Research Article

Executive Functioning and Narrative Language in Children With Dyslexia

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Purpose: Children with dyslexia often struggle with nonphonological aspects of language and executive functioning. The purpose of this study was to investigate the impact of executive functioning on language abilities at both structural (e.g., grammar in sentences) and functional (e.g., narrative) levels in 92 third- and 4th-grade students with dyslexia. Additionally, we asked if working memory updating contributed a significant amount of variance in narrative language ability beyond what would be expected by students' structural language skills alone.

Method: Students' language and executive functioning skills were evaluated using a range of language and cognitive measures including the Clinical Evaluation of Language Fundamentals–Fourth Edition (Semel, Wiig, & Secord, 2003), the Peabody Picture Vocabulary Test–Fourth Edition (Dunn & Dunn, 2007), the Test of Narrative Language (Gillam & Pearson, 2004), the Delis–Kaplan Executive Function Scale (Kaplan, Kramer, & Delis, 2001),

and the Corsi Block-Tapping Test (WISC-IV Integrated; Kaplan, Fein, Kramer, Delis, & Morris, 2004).

Results: Low correlations between the language measures suggested that each of these assessments captures a unique element of language ability for children with dyslexia. Hierarchical regression analysis indicated that working memory updating accounted for a significant amount of unique variance in oral narrative production beyond what would be expected by structural language ability.

Conclusions: The range of performance found across language measures suggests that it may be important to include a variety of language measures assessing both structural and functional language skills when evaluating children with dyslexia. Including cognitive measures of executive functioning may also be key to determine if deficits in working memory updating are contributing to functional expressive language difficulties.

Children with dyslexia have primary impairments in single-word reading with underlying phonological processing deficits, an area composed of component skills of phonological awareness and recoding (Wagner & Torgesen, 1987). *Phonological awareness* refers to the explicit understanding of the sound structure of one's language, and *phonological recoding* involves the ability to map these phonological units onto orthography for decoding words (Bishop & Snowling, 2004; Perfetti, 2009; Wagner & Torgesen, 1987). Phonological recoding is suggested to involve executive functions of working memory to efficiently translate

printed orthography into a sound-based representational system (Wagner & Torgesen, 1987). Some children with dyslexia have additional language impairments in areas of semantics, syntax, and functional discourse (Bishop & Snowling, 2004; Snowling, 2001; Stanovich & Siegel, 1994). In addition to these comorbid impairments in oral language, children with dyslexia may have impairments in other executive functions that can further impact outcomes in both reading and language production (Catts, 1993; Nation, Clarke, Marshall, & Durand, 2004; Reiter, Tucha, & Lange, 2005). Recently, Kaushanskaya, Park, Gangopadhyay, Davidson, and Ellis Weismer (2017) used a latent variables approach to identify if the executive functioning skills of inhibition, task shifting, and working memory updating were differentially related to lexical–semantic language skills versus syntactic skills in typically developing children. Characterizing the relationships among different aspects of language ability and executive functioning in children with dyslexia is important to improve our assessment of such children and our understanding of multidimensional models of dyslexia (Pennington, 2006) and also to improve interventions.

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In order to characterize relationships between executive functioning and language, it is important to consider differences in task demands across standardized language assessments and the degree to which executive functions may be taxed by these task demands. Standardized measures of language skills range from assessments of single-word vocabulary to comprehension and production of syntax, morphology, and functional language (e.g., narrative). These assessments vary in the extent to which performance is supported by specific subdomains of executive functioning. Standardized measures of receptive language ability have been supported by a domain-general ability referred to as *working memory updating*. Working memory updating is highly related to the more general term *working memory* but refers specifically to the process of integrating new information rather than maintaining old information (Vaughan & Giovanello, 2010). In Kaushanskaya et al.'s (2017) study, working memory updating was composed of two non-verbal working memory tasks, the *n*-back and Corsi block tasks. Inhibition tasks, however, have accounted for differences in expressive syntax in children, even after controlling for age, socioeconomic status, and IQ (Kaushanskaya et al., 2017). Therefore, students with dyslexia who have relative strengths in language production where the structure of the assessment is focused on production of grammar (i.e., syntax and morphology) and difficulty when participating in language assessments of narrative ability that require oral language to be organized into a cohesive sequence of events to tell a meaningful story may show differences in relative strengths and weaknesses in subdomains of executive functioning as well. Using language assessments that evaluate both production of grammar and narrative skill in children with dyslexia is important, because using only one type of language assessment may provide a limited perspective on their abilities and areas in need of intervention. Investigating the relationship between performance on assessments measuring structural language skills (e.g., vocabulary, grammar) in children with dyslexia versus functional oral language measures that require the production of an organized story grammar (e.g., narrative) creates a context in which to explore the role of different executive functions in the performance on these tasks and expand upon hypotheses regarding the relationship between executive functions and language production for children with dyslexia. The purpose of the current study is to describe the language skills of 92 third- and fourth-grade students with dyslexia when assessed using standardized measures of vocabulary, grammar, and narrative and define the role of executive functioning skills in their language performance.

