD-WL group (see Table 4). The purpose of these correlations was to evaluate whether the BASC ratings were related to some degree with the nature of the learning disability.

For dysgraphia, seven *BASC2 PRS* outcomes correlated with the alphabet 15 measure that assesses the orthographic loop of working memory in the language learning system. This measure requires accessing the ordered alphabet in long term memory, searching the serial letters to find each in sequential alphabetic order, and automatic (fast and effortless) letter production; it has been shown to be related to another transcription skill (spelling) and translation of ideas into written language (Berninger, 2009). The Table 4 results indicate that difficulty with this task has many emotional and behavioral correlates for developing students with persisting dysgraphia. Copy Fast was correlated with four *BASC2 PRS* outcomes, providing additional evidence that pressure to produce letters fast may be stressful for those with dysgraphia. For Copy Best, which requires executive functions for self-regulation, only parental ratings for Leadership were correlated significantly.

For dyslexia, only two of the *BASC2 PRS* outcomes were correlated significantly with oral reading of words. Of considerable educational significance, all *BASC2 PRS* outcomes in Table 4 were significantly correlated with dictated spelling of real words and four of them with dictated spelling of sounds (pseudowords). These findings serve as a reminder that spelling can be a source of continuing frustration during the upper elementary and middle school grades for students with dyslexia, which is not just a reading disability.

For OWL LD it is striking that four *BASC2 PRS* outcomes were significantly correlated with listening comprehension, all nine *BASC2 PRS* outcomes were significantly correlated with oral construction of sentence syntax from provided words and with reading comprehension, and with written composing (combining two sentences to express the ideas in one well-structured sentence), and all but two *BASC2 PRS* outcomes correlated with writing fluency (the timed analog of the oral sentence construction task). Across the SLDs-WL groups the magnitude of the correlations tended to be higher for the OWL LD group.

Discussion

Clearly, parent ratings can identify emotional and behavioral correlates of SLDs-WL that are related to the hallmark impairments of the various SLDs-WL and vary in their patterning across the SLDs-WL groups. Also, students with and without SLDs-WL who participated in our intervention studies shared perspectives that revealed the role affect plays beyond taught skills in their own learning (Berninger, Gesolowitz, & Wallis, in press).

STUDY 2

Brain Correlates of *BASC2 PRS*

Rationale and Approach—Brain research has shown that damage to amygdala, a structure in the limbic system below cerebral cortex, can affect an individual's emotional

expression (Kandell, Schwartz, Jessell, Siegelbaum & Hudspeth, 2012); however, current evidence indicates that a variety of functions are associated with amygdala (Yarkoni Poldrack, Nicholds, Van Essen, Wager, 2011). For example, Perlman (2012) found abnormal levels of amygdala activation during imaging in adolescents diagnosed with clinical depression. Hulvershorn et al. (2014) reported abnormal levels of amygdala activation in ADHD. Study 2 was therefore designed to address three research questions. First, do students with persisting SLDs in grades 4 to 9 show connectivity with amygdala while performing an fMRI writing task related to word spelling and reading? If so, do the control group and SLDs-WL group show the same patterns of fMRI connectivity with amygdala? Second, which language achievement measures are correlated with the amygdala connectivity during the fMRI word spelling/reading task? Third, is amygdala connectivity correlated with parent ratings on any *BASC2-PRS* ratings shown in Study 1 to differentiate the control and SLDs-WL groups?

Method

Participants—Children who were right handed and did not wear non-removable metal and had completed the Study 1 diagnostic assessment battery for assignment to groups were invited to participate in this brain imaging study, which was approved by the Institutional Review Board. Altogether 40 completed the imaging study ($n=9$ controls, $n=14$ with dysgraphia, $n=17$ with dyslexia). Sufficient fMRI data were not available for the OWL LD group who were not included in Study 2.

