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Links Among Attention-Deficit/Hyperactivity Disorder Symptoms and Psycholinguistic Abilities Are Different for Children With and Without Developmental Language Disorder

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ABSTRACT

Purpose: Both developmental language disorder (DLD) and attention-deficit/hyperactivity disorder (ADHD) represent relatively common and chronic neurodevelopmental conditions associated with increased risk for poor academic and interpersonal outcomes. Reports of common co-occurrence suggest these neurodevelopmental disruptions might also be linked. Most of the data available on the issue have been based on case–control studies vulnerable to ascertainment and other biases.
Method: Seventy-eight children, representing four neurodevelopmental profiles (DLD, ADHD, co-occurring ADHD + DLD, and neurotypical development), were administered a battery of psycholinguistic tests. Parents provided standardized ratings of the severity of their children's inattention, hyperactivity/impulsivity, and executive function symptoms. Examiners were blinded to children's clinical status. Group differences, correlations, and best subset regression analyses were used to examine potential impacts of children's ADHD symptoms on their psycholinguistic abilities.
Results: For children with DLD, significant links between their ADHD symptoms and psycholinguistic abilities were limited to the contributions of elevated hyperactivity/impulsivity symptoms to lower pragmatic abilities. For children without DLD, inattention symptoms contributed to lower levels of performance in pragmatic, sentence recall, receptive vocabulary, and narrative abilities.
Discussion: Links among children's ADHD symptoms and their psycholinguistic abilities were different for children with and without DLD. Implications for the provision of clinical services are discussed.

For some children, their well-being is compromised by repeated episodes of academic underachievement, disrupted peer relations, and difficulties following directions. There are various underlying neurodevelopmental conditions that could contribute either directly or indirectly to these general clinical signs, but two likely candidates are attention-deficit/hyperactivity disorder (ADHD) and developmental language disorder (DLD). Prevalence rates vary across reports, but even the most conservative estimates suggest that cases of ADHD and DLD both occur 2–3 times more frequently than cases of autism spectrum disorder, 5–7 times more frequently than intellectual disability, and 15–25 times more frequently than congenital hearing impairment (American Psychiatric Association, 2022; Korver et al., 2017; Maenner et al., 2023). Like most neurodevelopmental disorders, both ADHD and DLD represent chronic conditions with functional impairments persisting into adulthood for many affected individuals (Koepp et al., 2023; Law et al., 2009). At a societal level, managing the consequences of ADHD and DLD consumes considerable educational and health care resources (Pelahm et al., 2007; Sciberras et al., 2015).

A variety of clinical taxonomies and criteria have been implemented over the years directed at sharpening

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our understanding of the essential features associated with these two common disorders. Clinical reports documenting developmental profiles consistent with the current designations of ADHD and DLD can both be traced back to the first half of the 19th century (Lange et al., 2010; Leonard, 2019). The term "ADHD," which replaced the attention-deficit disorder designation nearly 40 years ago, refers to developmentally inappropriate levels of inattention and hyperactivity–impulsivity across multiple settings and is often, but not always, associated with deficits in executive function and behavioral regulation (American Psychiatric Association, 2022). ADHD is recognized as a highly comorbid condition, where over two thirds of all cases of ADHD present within the context of an additional neurodevelopmental or psychiatric condition (T. E. Brown, 2000; Larson et al., 2011).

Language delays as well as persistent deficits are common among individuals affected by various neurodevelopmental conditions. However, the term "DLD," a recent expansion of the specific language impairment (SLI) designation, is reserved for those cases of compromised language acquisition of unknown etiology (Leonard, 2019). DLD represents the majority of cases of pediatric language disorder (Johnson et al., 1999; Norbury et al., 2016; Redmond, Ash, et al., 2019; Shriberg et al., 1999). The range of psycholinguistic milestones and capacities potentially impacted by DLD is considerable (see Leonard, 2014). As a result, heterogeneity across specific psycholinguistic strengths and weaknesses is expected both between affected individuals as well as over the course of different stages of an affected individual's development (Bishop et al., 2016). Nonetheless, a very common profile associated with DLD consists of relative strengths in the areas of phonology, receptive vocabulary, and pragmatics in the context of considerable and persistent weaknesses in morphosyntax, grammar, and verbal memory (Leonard, 2014).

