



Published in final edited form as:

J Learn Disabil. 2017 ; 50(4): 434–449. doi:10.1177/0022219415617167.

Relationships of Attention and Executive Functions to Oral Language, Reading, and Writing Skills and Systems in Middle Childhood and Early Adolescence

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Abstract

Relationships between attention/executive functions and language learning were investigated in students in grades 4 to 9 ($N=88$) with and without specific learning disabilities (SLDs) in *multi-word syntax* in oral and written language (OWL LD), *word* reading and spelling (dyslexia), and *subword letter* writing (dysgraphia). Prior ADHD diagnosis was correlated only with impaired handwriting. Parental ratings of inattention, but not hyperactivity, correlated with measures of written language but not oral language. **Sustaining switching attention correlated with writing the alphabet from memory in manuscript or by keyboard and fast copying of a sentence with all the letters of the alphabet.** Multiple regressions based on a principal component for composites of multiple levels of language (subword, word, and syntax/text) showed that **measures of attention and executive function involving language processing** rather than ratings of attention and executive function not specifically related to language **accounted for more variance and identified more unique predictors in the composite outcomes for oral language, reading, and writing systems.** **Inhibition related to focused attention uniquely predicted outcomes for the oral language system.** Findings are discussed in reference to implications for assessing and teaching students who are still learning to pay attention to heard and written language and self-regulate their language learning during middle childhood and adolescence.

Liberman (1999) had the pioneering insight that there is more than one language system and described language by ear (listening to aural language), language by mouth (orally producing language), and language by eye (reading written language). Berninger (2000) explained how language by hand (writing written language) is also a language system that interacts with the other language systems by ear, by mouth, and by eye. Although these four language systems often develop at comparable rates, they may show dissociations, that is, uneven rates of development that are stable across grade levels (Berninger & Abbott, 2010). Research reviewed by Silliman and Berninger (2011) showed that specific learning disabilities (SLDs) can be differentiated on the bases of different language systems and their developmental trajectories. Oral and written language learning disability (OWL LD), which

emerges between age 1 and 3, initially affects language by ear and mouth but later language by eye and hand; dysgraphia, which emerges between ages 5 and 6, affects language by hand; and dyslexia, which also emerges between ages 5 and 6, affects language by eye and hand.

Adding further complexity, a half century of child language research has shown that language, whether heard and spoken or read and written, is multi-leveled, that is, units of different grain size are involved. For example, subword units contribute to word units, which in turn contribute to multi-word syntax units with or without non-syntactic idioms, which in turn contribute to larger discourse or text units (e.g., Butler & Silliman, 2002; Catts & Kamhi, 2005; Nelson, 2010; Nelson, Helm-Estabrooks, Hotz, & Plante, 2011; Nippold, & Scott, 2010; Scott, 2009; Scott & Nelson, 2009; Silliman, Huntley Bahr, & Peters, 2006). Moreover, individuals may have relative strengths or weaknesses at different levels of language (subword, word, syntax, discourse/text structures) within and across the four language systems (Berninger, 2015).

Given this complexity of the multileveled, multiple interacting functional language systems, it follows that mental government is necessary to manage the numerous processes. Posner and Rothbart (2007) showed that attention plays a role in self-regulation of language. Miyake, Friedman, Emerson, Witzki, Howerter, and Wagner (2000) identified inhibition and mental set shifting in regulating language functions. Das and colleagues (Das, Kirby, & Jarman, 1975; Das, Naglieri, & Kirby, 1997; and Das, Kar, & Parrila, 1996) called attention to the role of planning in regulating language. Writing researchers have identified planning, translating, reviewing, and revising as processes that regulate language by hand (Hayes & Flower, 1980; Hayes & Berninger, 2014). Multiple cognitive representations and operations are involved in the cognitive ↔ linguistic translation process, which operates bidirectionally and is regulated by executive functions for language by hand, ear, mouth, and/or eye (Berninger, Rijlaarsdam, & Fayol, 2012). A growing body of knowledge is adding knowledge of how working memory also contributes to language learning (e.g., Arrington, Kulescz, Francis, Fletcher, & Barnes, 2014; Daneman & Carpenter, 1980; Swanson, 1993a, 1993b, 1995, 1996, 1999, 2006; Swanson & Ashbaker, 2000; Swanson & Siegel, 2001). Lower order supervisory attention regulates storage and processing of words in working memory, and higher order executive functions such as planning, supported by working memory, contribute further to regulating language learning and use (Berninger, Swanson, & Griffin, 2014).

Although co-occurring ADHD is often diagnosed in students with specific learning disabilities (SLDs), the relationship between ADHD diagnosis or its inattention and hyperactivity/impulsivity subtypes (e.g., Topiak et al., 2012; Willicutt et al., 2012) and self-regulation of language learning is not fully understood. ADHD and its subtypes may change in expression across development and be better expressed as dimensions (based on number of symptoms) rather than categorical diagnoses (Willicutt et al.). ADHD or its subtypes are typically diagnosed on the basis of adults rating symptoms of a student's inattention and/or hyperactive/impulsive behaviors; recommended best practices is for parents to rate symptoms at home and teachers to rate symptoms at school. Moreover, learning disabilities involving language are often diagnosed without consideration of the relationships between

various kinds of attention and executive functions to specific language skills. On the one hand, assessment of a student's profile in each developmental domain—cognitive, language, sensorimotor, social emotional, and attention/executive function can be useful in diagnosing or ruling out developmental disabilities (Berninger, 2015). On the other hand, assessment of the relationships between two of these domains can be useful in understanding and teaching students with specific learning disabilities. For example, relationships between language and different attention and executive functions may be as informative as relationships between language and different input (ear and eye) and output (mouth and hand) sensorimotor modalities. Thus, four research questions about the relationships between language and attention/executive functions were addressed in the current study.