The SLDs-WL diagnostic groups showed the hallmark profiles for dysgraphia and dyslexia and had histories of persisting handwriting or spelling/word reading difficulties, respectively. Handwriting was lower in the dysgraphia group (*DASH Copy Best*, $M=7.79$, $SD=2.91$; *Copy Fast*, $M=6.07$, $SD=2.70$) than the control group (*Copy Best*, $M=11.69$, $SD=2.18$; *Copy Fast*, $M=10.71$, $SD=1.24$) or the dyslexia group (*Copy Best*, $M=8.75$, $SD=3.36$; *Copy Fast*, $M=7.50$, $SD=3.08$). Spelling and word reading were lower in the dyslexia group (*WJ III Spell Sounds*, $M=94.36$, $SD=10.00$; *WIAT III Spelling*, $M=87.41$, $SD=11.36$; *WJ III Word Identification*, $M=96.24$, $SD=10.87$) than the control group (*WJ III Spell Sounds*, $M=107.11$, $SD=10.24$; *WIAT III Spelling*, $M=107.11$, $SD=12.23$; *WJ III Word Identification*, $M=111.56$, $SD=8.50$) or dysgraphia group (*WJ III Spell Sounds*, $M=104.79$, $SD=20.30$; *WIAT III Spelling*, $M=98.93$, $SD=10.58$; *WJ III Word Identification*, $M=109.92$, $SD=10.03$) group. None of these diagnostic groups was impaired in listening comprehension (*WJ III Oral Comprehension*, control group, $M=110.33$, $SD=1.78$; dysgraphia group, $M=108.50$, $SD=2.28$; and dyslexia group, $M=113.56$, $SD=2.55$). None of the parents reported preschool histories of struggles with oral language learning.

Procedures

fMRI word-specific spelling/reading task: The task was programmed, timed, and coordinated with the scanner triggers using E-prime and in-house LabView software. During the fMRI scanning, the task was deciding whether a word was a correctly spelled real word versus a pseudohomonym foil (pronounced the same but not spelled correctly for a real word with a specific meaning). Making this decision requires knowledge beyond permissible grapheme-phoneme correspondences: The reader must also integrate orthographic and

phonological patterns and semantic knowledge for the whole lexical unit; this task has been shown to underlie both word reading and word spelling (Ehri, 1980; Olson et al., 1994; Perfetti, 2007). For example, *sammon* and *salmon*, both of which are pronounced the same, but only one is a correctly spelled word with meaning. Children practiced the task outside the scanner to achieve 90% accuracy before the scanning session began so that results reflect amygdala connectivity for accurate word-specific spelling.

Scanning: Structural (MRI) and functional magnetic resonance imaging (fMRI) connectivity scans were obtained on a Philips 3 T Achieva scanner (release 3.2.2 with the 32- channel head coil) at the Diagnostic Imaging Sciences Center/Integrated Brain Imaging Center. Each participant was screened for MRI safety before entering the scanner by performing physiological monitoring using the Philips pulse oximeter placed on the left hand index finger for cardiac recording. The Philips bellows system for which the air-filled bellows pad was placed on the abdomen was used for respiratory recording. An inflatable head-stabilization system (Crania, Elekta) was used to aid head immobilization. Scanning included the following MRI series: **1) 3-plane scout view with gradient echo pulse sequence:** TR/TE 9.8/4.6 ms; Field of view $250 \times 250 \times 50$ mm; acquisition time 30.3 s; **2) reference scan (used in parallel imaging) with gradient echo pulse sequence:** TR/TE 4.0/0.75 ms; Field of View $530 \times 530 \times 300$ mm; acquisition time 44.4 s; **3) fMRI scan with echo-planar gradient echo pulse sequence** (single shot): TR/TE 2000/25 ms; Field of view $240 \times 240 \times 99$ mm; slice orientation transverse, acquisition voxel size $3.0 \times 3.08 \times 3.0$ mm; acquisition matrix $80 \times 80 \times 33$; slice thickness 3.0, SENSE factor in the AP direction 2.3; epi factor 37; bandwidth in the EPI frequency direction 1933 Hz, SoftTone factor 3.5, sound pressure 6.1 dB, 180 dynamic scans; 5 dummy scans; fold over direction AP, 396 dynamic scans; **4) B0 field map imaging with gradient echo pulse sequence and 2 echos:** TR/TE 11/6.3 ms; delta TE 1.0 ms; slice orientation transverse, Field of view $240 \times 240 \times 129$ mm; voxel size $1.5 \times 1.5 \times 3.0$ mm; acquisition matrix $160 \times 160 \times 43$, output image magnitude and phase, acquisition time 2:29 min/s; **5) MPRAGE structural scan:** TR/TE 7.7/3.5 ms, Field of view $256 \times 256 \times 176$ mm, slice orientation sagittal, voxel size $1 \times 1 \times 1$ mm, inversion pulse delay 1100 ms, Sense factor 2 in the AP direction, acquisition time 5:33 min/s.