Reports indicate further that, in addition to contributing independently to children's risks for poor academic and social outcomes, ADHD and DLD frequently co-occur within clinical caseloads, although co-occurrence estimates vary across reports (Redmond, 2016a). A robust understanding of the interrelationships between these two common neurodevelopmental conditions is needed to advance theoretical models as well as guide clinical practice in key areas such as secondary prevention and differentiated treatment. In this study, we examined the potential impacts of ADHD symptoms on children's psycholinguistic abilities in a relatively underutilized four-group design (ADHD, DLD, ADHD + DLD, and neurotypical development [TD]). This allowed us to consider whether any observed links might be different for children with and without DLD.

Case–Control Designs

Previous investigations have deployed a variety of research designs to better understand potential links between children's ADHD symptoms and their psycholinguistic development. Case–control studies provide some support for the contention that ADHD might represent either a contributing or an aggravating factor to children's psycholinguistic deficits. For example, relative to comparison groups of children with TD, group means for children with ADHD on expressive, receptive, and pragmatic measures have been consistently lower across study samples (Green et al., 2014; Jepsen et al., 2022; Korrel et al., 2017; Westby & Watson, 2021). Although the presence of poorer levels of psycholinguistic performance in groups of children with ADHD relative to their peers with TD is sufficient to encourage routine screenings for potential undetected language disorders among children receiving clinical services for ADHD, accounting for these group differences is not straightforward (Redmond, 2016b). For example, reported differences could reflect the presence of an elevated minority of undetected cases of concomitant DLD among children with ADHD. Alternatively, ADHD might compromise children's language development independent of their DLD status. In other words, the presence of ADHD could be sufficient to produce cumulative impacts compromising affected individuals' development across the continuum of nonclinical, subclinical, and clinical levels of psycholinguistic ability (see Parks et al., 2021). Ascertainment biases within study samples that penalize children with ADHD and/or benefit children representing the TD comparison groups could also be partially responsible for reports of psycholinguistic deficit. A final potential contributor to observed group differences could be measurement error. Specifically, difficulties in sustained attention, concentration, impulse control, or planning, rather than underlying deficits in linguistic aptitudes, could be unduly penalizing individuals with ADHD during assessments of their psycholinguistic abilities, complicating the picture (Oram et al., 1999; Redmond, 2016b).

Three-Group Designs

Three-group designs, consisting of children representing profiles of ADHD, DLD, and TD—where cases of concomitant ADHD + DLD have been deliberately screened out—have the potential to provide clarity on the nature of the impact of ADHD on children's psycholinguistic development beyond what case–control designs can provide. This is because the extent to which weaknesses found in one clinical group approximates those found in the other clinical group can be examined directly. If, for example, ADHD represented an independent contributor to risk for a particular aspect of psycholinguistic development, then we would expect performances of children in the ADHD group to essentially split the observed difference in performances between the TD and DLD groups (i.e., TD > ADHD > DLD). Three-group designs have been particularly helpful for evaluating the extent to which clinical markers established in case–control comparisons can be used in differential diagnosis. For example, Redmond et al. (2011) in their three-group design calculated sensitivity, specificity, and areas under receiver operating characteristic (ROC) curves associated with using tense marking, nonword repetition, sentence recall, and narrative measures to differentiate 20 cases of DLD from 20 cases of TD as well as differentiate them from 20 cases of ADHD. Groups were matched for age and maternal education levels. Results indicated group mean differences between the children with ADHD and children with TD were small and not statistically significant. Furthermore, levels of sensitivity, specificity, and areas under the ROC curve across the different psycholinguistic measures were comparable in their differentiation of cases of DLD from TD cases and cases of DLD from ADHD cases. Optimal cutoff scores across psycholinguistic measures were very similar between the two types of differentiation, and the observed areas under the ROC curves all exceeded 0.85, indicating overall "excellent" levels of discrimination (Hosmer & Lemeshow, 2000). These results provide support for the use of these measures for differential diagnosis. Similar results have been reported in study samples of Dutch-speaking children (Parigger, 2012) and French-speaking children (Stanford & Delage, 2020). Collectively, the results of these three-group studies do not support the view of a clinically significant impact of ADHD on children's performances on these psycholinguistic measures.