Based on prior findings that handwriting and related writing problems often co-occur in individuals with ADHD (Re & Cornoldi, 2010) and inattention and distractibility have been linked to writing problems (McCandless & O'Laughlin, 2007), the first research question was whether ADHD was correlated with handwriting or other writing skills. Based on prior findings that parental inattention ratings, but not parental hyperactivity ratings, were related to written language learning in children with dyslexia in a multi-generational family study of dyslexia (Thomson et al., 2005), the second research question was whether this finding would replicate in a sample ascertained in a different way. Based on prior findings that sustained switching attention was related to reading and writing achievement in at-risk writers (Amtmann, Abbott, & Berninger, 2008; Berninger et al., 2006), the third research question was whether this finding would replicate in a sample of older students. Based on a systems model aimed at all levels of the multi-leveled language by ear, by mouth, by eye, and by hand systems, as discussed earlier, the fourth research question was which attention/executive functions best predict a multi-leveled oral language system, a multi-leveled reading system, and a multi-leveled writing system. Of interest was whether measures that assess attention/executive functions while processing language or measures that assess symptoms of attention/executive function difficulties that are not necessarily language-specific would account for the most variance in an achievement outcome factor based on multiple levels of an oral language system, reading system, or writing system. These four research questions were addressed in a sample of students in grades 4 to 9 who were typical language learners or who had carefully diagnosed specific learning disabilities in language—writing, reading, and/or oral language (Berninger, Richards, & Abbott, 2015).

The multi-leveled writing system was modeled by a composite of subword alphabet writing from memory (legible, automatic letters in alphabetic order), word-specific spelling (identifying correctly spelled real words), and sentence composition fluency (timed written syntax construction). The rationale was based on programmatic research showing these three skills, at different levels of increasing size, are sensitive to identifying at risk writers as well as those with dysgraphia (Berninger, 2009; Berninger et al., 2015). The multi-leveled reading system was modeled by a composite based on (a) subword phonological decoding (Morris et al., 1998), (b) word-specific spellings (Ehri, 1980a, 1980b, 2014; Olson, Forsberg, Wise, & Rack, 1994), and sentence/text reading comprehension (Cain & Oakhill, 2007). Not only alphabetic principle but also word-specific spelling contributes to the multi-leveled reading system because English is a morphophonemic orthography (e.g., Nagy, Berninger, & Abbott, 2006; Nunes & Bryant, 2006; Nunes, Bryant, & Bindman, 1997;

Richards et al., 2006a, 2006b; Venezky, 1970) and word-specific spelling underlies both word reading and spelling (Bowers, & Wolf, 1993; Olson et al., 1994), especially after the fourth grade transition to mostly silent reading and written assignments. Again, the rationale was based on programmatic research showing these three skills, at different levels of increasing size, are sensitive to identifying students at risk for dyslexia (Berninger et al., 2015; Silliman & Berninger, 2011). The multi-leveled aural/oral language system could be modeled by a composite of sublevel coding of heard and spoken sounds in working memory (Wagner & Torgesen, 1987), word level vocabulary meaning (Stahl & Nagy, 2005), and syntax/text aural comprehension (Butler, & Silliman, 2002; Nelson, 2010). Again, the rationale was based on programmatic research showing these three skills, at different levels of increasing size, are sensitive to identifying students at risk for OWL LD (Berninger et al., 2015; Silliman & Berninger, 2011).

Method

Participants

Flyers were distributed to local schools to recruit students in grades 4 to 9 with and without difficulty with written language learning—handwriting, word reading and spelling, reading comprehension and written expression. Interested parents who contacted the first author were interviewed over the phone to determine whether the student probably was a typical language learner or had an SLD rather than a developmental disability (cognitive and other developmental domains outside the normal range). ADHD, which is known to co-occur with SLDs, was not an exclusion criterion. Although diagnosed neurogenetic disorders other than SLD or brain injury were exclusion criteria, of the children whose parents were interviewed over the phone in response to the flyer, all appeared to have reported developmental and medical histories consistent with SLDs and longstanding and persistent struggles with language learning at school despite considerable special help in and often outside school. In addition, some parents also volunteered siblings who shared the same home environments as their children with SLDs but did not have histories of struggling in language learning; if assessment confirmed they did not have dysgraphia, dyslexia, or OWL LD they served as controls. Informed consent and assent was obtained using procedures approved by the institutional review board. The comprehensive assessment battery was administered by highly trained and supervised doctoral research assistants in a four-hour session with snack, movement, and bathroom breaks interspersed.

Altogether 29 females and 59 males ($N=88$, ages 9 to 15, $M=12$ years 3 months) completed the comprehensive assessment battery and their parents completed attention/executive function ratings. Reported racial identities were representative of the region where the research was conducted: White ($n=69$), More than One Race ($n=14$), Asian ($n=3$), Native Hawaiian or Other Pacific Islander ($n=1$), and Black or African American ($n=1$). Parent education levels included high school graduate (2.2%, mother; 4.4% father), more than high school but less than college (3.3%, mother; 7.8% father), college (41%, mother; 41.4% father), and more than college (48.9%, mother; 36.7%, father); but 4.4% of mothers and 7.8% of fathers did not report educational level. Except for four adopted children, parents reported family history of SLDs.

Following the comprehensive assessment, participants were assigned to one of four groups based on impairments ($< -2/3$ SD) in at least 2 test scores for handwriting but not reading (*dysgraphia*), for word reading and spelling but not listening comprehension or oral expression (*dyslexia*), for listening and reading comprehension and oral and written expression (*OWL LD*), or none of these impairments (controls) (see Silliman & Berninger, 2011; Berninger et al., 2015; for this evidence-based differential diagnosis model). Based on prior research (Berninger & Abbott, 2013), only if the child was twice exceptional with very high cognitive $\leftrightarrow$ linguistic translation, which can mask reading and spelling problems, could the word reading and spelling fall somewhat above the $-2/3$ SD cut off but below the population mean for dyslexia. Parent questionnaires completed while the child was assessed were examined for consistency of the pattern of test scores with parent-reported developmental, medical, and educational history to verify persistence of a specific learning disability (SLD), despite considerable special help in and often outside school. For additional information on assignment to diagnostic groups see Berninger et al. (2015). The focus of the current paper is on the attention and executive functions and their relationships to language learning outcomes for different levels (units) of language within and across functional systems in students with diverse language learning profiles (26 with dysgraphia, 38 with dyslexia, 13 with OWL LD, and 11 typical language learners), who on average are in the average range on language outcomes.