fMRI connectivity analyses: Four seeds were chosen from which to assess connectivity with amygdala based on prior research showing that (a) precuneus is involved in the highly interconnected networks of the rich club of the human connectome (van den Heuvel & Sporns, 2011), and (b) left occipital temporal, left supramarginal, and left inferior frontal are involved in processing and producing written words (Purcell, Turkeltaub, Eden, Rapp, 2011; Richards et al., 2015). An fMRI connectivity map for reading was generated for each individual using four different seed points in the left precuneus cortex PCC (MNI $-6, -58, 28$ mm, Jülich atlas label GM_Superior_parietal_lobule_7a_L), in the left temporooccipital cortex TOC (MNI $-50, -60, -16$ mm, between Jülich atlas labels GM_Visual_cortex_V4_L and WM_OptiC_radiation_L), in the left supramarginal gyrus SMG (MNI $-52, -32, 34$ mm, Jülich atlas label GM_Inferior_parietal_lobule_PF_L), and in the left inferior frontal gyrus, IFG (MNI $-52, 20, 34$ mm, Jülich atlas label GM_Broca's_area_BA44_L).

Functional images were corrected for motion using FSL MCFLIRT (Jenkinson et al., 2002), and then high-pass filtered at $\sigma = 20.83$. Motion scores (as given in the MCFLIRT report) were computed for each participant and average motion score (mean absolute displacement) for each of the groups: control 1.31 ± 1.37 mm, dysgraphia 1.50 ± 1.23 mm, and dyslexia 1.47 ± 1.03 mm. Spikes were identified and removed using the default parameters in AFNI3s 3dDespike. Slice-timing correction was applied with FSL3s slicetimer and spatial smoothing was performed using a 3D Gaussian kernel with FWHM = 4.0 mm. Time series motion parameters and the mean signal for eroded (1 mm in 3D) masks of the lateral ventricles and white matter (derived from running FreeSurfer3s reconall on the T1-weighted image) were analyzed. Co-registration of functional images to the T1 image was performed using boundary based registration based on a white matter segmentation of the T1 image through epi_reg in FSL. The MPAGE structural scan was segmented using FreeSurfer software; white matter regressors were used to remove unwanted physiological components.

For Group analyses, Oxford's fMRIB software library (FSL) randomize, which performs permutations and threshold-free cluster enhancement, was used to control for multiple comparisons. A global design matrix was used as part of the GLM model in randomize software to make the group statistical maps described by FSL guidelines for higher group level analysis (see http://fsl.fmrib.ox.ac.uk/fsl/fslwiki/glm#SingleGroup_Average_28One-Sample_T-Test.29). Group maps for fMRI functional connectivity were generated for the 3 groups (control, dysgraphia, dyslexia) for connectivity with amygdala from four different seed points in left precuneus cortex PCC, left temporooccipital cortex TOC, left supramarginal gyrus SMG, and left inferior frontal gyrus, IFG Broca's area. fMRI time-series were averaged within regions of interest (ROIs) formed from a 15 mm sphere centered at each seed. The averaged time-series at each ROI was correlated with every voxel throughout the brain to produce functional connectivity correlation maps, converted to z statistics using the Fisher transformation. These group maps show where in the brain functional connectivity from the seed point with amygdala is significant. Only connectivity with amygdala from those four seed points was examined in this study.