Other measures might yield different outcomes. In their three-group design consisting of 19 cases each of ADHD, DLD, and TD, Helland et al. (2014) used parental ratings of communication difficulties and socioemotional behavioral problems to determine whether children with DLD could be successfully differentiated from children with ADHD with these measures. Children in the ADHD group were, on average, 2 years older than children in the DLD and TD groups (10 vs. 8 years), complicating comparisons. Nonetheless, results indicated children in the DLD group received significantly poorer ratings of their syntactic abilities on the Children's Communication Checklist–Second Edition (CCC-2; Bishop, 2006) relative to children in the ADHD group, who were not significantly different from children in the TD group. On CCC-2 ratings of their semantic and pragmatic abilities, however, both clinical groups performed more poorly than the TD group, and they were not significantly different from each other.

Another value of three-group designs exclusive of cases of co-occurrence is cross-clinical comparisons can be leveraged to test the necessity and sufficiency of nonverbal weaknesses on children's linguistic deficits. For example, slowed speed of processing and rapid temporal processing deficits have been offered by some scholars as a potential causal mechanism for DLD (Benasich et al., 2001; Lum et al., 2014; Miller et al., 2001). Deficits in these areas have also been reported in children with ADHD (Ludlow et al., 1983; Scheres et al., 2001), but the contributions of undetected co-occurring DLD to these deficits have been unclear. By screening cases of co-occurrence from their clinical groups, Cardy et al. (2010) were able to directly evaluate the extent to which deficits in processing speed and/or rapid temporal processing could be culpable for the psycholinguistic deficits associated with DLD. Fourteen children with ADHD, 14 children with DLD, and 28 children with TD (age range: 6–11 years) completed auditory repetition, simple reaction time, and visual search tasks. Children in the ADHD group demonstrated slower processing and produced more invalid responses than children in the other groups, suggesting processing deficits of the sort measured in this study were more indicative of ADHD rather than DLD status.

Four-Group Designs

A full appreciation of the nature of links among children's ADHD symptoms and their psycholinguistic abilities, however, eventually requires consideration of the co-occurrence of ADHD + DLD (Mueller & Tomblin, 2012). One reason to deliberately include groups of co-occurring cases with sufficient levels of representation is we can examine the possibility that the impact of ADHD symptoms on children's psycholinguistic abilities might be different for children with and without DLD (Mueller & Tomblin, 2012). Co-occurrence is relatively common across neurodevelopmental conditions, and its presence is often associated with elevated symptoms in both conditions for affected individuals, suggestive of "additive" or "interactive" effects between the two disorders (Wachs, 2000). Cases of co-occurrence might also represent a qualitatively different subgroup either in terms of their symptom presentation, developmental associations, or etiology and for these reasons might require differentiated interventions/accommodations. On rare occasions, "subtractive" effects might be observed indicating the presence of less severe symptoms in cases of co-occurrence (Wachs, 2000). Subtractive effects can arise when the presence of one disorder offsets risk factors associated with the other. For example, co-occurring disorders might increase the likelihood of earlier identification and/or access to more comprehensive intervention services.