Measures—Attention and Self-Regulation

ADHD diagnosis—One of the questions on the parent questionnaire was whether the child had been diagnosed with ADHD. Systematic information was not collected on whether only inattention or only hyperactivity-impulsivity was diagnosed.

Parent ratings of attention—Following procedures in Thompson et al. (2005), parents rated each of the 18 items on a scale of 1 to 5 to indicate the degree to which their child exhibited specific symptoms. These ratings were then converted to a factor score based on 4 or 5 items corresponding to four factors in Thomson et al.'s (2005) study of predicting language learning outcomes in a family genetics study of dyslexia. For purposes of the current study only the inattention and hyperactivity factor scores for the parental ratings were analyzed.

Behavior Rating Inventory of Executive Functions (BRIEF)—(Goia, Isquith, Guy, & Kentworkthy, 2000). Parents rated their child's behavior on a three-point Likert scale (never, sometimes, and often) for each of 86 items related to executive functions. The *Behavioral Regulation Index* has three scales: (a) *Inhibit* (ability to control impulses and to inhibit engaging in a behavior); (b) *Shift* (ability to move freely from one activity or situation to another, to tolerate change, and to switch or alternate attention); and (c) *Emotional Control* (ability to regulate emotional responses appropriately in response to situations). The *Metacognition Index* has five scales: (a) *Initiate* (ability to begin an activity and to independently generate ideas or problem-solving strategies); (b) *Working memory* (ability to hold information when completing a task, when encoding information, or when generating goals/plans in a sequential manner); (c) *Plan/organize* (ability to anticipate future events; to set goals, to develop steps, to grasp main ideas, to organize and understand the

main points in written or verbal presentations); (d) *Organization of materials* (ability to put order in work, play, and storage spaces—desks, lockers, backpacks, and bedrooms); and (e) *Monitor* (ability to check work and to assess one's own performance). Prior research has demonstrated that the BRIEF scores are reliable (α range .78 to .96) and valid for assessing varied aspects of executive functioning. See McCandless and O'Laughlin (2007) for additional information on the reliability and construct validity of the *BRIEF*.

Delis Kaplan Executive Functions D-KEFS—(Delis, Kaplan, & Kramer, 2001). For *DK-EFS Color Word Form Inhibition*, based on the classic Stroop task, the task is to read orally a color word in black ink and then name the ink color for a written word in which the color of the ink conflicts with the color name of the word (e.g., the word red written in green ink). The difference in time for reading the words in black and naming the color of the ink that conflicts with the name of the color word is an index of ability to inhibit irrelevant information and focus attention on task relevant information (reliabilities range from .62 to .76). For *D-KEFS Verbal Fluency—Letters* (test-retest reliability .67), the task is to name as many words as possible that begin with a designated letter (time limit 60 seconds for each of three letters). For *D-KEFS Verbal Fluency—Category* (test-retest reliability .70), the task is to name as many examples of a named category (time limit 60 seconds for each of two categories). Both Verbal Fluency tasks require sustaining attention over time to stay on task for accessing written spellings (Letters) or accessing semantic word meanings (Categories). Repetitions (total number of repeats) during both Verbal Fluency tasks provides a measure of self-monitoring (ability to remember examples already given and not repeat them). For all measures, raw scores are converted to scaled scores for age ($M=10$, $SD=3$).

Rapid Automatic Switching (RAS)—letters and numerals (Wolf & Denckla, 2005)—The task is to name alternating lower case printed letters and written numerals arranged in rows. The total score (test-retest reliability .90) is the time required to name alternating letters and numerals in all the rows and is converted to a standard score ($M=100$ and $SD=15$). In addition, Amtmann et al.'s (2008) adaptation was used in which times were recorded for each of the five rows of the RAS.

Measures of Language Learning Outcomes

See Berninger et al. (2015) for information on the reliabilities and measurement properties of each measure for assessing language learning outcomes (standard score with mean of 100 and standard deviation of 15, scaled score with mean of 10 and standard deviation of 3, or z-score with mean of 0 and standard deviation of 1) and other details. Only task requirements and means and standard deviations for the total sample on each measure are described in this section. As explained in the data analyses section at the end of the methods, all these measures, which had been used in the differential diagnosis process described earlier and in Berninger et al. (2015) for learning profiles and phenotype profiles, were used in analyses for the first, second, and third research questions; but for the fourth research question, only measures at for the subword, word, or syntax/text levels of each language system were used.

Cognitive ↔ Linguistic Translation

Wechsler Intelligence Scale for Children, 4th Edition (WISC IV) (Wechsler, 2003) Verbal Comprehension Index—The Index Score ($M=108.07$, $SD=15.04$) is based on the Similarities subtest (explain orally how the named items are similar), the Vocabulary subtest (explain orally the meaning of a heard word or provide a synonym), and Comprehension subtest (answer questions that demonstrate understanding of real world facts or situations or ability to problem solve). Each of the tasks contributing to the overall index score requires that the student translate concepts or knowledge of the world into oral language constructions of one or more words (Niedo, Abbott, & Berninger, 2014).

Aural and Oral Language

WJ III Oral Comprehension (Woodcock, McGrew, & Mather, 2001b)—This syntax/text level task assesses ability to listen to spoken text and when there is a pause supply a word orally that would make sense in the current syntactic unit in the unfolding aural text which may or may not have referents in prior text ($M=109.99$, $SD=12.77$).

Clinical Evaluation of Language Function 4th Edition CELF IV Formulated Sentences (Semel, Wiig, & Secord, 2003)—The child is given three words and asked to construct an oral sentence on this syntax/text level task ($M=10.47$, $SD=3.30$).

Comprehensive Test of Phonological Processing (CTOPP) (Wagner, Torgesen, & Rashotte, 1999) Nonword Repetition—The subword-word level task is to listen to an audio recording of nonwords containing English sounds, which are pronounced one at a time with a pause in between each one for a response, analyze component sounds in them, and repeat orally the heard nonword exactly ($M=10.16$, $SD=2.56$).

Reading Comprehension and Written Expression

WJ III Passage Comprehension (Woodcock et al., 2001b)—This syntax/text level task is to read text in which there is a blank and supply orally a word that could go in the blank that fits the accumulating context of the sentence and preceding text ($M=99.24$, $SD=16.28$).