Results

First research question—As shown in Table 5, the control group showed no connectivity with amygdala; however, both SLD-WL groups did, but in contrasting ways. The dysgraphia group showed connectivity with right amygdala (superficial group) from two seeds (left occipital temporal cortex and left inferior frontal gyrus) and with right amygdala (centromedial group) from one seed (left inferior frontal). The dyslexia group showed functional connectivity with right amygdala (centromedial group, laterobasal group, and superficial group) from two seeds (left precuneus and left occipital temporal cortex), bilateral amygdala (superficial group) from one seed (left supramarginal gyrus), bilateral amygdala (centromedial group) from one seed (left inferior frontal), and right amygdala (laterobasal group, superficial group) from one seed (left inferior frontal). On a word-specific spelling task related to the hallmark deficit of dyslexia, the dyslexia group showed more connectivity with amygdala from the seeds (regions of interest) for written word processing and production than did the dysgraphia group. See Figure 1 and Table 5.

Second research question—One achievement measure in the Study 1 assessment battery—alphabet 15— correlated with amygdala connectivity: left amygdala from the left precuneus seed point $r=.33$, $p=.04$. Higher scores on alphabet 15 were correlated with more amygdala connectivity with left precuneus.

Third research question—The *BASC2-PRS* Internalizing Composite correlated significantly with connectivity with left amygdala from two seed points—left supramarginal, $r= -.41$, $p=.01$, and left precuneus, $r=.32$, $p=.05$. The correlation is negative with left supramarginal showing a higher score (worse) on Internalizing is associated with less connectivity with amygdala from this seed, but is positive with left precuneus showing a higher score (worse) is associated with greater connectivity with amygdala from this seed.

Discussion

Regarding the first research question, children with persisting dysgraphia or dyslexia showed connectivity with amygdala in limbic system, but the controls without dysgraphia or dyslexia did not. However, the dysgraphia and dyslexia groups showed different patterns of connectivity with amygdala, consistent with prior findings of different brain bases for dysgraphia and dyslexia related to contrasting patterns of white matter integrity and fMRI functional connectivity (Richards et al., 2015) *BASC2 PRS* and even the different patterns of parental *BASC2* ratings in Study 1.

Regarding the second research question, connectivity with the left amygdala from the left precuneus seed during a word-specific spelling/reading task was significantly and positively correlated with the alphabet 15 task. This finding is consistent with the alphabet 15 task being significantly correlated with word identification during silent word reading in an intervention study (Niedo, Lee, Breznitz, & Berninger, 2014). A tentative interpretation of this finding, requiring further research, is that amygdala may be involved in the emotional and behavioral correlates of ability to access, find, and retrieve ordered alphabet letters from memory during silent identification of word-specific spellings. Also see findings for dysgraphia in Table 4.

Regarding the third research question, *BASC2 PRS* Internalizing Problems Composite was significantly correlated with fMRI amygdala connectivity from two seed points during word-specific spelling judgments, consistent with there being brain bases for internalizing emotional correlates of struggles in written language learning. However, one correlation was negative and one was positive, suggesting that the same location in limbic system may be related in different ways to different locations in cortex regarding the internalized emotions/ behaviors associated with word-specific spelling. Of interest, greater amygdala connectivity with left precuneus, which was positively correlated with higher (worse) *BASC2 PRS* ratings, was also correlated with the automatic alphabet writing task. This finding suggests that greater anxiety, depression, and/or somatization, which contribute to the T score for the Internalizing Problems Index, may be related to difficulty in finding, accessing, and retrieving letters during word-specific spelling judgments for students in general with and without SLDs-WL in upper elementary and middle school. However, amygdala is not the only brain region involved in emotional functions (Critchley, 2005) and a brain region other

than amygdala may be related to the internalizing emotional/behavioral problems from the left supramarginal gyrus. Clearly additional research is needed to address these issues.