The results of Redmond et al.'s (2015) study aligned better with the presence of either null or subtractive effects rather than additive/interactive effects among their ADHD + DLD participants. In this study, the performances of 7- to 9-year-old children with DLD, ADHD + DLD, and TD on measures of nonword repetition, sentence recall, and elicited tense marking were compared. Groups were matched for age, maternal education levels, and nonverbal IQ, and each group consisted of 19 participants. For the most part, group means for the ADHD + DLD were slightly higher than that of the DLD group, although these differences failed to reach statistical significance. An unexpected statistically significant but modest positive association (r = .32) was observed between children's sentence recall performances and parental ratings of their ADHD symptoms, indicating a tendency for children with more severe ADHD symptoms to perform better on the sentence recall task.

A few studies examining the potential impact of ADHD on children's psycholinguistic abilities have been based on full four-group designs (ADHD, DLD, ADHD + DLD, and TD). Luo and Timler (2008) compared the narratives produced by six participants with ADHD, six participants with ADHD + DLD, five participants with DLD, and 13 participants with TD. Like Redmond et al. (2011), these investigators did not find significant differences between their ADHD and TD groups in their overall performances on a standardized narrative measure. Both Redmond et al. (2011) and Luo and Timler administered the Test of Narrative Language (TNL; Gillam & Pearson, 2004) protocol; however, Luo and Timler further analyzed children's use of goal–attempt–outcome (GAO) sequences within the picture sequence and single picture tasks from the TNL. Both additive/interactive effects as well as subtractive effects were observed across the ADHD + DLD and DLD comparisons in the Luo and Timler study sample, making interpretation of their data challenging. On some measures, the DLD group means were higher than the ADHD + DLD group (e.g., total number of GAO units), on some they were the same (total number of subordinate GAO units), and on others the ADHD + DLD group means were higher (total number of initiating event statements).

Hutchinson et al. (2012) used a full four-group design to examine potential group differences in children's working memory abilities. Their study sample consisted of 18 children with DLD, 16 children with ADHD, 11 children with ADHD + DLD, and 24 children with TD who were administered a series of tasks designed to assess different aspects of verbal and nonverbal working memory. The phonological loop was measured using digit recall, word list recall, and nonword repetition tasks. The episodic buffer was measured with sentence recall, and the central executive was assessed with backward digit recall, counting recall (a visuospatial memory task), and a dual processing task. These investigators hypothesized that because separate mechanisms might be involved in the profiles of working memory deficits associated with ADHD and DLD, the performances of children with co-occurring ADHD + DLD would be associated with elevated deficits relative to cases of either DLD or ADHD alone. Their results did not support their predictions. Children in the ADHD + DLD group performed similarly to the DLD group, suggesting working memory deficits were more indicative of DLD status than ADHD status.

In summary, our understanding of the impact of ADHD symptoms on children's psycholinguistic development has been hampered by a preponderance of case–control studies, which have not always accounted for the potential impact of undetected co-occurring DLD on children's performances. Results from three-group designs, where cases of co-occurrence have been screened out, suggest that reduced performance on key psycholinguistic measures are primarily associated with DLD status, and these measures have been shown to be as effective at segregating cases of DLD from ADHD as they are at segregating cases of DLD from TD. Results from four-group designs on the issue of the potential impact of co-occurring ADHD on children's language development have been mixed: The presence of additive/interactive, subtractive, and null effects of co-occurrence on children's clinical symptoms have all been documented. One relatively unexamined possibility is that links among children's ADHD symptoms and their psycholinguistic abilities might be different for children with and without DLD. Most of the evidence available has been cross-sectional. A full account of the co-occurrence of ADHD + DLD will need data from prospective, longitudinal, four-group designs to confirm pathways to co-occurrence and the underlying mechanisms responsible among children who initially present with only one of the two disorders.