Wechsler Individual Achievement Test, 3rd Edition (WIAT III) Sentence Combining (Pearson, 2009)—The syntax level task is to combine two provided sentences into one well written sentence that contains all the ideas in the two separate sentences ($M=98.95$, $SD=16.40$).

WJ III Writing Fluency (Woodcock et al., 2001b)—The task is to compose as many written sentences as possible within a 7 minute time limit for each set of three provided written words, which are to be used without changing them in any way ($M=95.95$, $SD=13.99$).

Word Reading and Spelling

Test of Word Reading Efficiency (TOWRE) (Torgesen, Wagner, & Rashotte, 1999)—For *TOWRE Sight Word Efficiency*, this word-level task is to read orally as many

real words accurately as possible on a list within 45 seconds ($M=101.60$, $SD=16.90$). For *TOWRE Pseudoword Efficiency*, this word-level task is to read orally as many nonwords accurately as possible on a list within 45 seconds ($M=95.81$, $SD=18.63$).

Test of Orthographic Competence (TOC) (Mather, Roberts, Hammill, & Allen, 2008)—For the *TOC Homophone Choice (ages 9 to 12) or Word Choice (ages 13 to 16)*, this word-level task is to identify a correct spelling for a specific word; even though there are different norms according to age of child, the scaled scores for age were analyzed (word-specific spelling) ($M=9.52$, $SD=3.54$). For the *TOC Word Scrambles*, this word-level task is to rearrange letters in an anagram with scrambled letters to create a correctly spelled real word (word-specific spelling) ($M=9.36$, $SD=2.87$).

Handwriting

Alphabet 15 Rapid Automatic Letter Writing (Berninger, 2009)—This subword task is to print the alphabet from memory in correct alphabet order in lower case manuscript letters as quickly as possible, but legibly, so others can recognize each letter ($M=-1.42z$, $SD=0.84z$).

Multiple-modes of alphabet writing—The alphabet task was adapted to compare multiple modes of letter production on the alphabet task on the basis of raw scores. This subword level task remains the same, but instructions vary as to whether children produce the lower case letters of the alphabet in manuscript ($M=9.21$, $SD=5.06$) or cursive ($M=1.97$, $SD=3.05$) or produce the alphabet by selecting keys (hunting and pecking) on a keyboard (capital letters) ($M=16.95$, $SD=6.45$).

Detailed Assessment of Speed of Handwriting (DASH) Best and Fast, Second Edition, DASH-2 (Barnett, Henderson, Scheib, & Schulz, 2007)—This subword/word level task is to copy a sentence with all the letters of the alphabet in one's usual way (manuscript or cursive or a combination), but in two contrasting manners: one's best handwriting ($M=9.32$, $SD=3.49$) or one's fast writing ($M=7.35$, $SD=3.40$).

Data Analyses

First research question—Pearson product zero-order correlations were computed between presence or absence of a prior diagnosis of ADHD and each of the measures just described that were included in the comprehensive assessment battery.

Second research question—Pearson product zero-order correlations were computed between factor scores based on parental ratings of inattention or hyperactivity and each of the measures just described that were included in the comprehensive assessment battery.

Third research question—Pearson product zero-order correlations were computed between the time scores for rows 1, 2, 3, 4, and 5 on *Rapid Automatic Switching (RAS)* and each of the measures just described that were included in the comprehensive assessment battery.

Fourth research question—First, correlations were examined between the total time score for *RAS*, each of the *D-KEFS* measures given, the *BRIEF* rating scores, the inattention and hyperactivity parental ratings, and each of the measures just described that were included in the comprehensive assessment battery; summary of all correlations are available by request from the first or second author. Based on the ones that were significantly correlated with the most oral language, reading, and writing outcomes, the following measures were selected for the first model tested for the fourth research question related to attention and executive functions during language processing tasks: *D-KEFS Color Word Form Inhibition*, *D-KEFS Verbal Fluency—Letters and Categories and Repetitions*, and *Wolf and Denckla RAS*. Based on the ones that were significantly correlated with the most oral language, reading, and writing outcomes, the following measures were selected for the second model tested for the fourth research question related to attention and executive functions that are not specific to language processing tasks: parental ratings of inattention, *BRIEF Behavioral Regulation Index*, *BRIEF Metacognition/Plan/Organize*, and *BRIEF Metacognition Working Memory*.

Second, three measures at the subword or subword/word, word, and syntax or syntax/text levels were chosen for each functional language system—writing, reading, and oral language; and then principal components were computed as an index of each multi-leveled composite. The multi-leveled writing composite was created by calculating the score on the first principal component of the correlation matrix of alphabet 15 (loading =.60), *TOC Word Choice* (loading =.77), and *WJ-3 Writing Fluency* (loading =.87). The first principal component accounted for 56.7% of the variance. The multi-leveled reading composite was created by calculating the score on the first principal component of the correlation matrix of *TOWRE Phonemic Reading Efficiency* (loading =.86), *TOC Word Choice* (loading =.82), and *WJ III Passage Comprehension* (loading =.85). The first principal component accounted for 71.3% of the variance. The multi-leveled aural/oral language composite was created by calculating the score on the first principal component of the correlation matrix of *CTOPP Nonword Repetition* (loading=.57), *WISC IV Vocabulary* (loading=.90), and *WJ III Oral Comprehension* (loading=.88). The first principal component accounted for 63.1% of the variance.

Third, two models were compared for attention/executive function predictors for each of the three composites of multi-leveled language systems. In Model 1 the writing, reading, and aural/oral language composite scores were predicted by *DK-EFS Color Word Form Inhibition* score, *D-KEFS Verbal Fluency Letters* score, *D-KEFS Verbal Fluency Category* score, *D-KEFS Repetitions* score, and *Wolf and Denckla RAS* score, all of which assess attention and executive functions during language processing. In Model 2, the same writing, reading, and aural/oral language composite scores were predicted by parent ratings of inattention and the *BRIEF Behavioral Regulation Index* score, the *BRIEF Metacognition Plan/Organize* score, and the *BRIEF Metacognition Working memory* score, none of which are specific only to attention and executive function processing during language tasks.