SYNTHESIS, EXTENSION, AND APPLICATION: STUDIES 1 AND 2

Collectively both studies have clinical and educational significance for assessing and teaching written language and the construct validity of *BASC2 PRS*. Both students with and without SLDs-WL fell in the clinical range (a few) or at-risk range (a larger number but not all) on *BASC2 PRS* parent ratings for Overall Index, Composites, Clinical Scales, and Adaptive Skills Scales. However, on average students, with various persisting SLDs-WL were significantly more impaired at $p .001$ than the typical controls without SLDs—WL on seven scores: Overall Index, Two Composites, Two Clinical Scales, and Two Adaptive Scales (Tables 3 and 4). In addition, fMRI connectivity with amygdala in the limbic system (emotional brain) was observed for the dysgraphia and dyslexia group but not the control group and in contrasting ways for the dysgraphia and dyslexia groups (Table 5, Figure 1). Finally, the *BASC2 PRS* Internalizing Problems Composite was significantly correlated with amygdala connectivity from two seeds involved in written word processing and production, one of which was correlated with alphabet 15, a measure related to word spelling and reading (Berninger, 2009). Collectively the Study 1 and Study 2 findings provide cross-disciplinary behavioral-educational-neuroscience evidence for the construct validity of the *BASC2 PRS* Internalizing Problems Composite based on Anxiety, Depression, and Somatization Clinical Scales.

More research is needed, however, on the effectiveness of treatment plans at school that include both support for emotional well-being and academic instruction compared to only academic instruction. In future studies, not only could *BASC2 PRS* ratings be collected before and after instructional intervention but also teacher ratings and student self-ratings could supplement the parent ratings. Also, emotional and behavioral issues should be studied in students who do and do not live in homes with parental support or who do and do not have family stressors. The participants in the current study received much family support, but if they had not, results for how many fell in clinical range may have been higher. Finally, more research is needed on parental profiles of emotional and behavioral functioning that could affect their parenting (Bonifacci, Storti, Tobia, & Suardi, 2016) and effective approaches for helping parents help their children deal with co-occurring anxiety and other emotional behavioral correlates of their SLDs-WL (Alton, 2015).

Limitations of the study include the following. The sample was ascertained for research purposes outside a school setting. Parents who completed the ratings did so as part of a larger research study rather than for the purpose of working with an interdisciplinary team at their child's school on behalf of specific kinds of problems their child may have been having at school. Although the participants showed the typical diversity in ethnicity of the region in which the research was conducted, overall percentages of ethnic groups were not representative of the US school age population in general. Also, the *a priori* goal was to study the kinds of emotional and behavioral problems that may occur along with SLDs-WL in general rather than specific kinds of SLDs-WL. Future research with other samples should address whether children with the specific kinds of SLDs-WL as investigated in the current

study exhibit the same kinds of emotional and behavioral difficulties as the current sample did on parental *BASC2* ratings. Despite these limitations, the current findings provide evidence that (a) the *BASC2* parental ratings are sensitive to emotional and behavioral correlates of SLDs-WL, and (b) children and youth with SLDs-WL may have co-occurring emotional and behavioral issues that need to be addressed along with their learning disabilities.

In conclusion, parents sharing their observations of their children's emotional and behavioral struggles outside school can help educators at school help students deal with both the language learning struggles and emotional and behavioral correlates of SLDs-WL. Even though these emotional and behavioral issues may not be as visible as in cases of children who meet diagnostic criteria for behavioral disabilities or specific mental health disorders, nevertheless they appear to be real. If professionals use rating scales like *BASC2 PRS* to identify them, then emotional and behavioral issues, whether consequence of or contributor to language learning struggles, can be taken into account in planning and delivering specialized instruction for SLDs-WL, especially in writing and oral language and not only reading.

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Figure 1.

Location of three seed regions for written language with significant connectivity with amygdala on right and/or left (see text) but left only displayed from back view (coronal) or top view (axial). The colored overlays are positioned on top of a standard MNI brain. Abbreviations: SMG = supramarginal gyrus Occ. Temp. = Occipitotemporal gyrus

Table 1

Comparisons of Control Group and Each of Three Specific Learning Disability (SLD-WL) Groups on Writing, Reading, and Oral Language Skills Assessed for Diagnosis Based on Profiles Defined by Patterns of Test Scores and Past and Current History Related to Hallmark Defining Impairments of Each SLD-WL.