Language and Dyslexia

Bishop and Snowling (2004) present a two-dimensional model of the relationship between children with dyslexia and children with language impairment. Children with language impairment have difficulty in primarily non-phonological language skills of syntax and morphology,

while children with dyslexia have impairments primarily in phonological processing. Given that successful reading comprehension requires phonological knowledge for decoding, children with dyslexia may have difficulty with reading comprehension due to the complex nature of translating the sounds of their language into meaningful text for comprehension (Hoover & Gough, 1990; Hulme & Snowling, 2011; Morris et al., 1998). For this reason, children with dyslexia who have primary difficulty with phonological aspects of language continue to have impairments in reading comprehension when they may have relative strengths in oral language comprehension (Hulme & Snowling, 2011).

A long-standing scientific debate exists regarding the diagnostic categorization of children's language ability. Tomblin, Records, and Zhang (1996) identify children with language impairment using norm-referenced measures of vocabulary, grammar, and narrative. Children with two or more composite scores below -1.25 *SDs* from the mean were classified as having language impairment (Tomblin et al., 1996). This debate regarding the classification of language abilities for diagnostic purposes becomes even more complex given the often comorbid conditions found in children with language impairment. Rice (2016) describes the findings of a number of comparative studies that suggest that language skills can develop normally within children who have comorbid speech, cognitive, and social difficulties but that language can also be impacted in these groups of children, suggesting a need to further define specific language impairment as its own diagnostic category. Distinguishing between specific language impairments in syntax and morphology, specifically tense morphology, versus language impairments more broadly, as Rice suggests, is important in understanding causal pathways for these language impairments. Recently, Bishop, Snowling, Thompson, and Greenhalgh (2017) have determined that classifying children as having developmental language impairment based on children's difficulty with any aspect of language is useful given that these children often go on to have impairments in multiple dimensions of language production. These dimensions of language production may be conceptualized as those that represent structural language skills (i.e., syntax and morphology), phonology, or pragmatic skills (i.e., functional, social communication).

Regardless of how language disorder is classified in children with language impairment, there is strong consensus that language ability is related to reading outcomes (National Institute of Child Health and Human Development, 2000). In addition to language impairment having detrimental effects on reading comprehension, impairments in language production across any dimension of language (semantics, syntax and morphology, phonology, pragmatics) can result in functional communication difficulties for children and may have far-reaching consequences in terms of child adaptive, emotional, and behavioral functioning (Yew & O'Kearney, 2013). Understanding the functional communication ability of children with dyslexia who often have

comorbid impairments in at least one dimension of language identified above is important to ameliorate language difficulties and should be an additional goal of educational interventions. Narrative language is one context that functional language ability may be evaluated in children with dyslexia.

Narrative Language and Dyslexia

Narrative language tasks require the simultaneous application of structural components of language for functional communication. Narrative language tasks can assess both comprehension and production of narrative language. Oral narrative tasks are designed to evaluate the ability of the child to orally convey a story in a cohesive manner using conventional story grammar elements, such as characters, settings, conflicts, and resolutions (Paul & Smith, 1993). Thus, oral narrative language performance reflects the integration of component language skills (e.g., vocabulary, syntax, and morphology) with mastery of story grammar. Narrative language tasks are a particularly important context in which to assess language ability in children with dyslexia. Oral narrative language ability has been found to be closely related to reading comprehension skill (Catts, Fey, Zhang, & Tomblin, 2001; Miller et al., 2006; Vandewalle, Boets, Boons, Ghesquiere, & Zink, 2012) and a more sensitive measure of language ability as children age in identifying persistent language impairment than structured tests of syntax and morphology alone. In a study aimed at understanding contributions of oral language to reading comprehension skill for children who are bilingual, Miller et al. (2006) found that oral narrative language ability in both Spanish and English predicted reading comprehension scores in both languages. In an attempt to understand cognitive processes that underlie both reading and narrative production, Vandewalle et al. (2012) found that children with both dyslexia and language impairment had greater difficulty with narrative tasks than children with language impairment alone. Bidirectional relationships have also been found between oral narrative ability and reading comprehension that suggest children develop interrelated cognitive and linguistic systems that work together to develop reading skills over time (Dickinson & McCabe, 2001). There may be similar cognitive processes that underlie both reading and narrative production that contribute to strengths or weaknesses in each area.

Executive functions of children may be one cognitive process that contributes to performance in each of these areas for children. Executive functions become increasingly important as children grow older and demands for sophisticated behavior with regard to long-term goals increase. Thus, executive functions play a major role in academic success or failure, especially in adolescence (Best, Miller, & Naglieri, 2011).

Executive Function, Language, and Dyslexia

Executive function is a term used to describe a collection of higher order abilities that enable goal-directed

behavior, including initiating, planning, organizing, and self-monitoring. When faced with a complex task, a child's executive functioning supports him or her in (a) beginning the task, (b) selecting an efficient approach, (c) changing the approach if necessary, (d) avoiding distraction, and (e) persisting until the task is complete. Executive functioning skills have been suggested to largely fall within three related but separable subcomponents of task shifting, inhibition, and working memory updating (Miyake et al., 2000; Roth, Isquith, & Gioia, 2014). Task shifting is the ability to flexibly switch between tasks or mental sets, inhibition is the ability to suppress attention to irrelevant information, and working memory updating refers to the ability to update and monitor working memory representations (Miyake et al., 2000). Kaushanskaya et al. (2017) used nonverbal executive functioning tasks with 71 typically developing children between 8 and 11 years of age and found that these three factors of task shifting, inhibition, and working memory updating explained 72.30% of the variance in the six tasks used to measure executive functioning. Inhibition was most closely linked with expressive syntax, and working memory updating was most closely linked to receptive language as measured by the Clinical Evaluation of Language Fundamentals–Fourth Edition (CELF-4; Semel, Wiig, & Secord, 2003).