In this report, we provide results from the first wave of data collection associated with our ongoing longitudinal study tracking psycholinguistic growth and ADHD symptom progression across four groups of children (ADHD, DLD, ADHD + DLD, and TD) initially enrolled at 6–8 years of age. Our aim in the current report was to enrich the literature by examining further potential links among children's inattention, hyperactivity/impulsivity, and executive function symptoms and their psycholinguistic abilities. We focused our initial exploratory analyses on the potential effects of ADHD symptoms on children's psycholinguistic abilities. Our coverage of psycholinguistic abilities included a wider range of semantic, morphosyntactic, pragmatic, and verbal memory measures than has been previously considered within the same study sample. Our four-group design provided important representations across the nonclinical, borderline clinical, and clinical ranges for both psycholinguistic abilities and ADHD symptoms. This diversity in children's neurodevelopmental profiles allowed for both categorical and dimensional assessments of potential links between these two common neurodevelopmental conditions.

We addressed the following research questions:

1. Are there significant group differences indicating lower levels of performance for children with ADHD relative to TD and for children with ADHD + DLD relative to DLD? A focus on these two pairwise comparisons is conceptually motivated. The premise that ADHD status represents an independent risk to children's development across different psycholinguistic domains leads to two predictions that can be addressed by categorical analyses. First, children with ADHD should significantly underperform relative to children with TD—even when both groups are performing above clinical thresholds associated with DLD status. Second, if ADHD status is an independent risk, then its contributions should combine with the impacts of children's DLD status and yield more severe deficits within cases of ADHD + DLD co-occurrence relative to cases of DLD alone. Based on previous research, we expected the contributions of ADHD status to be more pronounced on measures of semantics, pragmatics, and narratives relative to grammatical measures and measures of verbal memory.

2. Are there significant associations among children's ADHD symptoms (inattention, hyperactivity, executive function) and their psycholinguistic abilities, and are these associations different for children with and without DLD? In addition to expected categorical/group differences, if ADHD represents an independent contributor to children's psycholinguistic deficits, there should also be significant associations among children's ADHD symptoms and their psycholinguistic abilities. That is, children with the most severe ADHD symptoms should be at higher risk for diminished language performance than children with less severe ADHD symptoms. Dimensional analyses (correlation, regression) allow us to specify further how variation among children's specific ADHD symptoms (inattention, hyperactivity, executive function) contributes to variation across children's specific psycholinguistic abilities and whether these might be different for children with and without DLD. Based on previous reports, we predicted that links among children's ADHD symptoms and their psycholinguistic abilities would vary across different dimensions of ADHD with stronger levels of association between inattention symptoms and children's psycholinguistic performances than hyperactivity/impulsivity and executive function symptoms. We did not make specific predictions regarding the possibility of different associations among ADHD symptoms and psycholinguistic for children with and without DLD. However, exploring these differences represents an important consideration. For example, the presence of such differences would encourage categorical/taxonomic views of the ADHD and DLD phenotypes rather than seeing them dimensionally as potentially intersecting and cumulative developmental liabilities. There would also be potential implications for tailoring intervention efforts toward children's specific neurodevelopmental profiles.

3. Which ADHD symptoms or combination of symptoms best predict children's performances across different psycholinguistic measures? Both psycholinguistic ability and ADHD symptoms represent multidimensional constructs consisting of both shared and nonshared variation among their components. Regression analyses provide more detailed and potentially clinical useful information about the relative and combined contributions of inattention, hyperactivity/impulsivity, and executive function symptoms to children's different psycholinguistic abilities. Furthermore, the potential influence of children's DLD status on these contributions can be examined via regression procedures.

Method

Ethical approval for this study was secured from The University of Utah Institutional Review Board prior to its execution (IRB 00110933). Written parental consent and child assent procedures were followed. Recruitment into the longitudinal study was initiated in fall 2018, and data collection associated with this report was completed in fall 2022.