<u>Measure</u>	<u>Control</u> <i>M (SD)</i>	<u>Dysgraphia</u> <i>M (SD)</i>	<u>Dyslexia</u> <i>M (SD)</i>	<u>OWL LD</u> <i>M (SD)</i>	<u>df</u>	<i>Fp</i>
VCI	111.28 (16.17)	109.70 (15.70)	113.94 (11.59)	90.58 (13.94)	(4, 140)	10.72 ***
Oral Comp	110.76 (12.43)	114.14 (10.87)	113.09 (8.74)	94.21 (12.91)	(4, 141)	12.90 ***
Form Sent	11.74 (3.15)	10.10 (2.91)	11.18 (2.60)	5.63 (2.22)	(4, 151)	17.81 ***
Alph15	-0.61 (.85)	-1.64 (.67)	-1.21 (.70)	-1.46 (.60)	(4, 149)	9.03 ***
Copy Best	12.06 (3.02)	8.76 (3.12)	9.34 (3.55)	8.63 (3.64)	(4, 141)	5.87 ***
Copy Fast	11.15 (2.76)	6.62 (2.92)	7.53 (3.24)	6.11 (3.41)	(4, 141)	12.22 ***
Sp Sounds	104.83 (13.17)	103.31 (16.85)	91.23 (9.83)	84.05 (7.04)	(4, 149)	15.33 ***
Diet Spell	108.27 (15.20)	100.07 (18.55)	85.26 (11.27)	79.42 (11.46)	(4, 150)	24.35 ***
Writ Flu	111.53 (13.91)	100.83 (17.46)	98.49 (14.21)	87.94 (11.48)	(4, 146)	9.47 ***
Sent Comb	106.90 (15.10)	98.21 (12.41)	95.52 (10.13)	78.00 (14.50)	(4, 135)	15.60 ***
Word ID	108.10 (14.11)	109.43 (11.29)	96.71 (9.82)	87.78 (11.08)	(4, 149)	16.44 ***
Pass Comp	103.29 (13.29)	101.82 (11.41)	99.37 (9.80)	79.00 (12.18)	(4, 148)	17.14 ***

Notes:

p < .001

Results are based on measures that were completed and scorable which varied across analyses to some degree as reflected in slight differences in degrees of freedom. See Text for full name of each measure, description of tasks, and explanation of how assignments to diagnostic groups were made based on profiles.

Table 2

Number with SLDs-WL (outside parentheses) and without SLDs-WL (inside parentheses) of Total N (155) in Clinical or At Risk Range on Each BASC2 PRS Overall Index, Composite, and Scale

Rating	Separate Gender Norms		Combined Gender Norms	
	Clinical	At Risk	Clinical	At Risk
COMPOSITE SCORES				
Behavioral Symptoms Index^a	0	20 (1)	2	20 (3)
Externalizing Problems Composite	2	13	2	17
Internalizing Problems Composite	4	20 (2)	5	20 (1)
Adaptive Skills Composite	2	22	2	20
CLINICAL SCALES				
Hyperactivity^b	6 (1)	14 (1)	9	15
Aggression^b	2	10	1	15
Conduct Problems^b	2	15	2	15
Anxiety^c	11 (1)	20 (2)	10 (2)	21 (3)
Depression^c	4 (3)	13 (4)	6 (1)	12 (5)
Somatization^c	12	8 (2)	10	9 (2)
Atypicality	3	14	4	18
Withdrawal	9	20 (4)	9	20 (3)
Attention Problems	4	36 (6)	4	34 (7)
ADAPTIVE SCALES				
Adaptability^d	1	22 (4)	3	17 (5)
Social Skills^d	3	15 (1)	4	22 (1)
Leadership^d	0	18	0	18 (1)
Activities of Daily Living^d	4	29 (1)	5	30 (2)
Functional Communication^d	4	21 (1)	6	30

Notes. On Clinical Scales 41 to 69 is average, 60 to 69 is at risk, and 70 and above is clinically significant, that is higher scores are worse. On Adaptive Scales, 41 to 59 is average, 31 to 40 is at risk, and below 31 is clinically significant, that is, higher is better.