One aspect of executive functioning in which children with dyslexia have shown deficits is in updating to working memory (Jeffries & Everatt, 2004). The ability to temporarily store and manipulate information is crucial to everyday activities involving language comprehension, learning, and reasoning. Within the literature on dyslexia, children have shown relatively consistent deficits in verbal and phonological working memory, whereas findings that use nonverbal tasks of working memory are mixed (Pennington, Johnson, & Welsh, 1987; Varvara, Varuzza, Sorrentino, Vicari, & Menghini, 2014). Studies indicate that deficits in verbal working memory can be characteristic of children with language impairment as well, and thus, the high prevalence of such deficits among children with dyslexia is unsurprising in the context of the comorbidity between language impairment and dyslexia (Gathercole & Baddeley, 1990; Vugs, Hendriks, Cuperus, Knoors, & Verhoeven, 2017). Opinions differ regarding the mechanism leading to comorbid verbal working memory and language impairment. One theory suggests that verbal working memory impairments are secondary to language impairments because activation of language skills is necessary to maintain verbal stimuli in memory (Acheson & MacDonald, 2009). Alternatively, verbal working memory impairments may lead to language impairments because limitations in verbal working memory interfere with the acquisition of language skills (Gathercole, 2007). Examinations of nonverbal working memory updating tasks may be more productive in clarifying the contributions of executive function to language because such analyses would be less confounded by the overlap in task linguistic demands.

Children with dyslexia have also been found to have increased difficulty on tasks of inhibition such as Stroop

tasks designed to evaluate the ability to switch cognitive sets and control automatic word reading when naming a color. Everatt, Warner, Miles, and Thomson (1997) found that children with dyslexia had a more difficult time on Stroop tasks than children without dyslexia. Similarly, Stubenrauch et al. (2014) found that children with reading disabilities had a more difficult time with Stroop tasks than children with attention-deficit/hyperactivity disorder. These studies suggest that children with dyslexia may have difficulty with complex tasks that involve reading during tasks of inhibition. Importantly, the degree of difficulty a child experiences on Stroop tasks may be partially determined by the automaticity with which she or he is able to decode written words, leading some researchers to hypothesize that the size of the Stroop effect can be used as an indicator of the development of reading skills across childhood (Schwanenflugel, Morris, Kuhn, Strauss, & Siczko, 2008).

Assessment

Given the prevalence and functional impact of comorbid impairments in language and executive functions among children with dyslexia, accurate and informative assessment tools of language ability are extremely important for valid conceptualization of areas of strength and weaknesses in language that will lead to effective intervention. The objectives of individual language assessments vary, with some assessments aiming to measure lexical and structural components of language in isolation (e.g., single-word vocabulary comprehension and production, comprehension and production of syntax and morphology) and others aiming to measure the simultaneous application of these structural components of language for functional communication (e.g., oral narrative). The advantage of the former is that these assessments allow for the identification of specific weaknesses in various components of language, which may be appropriate intervention targets. The advantage of the latter is that these assessments provide information about how the child may perform in real-world contexts, in which integration of skills to produce longer and more complex responses is often necessary. A combination of both assessment types is useful because it enables process-oriented analyses, providing an in-depth understanding of the nature and functional impact of the child's language difficulties.

Subcomponents of executive functions of task shifting, inhibition, and updating to working memory each may impact narrative language production in children. Of particular relevance to narrative language production is updating. The child must maintain awareness of all of his or her previous statements, as well as elements of story grammar, while orally producing a narrative that is clear, well ordered, and complete. Therefore, children with dyslexia who may have relative strengths in grammatical language skills, but difficulty in working memory updating, may have greater difficulty communicating using narrative language but may perform relatively well when assessed using a structured

assessment of syntax and morphology such as the CELF-4 (Semel et al., 2003) that has been linked more closely with inhibition (Kaushanskaya et al., 2017). Investigating the relationship between performance on language assessments measuring component skills (e.g., vocabulary, syntax, and morphology) versus their performance on more functional language assessments that require the production of an organized story grammar (e.g., narrative) creates a context in which to explore the role of executive functioning on such assessment tasks and to expand hypotheses regarding the role of executive abilities in language production for students with dyslexia.

Research Aims

The purpose of this study was to investigate the impact of executive functioning on language abilities at both structural (e.g., syntax and morphology) and functional (e.g., narrative) levels in a sample of students with dyslexia. We analyzed language and executive functioning in a sample of 92 third- and fourth-grade students with dyslexia. The study had three aims: (a) describe the language profiles of the students in terms of their performance on standardized measures of receptive vocabulary, sentence repetition, sentence formulation, and narrative production—we hypothesized that students would vary in their profiles of strengths and weaknesses among the different vocabulary and language measures, with many students showing impairments on at least one measure; (b) examine the relationship between executive functioning and language measures—we hypothesized that executive functioning would be associated with performance on all language measures but not receptive vocabulary; and (c) determine if working memory updating contributes significant variance in narrative production beyond what would be expected based on sentence-level grammatical language skills alone. We selected a measure of nonverbal working memory updating for this analysis (Corsi Block-Tapping Test, backward condition) in order to minimize the linguistic demands in our executive functioning task. We hypothesized that working memory updating would account for significant variance in narrative ability.