Results

First research question

One third of the parents reported that their child had previously been diagnosed by ADHD; but reported prior diagnosis of ADHD was only correlated with three writing skills. Prior ADHD diagnosis was significantly correlated with both the *z*-score and raw score for writing alphabet from memory in lower case legible alphabet manuscript letters in order in the first 15 seconds, *z*-score, $r = -.25, p < .05$; raw score, $r = -.24, p < .05$, in the direction predicted—presence of ADHD was associated with lower performance on writing the alphabet from memory, a task which requires searching for and finding letter forms in memory automatically and then planning them for serial production. Although prior ADHD diagnosis was also correlated with *WIAT III Sentence Combining* $r = .27, p = .01$, the positive correlation indicates an association between the ADHD diagnosis and a higher the sentence composing score. This pattern of results, which replicates the prior research showing an association between ADHD and handwriting problems (see introduction) shows that an ADHD diagnosis is most likely to be associated with impaired handwriting legibility and automaticity rather than with written idea expression or other language learning outcomes.

Second research question

Only the inattention ratings factor score, not the hyperactivity ratings factor score, was significantly correlated with measures of reading and writing. The higher the factor score, indicating problems with inattention, the lower the score on two reading measures (*TOWRE Sight Word Efficiency*, $r = -.32, p < .01$; and *TOWRE Phonemic Efficiency*, $r = -.25, p < .05$), two spelling measures (*TOC Word Choice*, $r = -.19, p < .05$ and *Word Scramble*, $r = -.34, p < .01$), two handwriting measures (manuscript, $r = -.22, p < .05$, and cursive, $r = -.29, p < .01$ on alphabet 15), and two measures of written sentence composing (*WIAT II Sentence Combining*, $r = -.25, p < .05$ and *WJ III Writing Fluency*, $r = -.26, p < .05$). However, the inattention ratings factor score was not correlated with any oral language measures. Thus, the prior research findings showing that inattention was related to written language but not oral language learning also replicated (see introduction).

Third research question

RAS times for rows 4 and 5 (not earlier rows) were significantly correlated with handwriting outcomes and related compositional fluency, consistently with the last two rows of *RAS* reflecting ability to sustain switching attention over time (see introduction). Times for both rows 4 and 5 were correlated negatively (more time associated with low alphabet printing raw scores (row 4, $r = -.27, p < .05$, row 5, $r = -.25, p < .05$) and keyboarding raw scores (row 4, $r = -.24, p < .05$, row 5, $r = -.26, p < .05$), *DASH-2 Copy Fast* scaled scores (row 4, $r = -.24, p < .05$, row 5, $r = -.28, p < .01$), and *WJ III Writing Fluency* standard scores (row 4, $r = -.22, p < .05$, row 5, $r = -.26, p < .05$).

Fourth research question

Table 1 reports the means, standard deviations, correlations, and *p*-values for each of the composites for language systems—writing composite, reading composite, and oral language

composite, the *D-KEFS* and *Wolf and Denckla RAS* measures used as predictors in Model 1 (attention and executive functions during language processing), and the inattention ratings and *BRIEF* ratings for Model 2 (attention and executive functions not necessarily language specific).

Table 2 shows the multiple regression results of Model 1 for the writing, reading and oral language composite outcomes. Table 3 shows the multiple regression results of Model 2 for the same writing, reading, and oral language composite outcomes. Note that within both models, the set of predictors remained constant across the contrasting multi-leveled functional language systems (multi-level composite for writing, reading, or aural/oral language). Table notes indicate which measures were used to model each subword/word, word, or multiword/syntax/text level for each system.

Comparing the results for Model 1 and for Model 2 shows whether language-specific attention and executive function predictors explain comparable variance and identify unique predictors compared to attention and executive functions that are not language specific (see Table 3). Results are reported separately for each multi-leveled composite language system.

Writing Composite

Collectively the Model 1 predictors based on language-related measures of attention/executive functions explained 44% of the variance in the writing composite (see adjusted R^2 in Table 2). Both *D-KEFS Verbal Fluency-Letters* and *Wolf and Denckla RAS* explained unique variance in the same writing composite (see Table 2). In contrast, collectively, the predictors based on parental inattention ratings and *BRIEF* executive function ratings explained 9% of the variance in the same writing composite (see adjusted R^2 in Table 3). None of the predictors in Model 2 explained unique variance in the multi-leveled writing composite.

Reading composite

Collectively the predictors based on Model 1 explained 50% of the variance in the reading composite (see adjusted R^2 in Table 2). *D-KEFS Inhibition*, *Verbal Fluency-Letters and Repetitions*, and *Wolf and Denckla RAS* explained unique variance in the reading composite (see Table 2). In contrast, collectively, the predictors based on parental inattention and *BRIEF* executive function ratings explained 16% of the variance in the reading composite (see adjusted R^2 in Table 3). *BRIEF Metacognition Working Memory* explained unique variance in the multi-leveled reading composite (see Table 3).

Aural/oral language composite

Collectively the predictors based on language-related measures of attention/executive functions explained 31% of the variance in the same aural/oral language composite (see adjusted R^2 in Table 2). *D-KEFS Inhibition*, and *Verbal Fluency-Letters and Categories and Repetitions* explained unique variance in the aural/oral language composite (see Table 2). In contrast, collectively, the predictors based on inattention and executive function ratings explained 3% of the variance in the aural/oral language composite (see adjusted R^2 in Table 3). None explained unique variance in the aural/oral language composite (see Table 3).

Summary of results for fourth research question

On the one hand, the different language systems are highly correlated (see Table 1 correlations for composites) indicating considerable commonality across the language systems. On the other hand, results for the fourth research question extend prior research on the unique ways language systems may vary in their interactions with the external environment according to different input (ear and eye) and output (mouth and hand) modes, but also in how they coordinate their multiple component processes across levels of language. Attention and executive functions play a role in that coordination process. Comparison of results for Model 1 and Model 2 showed that attention and executive functions specifically linked to language processing accounted for more variance in all multi-leveled language systems analyzed than did attention and executive functions not explicitly linked to language processing. However, amount of variance explained and which attention/executive function predictors explained unique variance in those multi-leveled language composites varied across the writing, reading, and oral language composite systems, providing yet additional evidence that language by hand, language by eye, and language by ear and hand may not be completely identical, homogeneous language systems. Rather, different attention and executive functions contribute in unique ways to coordinating the different levels of language so that they work together in concert in a particular functional language system. Also of note, *BRIEF Working Memory* did contribute uniquely to the multi-leveled reading system, consistent with what is known about the role of working memory in supporting multi-leveled language processing (Swanson, 1996).