^aOverall Score

^bExternalizing Problems Composite (Acting Out)

^cInternalizing Problems Composite (Internal Distress)

^dAdaptive Scales (Prosocial Desirable Behaviors)

Table 3

Significant Main Effects for Differences among Four Diagnostic Groups on Clinical Scales and Adaptive Scales of *BASC2 PRS* with Follow-Up Comparisons between Control Group and Each SLDs-WL Group Separately.

	<u>Control</u> MSD	<u>Dysgraphia</u> MSD	<u>Dyslexia</u> MSD	<u>OWL LD</u> MSD	(df)	Fp
COMPOSITES						
Behavioral Problems Index	45.71 (7.58)	51.42 (6.58)	50.52 (8.36)	54.25 (7.53)	(3, 137)	5.83***
Control vs Dysgraphia					(1, 62)	9.73**
Control vs Dyslexia					(1, 96)	8.63**
Control vs OWL LD					(1, 52)	14.33***
Internalizing Problems Composite	45.61 (6.72)	54.08 (15.59)	51.48 (11.03)	53.94 (6.53)	(3, 138)	4.33**
Control vs Dysgraphia					(1, 62)	8.87**
Control vs Dyslexia					(1, 98)	6.62**
Control vs OWL LD					(1, 52)	17.60***
Adaptive Skills Composite	54.79 (7.52)	46.78 (9.96)	52.48 (9.98)	45.63 (10.89)	(3, 139)	5.98***
Control vs Dysgraphia					(1, 63)	13.66***
Control vs Dyslexia					(1, 97)	1.75 ns
Control vs OWL LD					(1, 52)	21.05***
CLINICAL SCALES						
Atypicality	44.8 (5.16)	41.81 (7.68)	50.16 (8.27)	54.75 (8.37)	(3, 139)	5.83***
Control vs Dysgraphia					(1, 63)	3.43 n.s.
Control vs Dyslexia					(1, 93)	12.93***
Control vs OWL LD					(1, 52)	28.03***
Attention	48.34 (9.27)	54.78 (8.23)	54.21 (9.86)	58.88 (6.75)	(3, 139)	5.05***
Control vs Dysgraphia					(1, 63)	8.34**
Control vs Dyslexia					(1, 97)	8.71**
Control vs OWL LD					(1, 52)	16.82***
ADAPTIVE SCALES						
Adaptability	54.79 (7.52)	46.78 (9.96)	52.48 (9.98)	45.63 (10.89)	(3, 139)	4.59 **
Control vs Dysgraphia					(1, 63)	13.66***
Control vs Dyslexia					(1, 97)	1.75 ns.

	<u>Control</u> <u>M SD</u>	<u>Dysgraphia</u> <u>M SD</u>	<u>Dyslexia</u> <u>M SD</u>	<u>OWL LD</u> <u>M SD</u>	(df)	<i>F_p</i>
Control vs OWL LD					(1, 52)	12.69***
Activities of Daily Living						
Control vs Dysgraphia	52.79 (7.39)	43.92 (7.83)	45.70 (8.98)	42.50 (8.07)	(3, 137)	7.12***
Control vs Dyslexia					(1, 62)	21.18***
Control vs OWL LD					(1, 96)	16.55***
					(1, 52)	16.13***
Leadership						
Control vs Dysgraphia	56.39 (8.50)	50.00 (9.92)	52.98 (8.98)	46.13 (8.77)	(3, 138)	4.58**
Control vs Dyslexia					(1, 82)	7.62**
Control vs OWL LD					(1, 95)	3.85 n.s.
					(1, 52)	16.13***
Functional Communication						
Control vs Dysgraphia	53.97 (8.20)	48.11 (10.02)	48.60 (8.97)	39.81 (7.74)	(3, 139)	7.51***
Control vs Dyslexia					(1, 63)	6.71**
Control vs OWL LD					(1, 97)	9.59**
					(1, 52)	34.70***

Notes. ** p <.01, *** p <.001 for main effects for all four groups. Bonferroni correction for multiple comparisons **p<.0125, ***p<.001 for posthoc comparisons of each SLD group with the control group. Results are based on complete ratings with clear response. ANOVAs are based on separate gender norms because of greater number of boys than girls in the sample.