Method

Participants

Participants in this study included 92 third and fourth graders ($M_{\text{age}} = 9.25$ years, $SD = 1.40$) with developmental dyslexia (male, $n = 54$; female, $n = 38$). These students were originally recruited to participate in a larger reading intervention study for students with developmental dyslexia. Students were referred by teachers/schools to participate in the study if they exhibited difficulty learning to read based on classroom performance and/or school-administered, standardized assessments. Project evaluators screened students using the Wechsler Abbreviated Scale of Intelligence—Second Edition, Two-Subtest Form (Wechsler, 2011); Woodcock-Johnson Test of Achievement—Third Edition

(WJ-3; Woodcock, Mather, & McGrew, 2001); and the Test of Word Reading Efficiency–Second Edition (TOWRE-2; Torgeson, Wagner, & Carol, 2011). Students were included if they were native speakers of English and had an abbreviated full-scale IQ of ≥ 80 . Students with chronic absenteeism (> 15 absences per year), hearing impairment, serious emotional/psychiatric disturbance, or chronic medical/neurological condition (e.g., seizure disorder) were excluded.

All participants included in the present analyses showed low achievement in word reading and/or phonemic decoding. Students met study entry criteria for developmental dyslexia if they had low achievement in reading, which was defined as a composite score ≥ 1 *SD* below age-norm expectations (standard score [SS] < 85) on at least one of the following: WJ-3 Broad Reading Cluster subtests or composite (Letter–Word Identification, Reading Fluency, Passage Comprehension), the Basic Reading Cluster subtests or composite (Letter–Word Identification and Word Attack), or subtests or composite on the TOWRE-2. For the purpose of this article, we excluded students who only met study criteria based on difficulty with measures related to reading comprehension or SS < 85 only on Passage Comprehension ($n = 2$).

Table 1 displays a summary of participant performance on study screening measures. Participant abbreviated full-scale IQ ranged from low average to superior ($M = 94.90$, $SD = 10.44$). Mean performance on reading measures was consistently low average for WJ-3 subtests (Word Attack: $M = 88.18$, $SD = 9.41$; Letter–Word Identification: $M = 87.74$, $SD = 9.26$; Reading Fluency: $M = 85.82$, $SD = 10.9$; Passage Comprehension: $M = 81.62$, $SD = 9.85$) and below average for TOWRE-2 subtests (Sight Word Efficiency: $M = 75.29$, $SD = 10.43$; Phonemic Decoding Efficiency: $M = 73.08$, $SD = 8.03$).

Table 1. Descriptive statistics ($N = 92$).

Measure	<i>M</i> (<i>SD</i>)
WASI-II Two-Subtest Form	
Vocabulary	98.52 (11.58)
Matrix Reasoning	92.61 (12.38)
Full-scale IQ	94.90 (10.44)
WJ-III Tests of Achievement	
Word Attack	88.18 (9.41)
Letter–Word Identification	87.74 (9.26)
Reading Fluency	85.82 (10.92)
Passage Comprehension	81.62 (9.85)
WJ-III Basic Reading Cluster	86.92 (8.88)
WJ-III Broad Reading Cluster	82.23 (10.22)
TOWRE-2	
Sight Word Efficiency	75.29 (10.43)
Phonemic Decoding Efficiency	73.08 (8.03)
Total Word Reading Efficiency	72.79 (8.40)

Note. All scores are reported as standard scores ($M = 100$, $SD = 15$). WASI-II = Wechsler Abbreviated Scale of Intelligence–Second Edition; WJ-III = Woodcock–Johnson Test of Achievement–Third Edition; TOWRE-2 = Test of Word Reading Efficiency–Second Edition.

Measures

Language

The CELF-4 (Semel et al., 2003) is a widely used measure of language comprehension and production. Each student was administered the four subtests of the CELF-4 required to obtain a Core Language Composite at his or her respective age level. Two subtests were administered to the entire sample: Recalling Sentences and Formulated Sentences. These subtests capture a student's ability to listen to and repeat spoken sentences of increasing length and complexity (Recalling Sentences) and to formulate complete, grammatically correct spoken sentences of increasing length and complexity (Formulated Sentences). Both of these tasks are highly structured and indicative of isolated structural, less functional, language skills. For example, the Formulated Sentence subtest requires students to integrate one word into a single sentence about an individual picture.

Conversely, the Test of Narrative Language (TNL; Gillam & Pearson, 2004) was administered to measure how well students used language in functional discourse. Narrative discourse is one example of functional communication that includes both comprehension and oral language skills. To assess a student's comprehension of narratives, they listened to three stories and then answered questions about characters, settings, and main events in each. To assess a student's oral narrative abilities, they were required to retell and create stories with and without picture prompts. The oral narrative assessment consisted of three story formats: a script with no picture cues, in which a student listened to a story told to them by the examiner and then was asked to retell it; a personal narrative with sequenced picture cues, in which the student was shown five sequenced pictures and is asked to tell the story; and a fictional narrative using a single picture cue, in which the student was asked to tell a story about the picture. Each of these subtests contributed to an overall Oral Narrative (ON) subtest scaled score, which we used in this study to compare to the expressive measures from the CELF-4.

The Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4; Dunn & Dunn, 2007) was used to measure single-word receptive vocabulary and is a well-established measure with good reliability and validity. PPVT-4 SSs were transformed to scaled scores for comparison with other measures.

Executive Functions

The Delis–Kaplan Executive Function Scale (D-KEFS; Kaplan, Kramer, & Delis, 2001) and the Corsi Block-Tapping Task–Spatial Span (WISC-IV Integrated; Kaplan, Fein, Kramer, Delis, & Morris, 2004) were used to measure executive function abilities. Students were administered three D-KEFS subtests: Color–Word Interference, Sorting, and Trail-Making. The D-KEFS is a well-established measure that assesses executive functions within both verbal and spatial realms using a cognitive process approach to analyze specific elements of higher order functions.

Color–Word Interference. The average scaled scores from Conditions 3 and 4 of the Color–Word Interference subtest, which required students to inhibit automatized responses and shift between response types, was used for this study. These measures required the students to view color names printed in a different color ink, as well as to name the ink color, and are considered to measure both inhibitory abilities and set shifting abilities.

Sorting. The Total Free Sorts scaled score from the Sorting subtest was also utilized. This subtest required students to sort and categorize six cards that display different attributes, including visual–spatial (e.g., shapes and colors of cards) and semantic (e.g., meaning or function of a single word printed on each card) characteristics. The student was asked to make two groups, with three cards in each, based on as many different categories as possible (maximum of eight correct sorts). Additionally, students were asked to verbally explain their categorical reasoning to the examiner after each sort. This subtest targeted executive functioning skills related to problem-solving behaviors (verbal and nonverbal), explaining abstract concepts, and inhibition.

Trail-Making Test. Finally, Condition 4 of the Trail-Making subtest was used, which required students to shift between sequencing numbers and letters as quickly as possible. This task was observed in the context of a pencil-and-paper activity in which students were asked to connect the numbers and letters in the correct order. This task measured set-shifting and sequencing abilities as well as processing speed.

Corsi Block-Tapping Test. The Corsi Block-Tapping Task–Spatial Span (WISC-IV Integrated; Kaplan et al., 2004) is a commonly used measure of nonverbal attention, sequencing abilities, and working memory updating. It required students to mimic a spatial pattern modeled by the examiner as tapped on a display with nine blocks. The backward condition of the test was used for the current study to assess the students' nonverbal working memory updating. In the backward condition, students were asked to tap the blocks touched by the examiner in reverse order.

Procedure

All data were collected within the students' schools prior to beginning the reading intervention program. Project staff trained in test administration individually assessed each child over two or three evaluation sessions. All tests were administered according to the standard protocols specified in the testing manuals. A trained project evaluator scored all assessments excluding the CELF-4 and TNL. The CELF-4 and TNL assessments were audio-recorded and scored by a speech-language pathologist and a second trained project staff member or graduate student. If disagreements on specific items arose, the two scorers discussed differences and came to consensus.

Data Analysis

All data analyses were conducted in SPSS Version 25 (IBM Corp., 2017). To accomplish Research Aim 1 (describe language profiles), we examined descriptive statistics and correlations among language measures. To accomplish Research Aim 2 (examine relationship between executive function and language measures), we examined correlations between executive function and language measures. In order to reduce the familywise error rate, we applied the Benjamini–Hochberg procedure with a false discovery rate of 0.10 (Benjamini & Hochberg, 1995). We also calculated mean scaled scores separately for the four executive function measures (D-KEFS Color–Word Interference, Sorting, and Trail Making, and Corsi Backward) and the three structural language measures (CELF-4 Recalling Sentences and Formulated Sentences and PPVT-4) and examined subgroups of children with impairments ($SS < 7$) in each domain. To accomplish Research Aim 3 (determine if working memory updating contributes to narrative production beyond structural language), we examined narrative language performance among students exhibiting each of the four executive function and structural language profiles. We also conducted a stepwise multiple regression, in which we entered the mean structural language measure in the first step and executive function in the second step. We selected the Corsi Backward as a measure of executive function in this analysis due to the relatively low linguistic demands of this task, which make it the most conceptually distinct from our structural language measures.

Results

Research Aim 1: Describe the Language Profiles of Students With Dyslexia

First, descriptive statistics were calculated for the PPVT-4, CELF-4 Formulated Sentences, CELF-4 Recalling Sentences, and TNL ON scores. Means and variances are displayed in Table 2. All three measures produced skew and kurtosis values indicating a normal distribution ($-1.96 < t < 1.96$). We examined boxplots to determine the presence of outliers, using the interquartile range rule (Field, 2013). Two high outliers were identified for the CELF-4 Recalling Sentences. Outliers were included due to the limited number of participants. No outliers were present in the other measures.