Discussion

Linking Attention and Executive Functions to Language Learning Assessment

ADHD as a predictor of language learning outcomes—It is important to keep in mind that the participants in the current study were not recruited for a study of ADHD. Nor were they assessed during the study for whether they met symptoms for currently accepted criteria for diagnosing either the inattention or hyperactivity/impulsivity subtypes of ADHD (Topiak et al., 2012; Willcutt et al., 2012). The results are relevant, however, to the issue of whether a prior ADHD diagnosis by an appropriately credentialed professional is sufficient for understanding all the attention and executive functions that may play a role in learning to self-regulate language learning, especially for language learning outcomes linked to multi-leveled language systems by hand, by eye, and by ear and mouth. Nevertheless, **handwriting problems (Re & Cornoldi, 2010) and related writing problems (McCandless & O’Laughlin, 2007) often co-occur in individuals with ADHD.**

Not only do the current results replicate prior findings on this ADHD-handwriting connection but also they provide evidence for assessing all students diagnosed with ADHD for possible co-occurring dysgraphia. Both ADHD and dysgraphia can significantly interfere with school achievement in written language, but dysgraphia is often not identified and treated in schools (Berninger et al., 2015). Whenever a child or youth presents with symptoms of inattention and/or hyperactivity/impulsivity, diagnostic assessment for ADHD is warranted, but so is assessment of other attention and executive functions that may interfere with identified impairments in language learning outcomes. ADHD is one kind of

attention and executive function problem that can interfere with oral and written language acquisition, but not the only one, as the results for the other three research questions show.

Parental ratings of inattention as predictor of language learning outcomes—

Two current findings replicated Thompson et al.'s (2005) prior findings that **inattention ratings, but not the hyperactivity/impulsivity ratings, were related to (a) written language learning outcomes, (b) but not aural/oral language outcomes**. These results highlight the value of reaching out to parents of all students in the upper elementary and middle school grades and asking them to complete ratings of inattention. Collecting these ratings is not very time consuming but can draw teachers' attention to whom in their class may benefit from special strategies for paying attention to written language when they read and write. Instructional strategies have been validated for doing so (e.g., Berninger et al., 2006; Berninger & Wolf, in press).

RAS total time scores for predicting language learning outcomes—

Just as the parent ratings of inattention were not correlated with measures of aural or oral language learning outcomes, but were with the multi-leveled writing and reading systems, so were the **RAS total time scores only significantly correlated with written language not oral language measures**. This finding is consistent with prior research findings based on typical language learners and those with dyslexia (Altemeier, Abbott, & Berninger, 2008). Language learners need to learn to pay attention to written language as well as aural language, which can be challenging for some students with SLDs.

Language-sensitive measures of attention and executive functions in predicting language learning outcomes—

The preliminary inspection to choose a constant set of predictors for the fourth research question had shown that ***D-KEFS Inhibition* and *Verbal Fluency* measures were significantly correlated with all the language by ear and language by mouth learning outcomes**. This robust finding serves as a reminder that much of school learning depends on processing academic language heard in oral teacher instructional talk and expressing answers orally (Wilkinson, & Silliman, 2012). The findings showing **significant correlations between *D-KEFS on Color Word Form Inhibition* (focused attention and *D-KEFS Repetitions* (self-monitoring) correlating with listening comprehension** in students in middle childhood and adolescence are consistent with those of Kim and Phillips (2013) in early childhood. Moreover, **the *D-KEFS Inhibition* and *Verbal Fluency* scores were significantly correlated with the measure of the cognitive ↔ linguistic translation process**; this finding serves as a reminder that students are continually translating across the cognitive and language domains during academic learning (see Stahl & Nagy, 2005) and such translation may be difficult during language learning development for some students with SLDs. ***D-KEFS* measures were also correlated with multiple written language measures**. For example, ***Verbal Fluency-Letters* may have been correlated with multiple reading and spelling because word spelling is related to both (see introduction) and with handwriting** measures because finding word spellings based on initial letter may be facilitated by silently naming the letters; letter names are thought to serve as overt or covert retrieval cues for letter forms from memory (Berninger, 2009).

Of interest, for the multi-level writing system, only D-KEFS *Verbal Fluency Letters* and *Wolf and Denckla RAS* for letters and numerals explained unique variance in integration across subword, word, and sentence writing. Finding written spellings and switching attention across graphemes in written words may help regulate the writing system while learning to write during the upper elementary and middle school grades. For the multi-level reading system, however, *D-KEFS Inhibition*, *Verbal Fluency Letters and Repetitions*, and *Wolf and Denckla RAS* contributed uniquely to this integration across subword, word, and sentence/text reading. In contrast to the writing system, focused attention contributes to regulation of the multi-level reading system. Also, for the Model 2 analysis, *BRIEF Metacognitive Working Memory Index* contributed uniquely, documenting the role of working memory in coordinating across levels in a functional multi-level reading system (Swanson, 1993a, 1993b, 1996). For the multi-level aural/oral language system, however, *D-KEFS Inhibition and Verbal Fluency—Letters, Categories, and Repetitions* contributed uniquely, but *Wolf and Denckla RAS* did not.

Thus, some constants but also variations were observed in which attention/executive functions explained unique variance across different functional language systems for multi-leveled writing, reading, and oral language systems. *RAS does not contribute uniquely to aural/oral language but does to writing and reading. Inhibition contributes uniquely to reading and aural/oral language. Verbal Fluency Letters (word finding based on spelling) contributes uniquely to all three language systems* and may be the constant across them, consistent with word-specific spelling impairment at the behavioral levels across dysgraphia, dyslexia, and OWL LD, but differing brain bases for this common word-specific spelling behavioral marker (Berninger et al., 2015). These findings have important implications for which attention and executive functions to assess depending on the reason for referral for a particular student who is struggling in some aspect of language learning.