Table 4

For *BASC2-PRS* Ratings Showing Significant Differences between Control Group and A Specific SLDs-WL Group (at $p < .0125$, see Table 3), Correlations (r) between the Ratings and Hallmark Language Impairments for that SLDs-WL group.

DYSGRAPHIA		Alpha 15	Copy Best	Copy Fast		
Behavioral Problems Index		-.27 *	-.17	-.14		
Internalizing Problems Composite		-.36 **	-.25	-.22		
Adaptive Skills Composite		.22	.20	.30 *		
Attention Problems		-.31 **	-.17	-.23		
Adaptability		.28 *	.24	.35 **		
Activities of Daily Living		.38 **	.22	.32 **		
Leadership		.21	.26 *	.35 **		
Functional Communication		.27 *	.17	.24		
DYSLEXIA		Word ID	Dict Spell Real	Dict Spell Sounds		
Behavioral Problems Index		-.12	-.21 *	-.23 *		
Internalizing Problems Composite		-.15	-.21 *	-.13		
Atypical		-.13	-.25 **	-.27 **		
Attention Problems		-.24 *	-.29 **	-.32 **		
Activities of Daily Living		.28 **	.40 ***	.22 *		
OWL LD		Oral Comp	Read Comp	Oral Sent	Writ SentCom	Flu
Behavioral Problems Index		.36 **	-.37 **	-.38 **	.50 ***	-.25
Internalizing Problems Comp		-.43 ***	-.34 **	-.30 *	-.42 **	-.39 **
Adaptive Skills Composite		.15 .27 *	.27 *	.38 **	.18	
Atypical		.48 ***	.44 ***	.55 ***	.36 **	.43 **
Attention Problems		-.27	-.40 **	-.32 *	-.50 ***	-.34 *
Adaptability		.33 *	.45 ***	.46 ***	.50 ***	.35 *
Leadership		.23	.40 **	.34 **	.44 ***	.32 *
Activities of Daily Living		.46 ***	.52 ***	.50 ***	.56 ***	.45 **

OWL LD	Oral Comp	Read Comp	Oral Sent	Writ SentCom	Flu
Functional Communication	.54***	.59***	.62***	.52***	.50***

Notes.

- * p <.05,
- ** p<.01,
- *** p<.001.

Separate norms for gender were used because of the larger number of boys than girls in the sample. Because some fell within the clinical or at risk ranges in both the control and the SLDs-WL groups both were included in the correlational analyses for specific hallmark impairments for specific diagnoses. See Text for full names of test and description of tasks.

Table 5

Magnitude of Significant fMRI Connectivity with Amygdala from Specific Seeds. See Table Note.

GROUP	Seed-Region of Connectivity	volume (pixels)	mean magnitude	x	y	z
DYSGRAPHIA						
Left Occipital Temporal	right amygdala in superficial group	11	6.296	28	2	-12
	Left Inferior Frontal					
right amygdala in centromedial group	right amygdala in centromedial group	16	6.674	26	-2	-2
	right amygdala in superficial group	21	6.603	16	-4	-12
DYSLEXIA						
Left Precuneus	right amygdala in centromedial group	15	6.554	28	-2	-8
	right amygdala in laterobasal group	24	6.523	26	4	-20
Left Occipital Temporal	right amygdala in superficial group	18	6.724	20	2	-16
	right amygdala in superficial group	25	6.653	-24	4	-12
Left Supramarginal	left amygdala in superficial group	26	6.687	20	2	-16
	amygdala in centromedial group	18	6.890	-30	-14	-2
right amygdala in laterobasal group	left amygdala in centromedial group	27	6.586	26	-2	-2
	right amygdala in superficial group	10	6.504	26	-6	-12

Note. There was no connectivity to amygdala in the control group.