Second, the relationships among language measures of vocabulary, grammar, and narrative were examined. Table 3 reports correlations among all study variables. In order to reduce the familywise error rate, the Benjamini–Hochberg procedure was applied with a false discovery rate of 0.10 (Benjamini & Hochberg, 1995). Given the exploratory nature of the correlation analyses, the table indicates both uncorrected statistically significant correlations and ones that were robust to the Benjamini–Hochberg procedure. Among the language measures, the TNL and the

Table 2. Descriptive statistics ($N = 92$).

Measure	M (SD)
TNL Oral Narrative	8.12 (2.32)
CEL-4 Recalling Sentences	7.46 (2.62)
CEL-4 Formulated Sentences	8.52 (2.95)
PPVT-4	8.96 (2.90)
D-KEFS CW	8.07 (3.08)
D-KEFS Sorting	8.46 (2.56)
D-KEFS TM	6.66 (3.67)
Corsi Backward	8.77 (3.19)

Note. All scores are reported as scaled scores ($M = 10$, $SD = 3$). TNL = Test of Narrative Language; CEL-4 = Clinical Evaluation of Language Fundamentals–Fourth Edition; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition; D-KEFS CW = Delis–Kaplan Executive Function System Color–Word Interference Test average scaled score from Conditions 3 and 4; D-KEFS Sorting = Delis–Kaplan Executive Function System Sorting Test Correct Sorts; D-KEFS TM = Delis–Kaplan Executive Function System Trail-Making Test condition; Corsi Backward = Corsi Block-Tapping Testing backward condition.

CEL-4 Recalling Sentences were significantly correlated ($r = .21$, $p = .04$). The two subtests of the CEL-4 were also correlated with one another ($r = .51$, $p < .01$). The PPVT-4 was not significantly correlated with the CEL-4 subtests or the TNL ON. Scatter plots of the language measures are displayed in Figure 1. Consistent with the correlation analyses, the scatter plots indicate a strong linear relationship between the two CELF subtests, possible weak linear relationships between each CELF-4 subtest and the TNL, and

Table 3. Bivariate correlations among measures.

Measure	1	2	3	4	5	6	7	8
1. TNL ON	—							
2. CEL-4 RS	.21*	—						
3. CEL-4 FS	.19	.51**	—					
4. PPVT-4	.07	.07	.03	—				
5. D-KEFS CW	.16	.01	.06	.05	—			
6. D-KEFS Sorting	.12	.27*	.36**	.01	.21	—		
7. D-KEFS TM	.19	.21*	.19	.22*	.36**	.28**	—	
8. Corsi Backward	.28**	.23*	.23*	-.08	.09	.22*	.34**	—

Note. Bolded values indicate that the correlation remained statistically significant after the Benjamini–Hochberg procedure was applied with a false discovery rate of 0.10. TNL ON = Test of Narrative Language Oral Narrative scaled score; CEL-4 RS = Clinical Evaluation of Language Fundamentals–Fourth Edition scaled score of the Recalling Sentences subtest; CEL-4 FS = Clinical Evaluation of Language Fundamentals–Fourth Edition scaled score of the Formulating Sentences subtest; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition scaled score; D-KEFS CW = Delis–Kaplan Executive Function System Color–Word Interference Test average scaled score from Conditions 3 and 4; D-KEFS Sorting = Delis–Kaplan Executive Function System Sorting Test Correct Sorts; D-KEFS TM = Delis–Kaplan Executive Function System Trail-Making Test Condition 4; Corsi backward = Corsi Block-Tapping Testing backward condition.

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

Figure 1. Scatter plot of language measures. TNL ON = Test of Narrative Language Oral Narrative scaled score; CEL-4 RS = Clinical Evaluation of Language Fundamentals–Fourth Edition scaled score of the Recalling Sentences subtest; CEL-4 FS = Clinical Evaluation of Language Fundamentals–Fourth Edition scaled score of the Formulating Sentences subtest; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition scaled score.

no discernable relationship between the PPVT-4 and any other language measures.

Research Aim 2: Investigate the Relationship Between Executive Functioning and Structural Language Measures

Descriptive statistics for the D-KEFS Color–Word Interference, D-KEFS Sorting, D-KEFS Trail Making, and Corsi Block-Tapping backward were first calculated. Means and variances are displayed in Table 2. All three measures produced skew and kurtosis values indicating a normal distribution ($-1.96 < t < 1.96$). Boxplots were examined to determine the presence of outliers using the inter-quartile range rule. One high outlier was identified for the Corsi Backward. No outliers were present in the other measures.

Next, the relationships among measures of executive functioning and language were examined (see Table 3). D-KEFS Sorting was correlated with both CELF-4 subtests (Recalling Sentences: $r = .27$, $p = .01$; Formulated Sentences: $r = .36$, $p < .01$). D-KEFS Trail Making was correlated with CELF-4 Recalling Sentences ($r = .21$, $p = .04$) and the PPVT-4 ($r = .22$, $p = .03$). Corsi Backward was correlated with TNL ON ($r = .28$, $p < .01$), CELF-4 Recalling Sentences ($r = .23$, $p = .03$), and CELF-4 Formulated Sentences ($r = .23$, $p = .02$). D-KEFS

Color–Word Interference was not significantly correlated with any language measure.