Linking Attention and Executive Functions to Language Instruction

Programmatic research has shown the value of teaching to multiple levels of language within a given lesson rather than focusing on a target skill in isolation without linking it to other levels or units of language in a functional language system (for review, see Berninger, 2009; Berninger & Wolf, in press). Often the different levels of language are taught close in time so that skill at one level transfers to higher levels and creates cross-level connections. Yet little is known about effective ways to teach the attention and executive functions that enable creation of connections across the multiple levels of language within and across multiple functional language systems or how to teach these to facilitate development of self-regulation of language learning. The current study provides initial evidence regarding the attention and executive functions that may play a role in creating such cross-level connections in the multi-leveled writing, reading, and aural/oral language systems, but further instructional research is needed on this instructionally relevant issue.

Limitations, Future Research Directions, and Conclusion

One limitation of the current study was that attention and executive functions ratings were collected only from parents and not from teachers. Another limitation was that relatively few participants in the current study had OWL LD, the diagnostic group that would be expected

to have the most difficulty in paying attention to and self-regulating aural/oral language. Future research might investigate the relationships of both teacher and parent ratings of attention to aural language in larger samples of students with OWL LD. Moreover, *BRIEF Working Memory and BRIEF Inhibition* were associated with two writing skills (timed sentence combining and construction), consistent with much writing research (Hayes & Berninger, 2014). Further research is needed with the BRIEF and other samples with and without writing disabilities and the same and other writing learning outcomes measures.

The current results, grounded in research questions based on past research, will hopefully inform future research. For example, the same and different measures of attention and executive functions and oral and writing language could be administered to a larger sample of students in grades 4 to 9 with and without carefully diagnosed SLDs. Both teacher and parent ratings for attention and executive functions could be collected. Future research could examine effective instruction for improving attention and executive functions for oral and written language learning. Moreover, given the significant social emotional consequences of chronic struggles in language learning and sometimes co-occurring difficulties in self-regulation of behavior in the classroom, *BRIEF* scales not related to language learning may be helpful in identifying executive functions that contribute to social emotional and behavioral self-regulation. Indeed, research supports the contribution of executive functioning skills to support students engagement in the learning process whether it involves language or not (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008).

Adding further complexity is the very nature of co-occurrence. Some students have ADHD but no language learning problems. Some have language learning problems but no ADHD. Some students with or without language learning problems do not meet criteria for ADHD but may or may not have other specific inattention or executive function problems. Moreover, not all specific learning disabilities are the same; not only language learning but also other domains like math and social cognition may be affected or these other domains may be affected but not language learning. In addition, different kinds of SLDs may co-occur. Ultimately attention and executive functions need to be assessed and facilitated instructionally for each individual student's overall profile of strengths and weaknesses across the academic curriculum and profile of attention and executive functions needed to coordinate the multiple components and levels of complex learning systems. Teachers also need to develop their own extraordinary attention and executive functions to orchestrate this amazing feat concurrently for multiple individual students.

Acknowledgments

Grant P50HD071764 from the *Eunice Kennedy Shriver* National Institute of Child Health and Human Development (NICHD) at the National Institutes of Health (NIH) to the University of Washington Learning Disabilities Research Center supported this research. The authors thank the parents and children who participated in this research and the graduate students who administered and scored the various measures used in this study or assisted with data management, including Roxana Del Campo, Whitney Griffin, Jasmin Niedo Jones, and Terry Mickail. The authors also acknowledge the pioneering contributions of the late Barbara Wilson, the Long Island neuropsychologist, who drew attention to the attention problems in individuals with language processing problems and the language processing problems in individuals with ADHD and reminded professionals to ask whether the attention problems are causes or effects of language problems and vice versa. Also, the pioneering contributions of the late Edith Kaplan and her colleague Dean Delis who carries on the work have given professionals tools for assessing those attention-language relationships.

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Table 1

Means, standard deviations (SD), and correlations among writing, reading, and oral language composites and attention/executive function predictors. See text for means of measures contributing to writing, reading, and oral language composites.

		Mean	SD	1	2	3	4	5	6	7	8	9	10	11	12
1	Writing composite	-.08	0.98	1.0											
2	Reading composite	.02	1.01	.81	1.00										
3	Aural/Oral Language composite	.09	1.04	.50	.64	1.00									
4	Inattention ratings by parent	2.31	0.70	.30	-.32	-.20	1.00								
5	BRIEF Behavioral Regulation	54.14	12.58	.05	-.04	-.07	.40	1.00							
6	BRIEF Plan/Organize	60.60	11.43	.24	-.26	-.19	.59	.60	1.00						
7	BRIEF Working Memory	61.41	11.92	.32	-.40	-.24	.75	.52	.78	1.00					
8	DK Inhibition	9.24	3.11	.40	.58	.45	-.23	-.06	-.17	-.22	1.00				
9	DK Letters	10.97	3.21	.61	.54	.37	-.27	-.08	-.12	-.22	.38	1.00			
10	DK category	11.42	3.18	.48	.39	.42	-.21	-.06	-.11	-.10	.33	.61	1.00		
11	DK Repetitions	7.56	2.31	.17	.15	.22	-.05	-.20	-.06	-.15	-.09	.04	.06	1.00	
12	RAS Letters and Numbers	102.37	13.64	.52	.55	.21	-.28	.04	-.21	-.27	.46	.48	.37	.03	1.00

Table 2

Model 1 Multiple regression results for writing, reading and oral language composites with normed RAS and Delis-Kaplan predictors. See table notes for measures contributing to composites.