Third, we calculated mean scaled scores separately for the four executive function measures (D-KEFS Color–Word Interference, Sorting, and Trail Making, and Corsi Backward) and measures of structural language and vocabulary ability (CELF-4 Recalling Sentences and Formulated Sentences and PPVT-4) in order to examine profiles of strengths and weaknesses. See Figure 2 for a scatter plot of mean executive function and language measures. Low performance on measures was defined as scores greater than 1 *SD* below the standardized mean (< 7 for scaled scores). Four profiles of strengths and weaknesses emerged; 13 students (14%) showed low mean performance on both executive function and structural language measures, 23 students (25%) showed low mean performance on only executive function measures, 12 students (13%) showed low mean performance on only language measures, and 44 students (48%) were within the average range or above in both areas.

Research Aim 3: Evaluate the Contribution of Executive Functions to Narrative Language

First, we examined narrative language performance among students exhibiting each of the four executive function and structural language ability profiles. See Table 4 for the descriptive statistics of each group. Students with

low performance on both executive function and structural language measures experienced more difficulty with narrative language, whereas all three other groups displayed mean scores in the average range.

Second, we used a stepwise multiple regression to examine the contribution of executive function to narrative language above and beyond structural language skills (CELF-4 Recalling Sentences and Formulated Sentences and PPVT-4). Before proceeding with the analysis, data were examined for violations of the assumptions of multiple regression. Although mean structural language and Corsi Backward were significantly correlated with one another, all variance inflation factor values were low (< 2), indicating that multicollinearity did not strongly influence the analyses. No outliers were observed in the scatter plots of each predictor variable on TNL ON. The standardized residual plot indicated that the data did not violate the assumption of homoscedasticity and that a linear model was appropriate for the data. The results of the Durbin–Watson test indicated that the residuals were not correlated with one another, Durbin–Watson = 2.10. The appearance of the pp plot indicated that residuals were normally distributed.

Entry of Block 1

Table 5 displays the results of the stepwise regression analysis. Mean structural language was first entered into the model, resulting in a regression equation that

Figure 2. Scatter plot of mean language and executive function scaled scores. Mean language scaled score was calculated using the Clinical Evaluation of Language Fundamentals–Fourth Edition Recalling Sentences and Formulating Sentences subtests and the Peabody Picture Vocabulary Test–Fourth Edition. Mean executive function scaled score was calculated using Delis–Kaplan Executive Function Scale (D-KEFS) Color–Word Interference Test average scaled score from Conditions 3 and 4, D-KEFS Sorting Test Correct Sorts, D-KEFS Trail-Making Test Condition 4, and Corsi Block-Tapping Testing backward condition. Reference lines are placed at 7 in order to highlight the subset of the sample impaired in each domain.

Table 4. Narrative language performance by profile.

Group	<i>M</i> (<i>SD</i>)	<i>n</i>
Average or above EF and language	8.30 (2.40)	44
Low EF only	8.30 (2.44)	23
Low language only	8.75 (2.22)	12
Low EF and low language	6.62 (1.26)	13

Note. All scores are reported as scaled scores ($M = 10$, $SD = 3$). Low performance on measures was defined as scores greater than 1 SD below the standardized mean (< 7 for scaled scores). EF = the mean of the four executive function measures (Delis–Kaplan Executive Function System Color–Word Interference, Sorting, and Trail Making and Corsi Backward); language = mean of the three structural language and vocabulary ability measures (Clinical Evaluation of Language Fundamentals–Fourth Edition Recalling Sentences and Formulated Sentences and Peabody Picture Vocabulary Test–Fourth Edition).

accounted for a significant amount of variance in TNL ON, $R^2 = .05$, $F(1, 90) = 5.06$, $p = .03$. This suggested that structural language ability was significantly related to oral narrative ability ($\beta = .23$, $t = 2.25$, $p = .03$) and accounted for 5% of the variance in oral narrative ability.

Entry of Block 2

Corsi Backward was next entered into the model. Nonverbal working memory updating accounted for an additional, significant increase in explained variance above mean structural language, $R^2 = .11$, $\Delta R^2 = .06$, $\Delta F(1, 89) = 5.79$, $p = .02$. These results suggest that nonverbal working memory updating was significantly associated with oral narrative ability even after the inclusion of structural language ability ($\beta = .25$, $t = 2.41$, $p = .02$). In the final model, the effect of structural language ability on oral narrative ability was not significant ($\beta = .19$, $t = 1.83$, $p = .07$).

Discussion

Language Measures

The results of this study support and extend prior research on language skills in children with dyslexia (Bishop

& Snowling, 2004; Snowling, 2001; Stanovich & Siegel, 1994). Mean performance on nonphonological language measures was consistently below normative sample means, and 25 participants (27%) showed impaired average structural language measure scores (see Table 4). This finding further supports the importance of exploring the intersection of language and executive functions in order to best understand the nature of nonphonological language difficulties in dyslexia.

Executive Function and Language

With regard to the relationship between language and executive function, our analyses revealed several statistically significant correlations. These results suggest that executive functions may support performance on common language measures, and this seems especially plausible when examining language measures that require longer oral responses from children. On such measures, performance is likely boosted by the child's ability to plan and organize responses, as well as to engage in self-monitoring while responding. Additionally, some language tasks, such as sentence repetition, overtly incorporate executive function components, such as working memory updating. Thus, the statistically significant correlation observed between CELF-4 Recalling Sentence and Corsi Backward can be explained by the fact that these two tasks reflect verbal and nonverbal working memory updating, respectively.