Writing Composite Outcome ^a :									
Model 1 Summary									
					Change Statistics				
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	
.688 ^a	.473	.437	.68917401	.473	13.130	5	73	.000	
ANOVA									
	Sum of Squares	df	Mean Square	F	Sig.				
Regression	31.180	5	6.236	13.130	.000 ^a				
Residual	34.672	73	.475						
Total	65.852	78							
Coefficients									
Unstandardized Coefficients					Standardized Coefficients				
	B	Std. Error	Beta	t	Sig.				
(Constant)	-4.017	.647		-6.205	.000				
DK-EFS Inhibition	.030	.030	.102	1.009	.316				
DK-EFS Letters	.104	.034	.364	3.077	.003				
DK-EFS Category	.035	.032	.123	1.117	.268				
DK-EFS Repetitions	.059	.034	.148	1.723	.089				
Wolf and Denckla RAS Letters and Numerals	.016	.007	.241	2.306	.024				
Reading Composite Outcome ^b									
Model 1 Summary									
					Change Statistics				
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change	
.726 ^a	.526	.495	.69488018	.526	16.898	5	76	.000	

ANOVA				
	Sum of Squares	df	Mean Square	F Sig.
Regression	40.797	5	8.159	16.898 .000 ^a
Residual	36.697	76	.483	
Total	77.494	81		

Coefficient				
Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t Sig.
(Constant)	-4.219	.642		-6.576 .000
DK-EFS Inhibition	.112	.027	.379	4.120 .000
DK-EFS Letters	.088	.033	.284	2.642 .010
DK-EFS Category	-.004	.032	-.014	-.136 .893
DK-EFS Repetitions	.072	.034	.169	2.119 .037
Wolf and Denckla RAS Letters and Numerals	.017	.007	.240	2.483 .015

Aural Oral Language Composite ^c						
Model 1 Summary						
			Change Statistics			
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig. F Change
.594 ^a	.352	.310	.82551380	.352	8.378	.000

ANOVA				
	Sum of Squares	df	Mean Square	F Sig.
Regression	28.547	5	5.709	8.378 .000 ^a
Residual	52.473	77	.681	
Total	81.021	82		

Coefficients				
Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t Sig.
(Constant)	-2.166	.762		-2.842 .006
DK-EFS Inhibition	.121	.032	.403	3.765 .000

	Coefficients			
	Unstandardized Coefficients	Std. Error	Beta	t
DK-EFS Letters	.039	.039	.125	1.000
DK-EFS Category	.075	.037	.238	2.026
DK-EFS Repetitions	.104	.040	.241	2.605
Wolf and Denckla RAS Letters and Numerals	-.010	.008	-.129	-1.155

^aDependent Variable: Principal Component Score Writing based on composite of subword alphabet writing from memory first 15 seconds (legible, automatic letters in alphabetic order), word-specific spelling (TOC Word Choice), and sentence composition fluency (WJ III Writing Fluency).

^bDependent Variable: Principal Component Score Reading based on composite score for subword phonological decoding (TOWRE Phonemic Efficiency), word-specific spelling (TOC Word Choice), and sentence/text reading comprehension (WJ III Passage Comprehension).

^cDependent Variable: Principal Component Score Oral Language based on composite of sublevel coding of heard and spoken sounds in working memory (CTOPP Nonword Repetition), word level vocabulary meaning (WISC IV Vocabulary), and syntax/text aural comprehension (WJ III Oral Comprehension).

Table 3

Model 2 Multiple regression results for writing, reading and oral language composites with inattention and BRIEF ratings predictors. See table notes for measures contributing to composites

Writing Composite Outcome ^a						
Model 2 Summary						
Change Statistics						
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig. F Change
.359 ^a	.129	.089	.93733232	.129	3.227	.016
ANOVA						
	Sum of Squares	df	Mean Square	F	Sig.	
Regression	11.340	4	2.835	3.227	.016 ^a	
Residual	76.437	87	.879			
Total	87.777	91				
Coefficients						
Unstandardized Coefficients						
	B	Std. Error	Beta	t	Sig.	
(Constant)	1.297	.578		2.244	.027	
inattention ratings	-.193	.206	-.137	-.937	.351	
Brief Behavioral Regulation Index	.012	.010	.159	1.289	.201	
Brief Metacognition Plan/Organize	-.006	.014	-.065	-.391	.697	
Brief Metacognition Working Memory	-.021	.015	-.249	-1.347	.182	
Reading Composite Outcome ^b						
Model 2 Summary						
Change Statistics						
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig. F Change
.438 ^a	.192	.156	.93169623	.192	5.336	.001

ANOVA				
	Sum of Squares	df	Mean Square	F Sig.
Regression	18.530	4	4.632	5.336 .001 ^a
Residual	78.125	90	.868	
Total	96.655	94		

Coefficients				
Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t Sig.
(Constant)	1.681	.568		2.959 .004
inattention ratings	-.113	.201	-.079	-.564 .574
Brief Behavioral Regulation	.017	.010	.213	1.813 .073
Brief Metacognition	-.001	.014	-.012	-.075 .941
Plan/Organize				
Brief Metacognition	-.037	.015	-.433	-2.444 .016
Working Memory				

Model 2 Summary						
Aural Oral Language Composite Outcome ^c						
			Change Statistics			
R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	Sig. F Change
.256 ^a	.065	.029	1.02624205	.065	1.782	.138

ANOVA				
	Sum of Squares	df	Mean Square	F Sig.
Regression	7.506	4	1.876	1.782 .138 ^a
Residual	107.424	102	1.053	
Total	114.929	106		

Coefficients				
Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t Sig.
(Constant)	1.258	.575		2.189 .031
inattention ratings	-.080	.217	-.053	-.367 .714

	Coefficients			
	Unstandardized Coefficients	Standardized Coefficients		
	B	Std. Error	Beta	t
Brief Behavioral Regulation Index	.008	.010	.090	.752
Brief Metacognition Plan/Organize	-.004	.015	-.049	-.300
Brief Metacognition Working Memory	-.019	.016	-.212	-1.143

^aDependent Variable: Principal Component Score Writing based on composite of subword alphabet writing from memory first 15 seconds (legible, automatic letters in alphabetic order), word-specific spelling (TOC Word Choice), and sentence composition fluency (WJ III Writing Fluency).

^bDependent Variable: Principal Component Score Reading based on composite score for subword phonological decoding (TOWRE Phonemic Efficiency), word-specific spelling (TOC Word Choice), and sentence/text reading comprehension (WJ III Passage Comprehension).

^cDependent Variable: Principal Component Score Oral Language based on composite of sublevel coding of heard and spoken sounds in working memory (CTOPP Nonword Repetition), word level vocabulary meaning (WISC IV Vocabulary), and syntax/text aural comprehension (WJ III Oral Comprehension).