On the other hand, language abilities may support performance on executive function measures. This seems especially plausible on executive function tasks in which the instructions are long and complex, because the child must comprehend the instructions in order to perform the task. Alternatively, language may also support performance on executive function tasks because the task itself requires processing linguistic stimuli or producing oral responses. For example, the D-KEFS Sorting test involves both word reading and identification of verbally encoded categories (e.g., vehicles, animals). Thus, the significant correlations observed between D-KEFS Sorting and both CELF-4 subtests can be explained by the fact that both tasks reflect language abilities.

In contrast, the D-KEFS Color–Word Interference test was not correlated with any language measures. This may reflect the unique nature of our sample, in that specific deficits in fluent word reading or rapid naming and the lack of automaticity in word reading in children within dyslexia (Morris et al., 1998; Vellutino, Tunmer, Jaccard, & Chen, 2007) could obscure the expected relationship between executive functions and language on this measure. This interpretation is supported by findings from Everatt, Warner, Miles, and Thomson (1997), which indicated that impairment on the Stroop task is related to the degree of reading impairment exhibited by the children with dyslexia. Similarly, Stubenrauch et al. (2014) suggested that Stroop performance is determined by an individual child's allocation of effort or attention in a complex task, which would likely differ in dyslexia due to word reading deficits.

Table 5. Stepwise regression of narrative language on basic language and executive functioning.

Predictor	<i>B</i>	<i>SE</i>	β	<i>R</i>	<i>R</i> ²	ΔR^2
Entry of Block 1				.23	.05	
Mean structural language	0.28	0.12	.23*			
Entry of Block 2				.33	.11*	.06
Mean structural language	0.22	0.12	.19*			
Corsi Backward	0.18	0.07	.25*			

Note. Mean language scaled score was calculated using the Clinical Evaluation of Language Fundamentals–Fourth Edition Recalling Sentences and Formulating Sentences subtests and the Peabody Picture Vocabulary Test–Fourth Edition. Corsi Backward = Corsi Block-Tapping Testing backward condition.

* $p < .05$.

Narrative and Nonverbal Working Memory Updating

A measure of nonverbal working memory updating contributed to the prediction of oral narrative abilities after the inclusion of structural language measures. This is consistent with the idea that complex linguistic tasks require the integration of both foundational language abilities and executive functions. Overall, the contribution of both working memory updating and syntax and morphology to narrative in our bivariate correlation analyses suggests that there may be multiple pathways to difficulties in narrative production. Both children with impairments in syntax and morphology and/or executive function may struggle with narratives. Children with comorbid impairment in both domains may struggle the most.

Working memory updating may support narrative skills in several ways. First, working memory updating may assist the child in recalling the examiner's instructions while producing the narrative and thereby increase the probability that he or she will include each of the elements that are scored. Second, working memory updating facilitates the production of coherent narratives by allowing the child to maintain information from his or her own previous statements and build upon those statements in logical ways. For example, he or she may be more likely to resolve conflicts that he or she previously introduced or follow up regarding the mental states of characters.

Implications

This study has several implications for research on cognitive processes in dyslexia. First, the findings have the potential to clarify relationships among language components, their measurement, and possible domain-general cognitive processes that may underlie their organization. Second, they also have relevance to models of dyslexia, especially the contribution of working memory updating to difficulties in reading.

This study also has several implications for clinical assessment and intervention. In terms of assessment, our observation of variability in performance among structural and narrative language measures supports the need for comprehensive assessment of language in children suspected of having dyslexia. Different language measures with different levels of structural and narrative requirements, mediated by a child's level of executive functioning, may also result in different diagnostic conclusions regarding whether a child with dyslexia is comorbid for a language impairment and what treatment options would be most beneficial. Additionally, supplementary measures of executive function may be helpful in elucidating mechanisms leading to an individual child's difficulties. In terms of interventions, it is likely that improved classification of children with dyslexia will lead to efforts to better tailor interventions to an individual child's needs. For example, if a child struggles with functional discourse secondary to executive function difficulties, teaching metacognitive

strategies, such as breaking a task down into parts, may be a productive treatment approach.

Limitations and Future Directions

One interesting finding from the current study is that the final multiple regression model only explained a modest amount of variance in oral narrative performance (11%). This is to be expected in the context of relatively small bivariate correlations among language measures and large standard errors in our language data. Nonetheless, questions remain about other factors that may contribute to oral narrative performance. One variable worth exploring in future studies is child exposure to or knowledge of story grammar. Children with dyslexia may have limited exposure and experience with story grammar due to their limited reading. It seems likely that awareness of expected story elements would support students in producing their own coherent narratives. Similarly, future studies might examine the impact of cultural and dialectal differences on the relationship between sentence-level and narrative language.

Another extension to this study would involve integrating parent or teacher ratings of students' executive functions and communication skills. This would allow the further investigation of the ecological validity of both executive function and language tasks by comparing short, highly structured, direct assessment measures with adult observations of students in everyday life.

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