Participants

Participants in this study (N = 78) were recruited into our longitudinal investigation of the developmental course of language disorders, attention deficits, and their co-occurrence. Our targeted age range for initial enrollment was 6–9 years, representing a period when many diagnoses of pediatric ADHD have been established. Potential participants were recruited from six local school districts through recruitment flyers distributed via school district e-mails to the families of all first- to third-grade students as well as through bulletins posted by the Children and Adults With Attention-Deficit/Hyperactivity–Utah Chapter. These broadband recruitment efforts were supplemented by more strategic recruitment efforts from the caseloads of three speech-language clinics and three community clinical psychologists through individually delivered recruitment flyers. Interested families contacted the Project Manager and completed a brief phone screening to confirm children's monolingual English-speaking status and to attest to the absence diagnoses of autism spectrum disorder, intellectual disability, or hearing impairment. All participants were speakers of General American English. During the phone screening, parents reported on any speech and language, reading, or other clinical/educational services their children were receiving. Parents of potential ADHD or ADHD + DLD participants confirmed an independent diagnosis of combined-type ADHD by a qualified health care professional and reported to the Project Manager if their children were receiving any behavioral medications for the treatment of their ADHD symptoms.

After passing our phone screening, potential participants were invited to complete confirmatory testing with one of our examiners to further establish their eligibility and to assign them into one of our groups. For the purposes of ruling out potential cases of intellectual disability from our study sample when assigning children to either our TD, DLD, ADHD, or ADHD + DLD groups, we applied conventional thresholds for nonverbal IQ performance associated with DLD and ADHD criteria (standard score > 70; Ahuja et al., 2013; Bishop et al., 2016). All participants had nonverbal standard scores of > 75 on the Naglieri Nonverbal Achievement Test (Naglieri, 2003). Parents completed the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2001) and *T* scores (M = 50, SD = 10) from its *Diagnostic and Statistical Manual of Mental Disorders (DSM)* ADHD syndrome scale were used to provide descriptive information regarding the overall severity of parent-reported ADHD symptoms across our four groups. For design purposes associated with the longitudinal study, measures used during eligibility assessments were different than the ones used experimentally to explore potential links among children's ADHD symptoms and their psycholinguistic abilities (reported below).

TD Group

Participants were assigned to our TD group if they had not been previously diagnosed with a neurodevelopmental or psychiatric condition, were not receiving clinical or educational services at study entry, and performed within normal limits on at least two of the three measures we used to assign DLD status.

DLD Group

Participants were assigned to the DLD group if they did not have a diagnosis of ADHD and demonstrated low performance (< 85 standard score) on at least two of the following indices of language disorder: the grammatical composite from the Test of Early Grammatical Impairment (TEGI: Rice & Wexler, 2001), percent consonants correct on the Dollaghan and Campbell nonword repetition task (Dollaghan & Campbell, 1998), and total scores on the Redmond Sentence Recall Task (Redmond, 2005). Standard scores were generated using community-based norms for these measures previously established by Redmond, Ash, et al. (2019). Enrollment in speech and language services at study entry was not a requirement for DLD status, although majorities in our DLD and ADHD + DLD groups were receiving speech and language services according to parental report (84.2% and 88.2%, respectively). In the absence of an agreed-upon "gold standard" for assigning DLD status, researchers and clinicians have several options available to them. The criteria for DLD used in this study align best with a "converging clinical marker" view of affected status (see Pawłowska, 2014; Rice & Wexler, 1996). For design purposes, different measures of nonword repetition, sentence recall, and tense marking were used to assign group status than those used to explore potential concurrent and longitudinal associations among children's psycholinguistic abilities and their ADHD symptoms.

ADHD Group

Participants were assigned to the ADHD group if they had an independent diagnosis of ADHD by a qualified health care professional and were receiving services for their ADHD symptoms at study entry. All children assigned to the ADHD group received CBCL ADHD *T* scores of > 65, indicating parents rated the severity of their children's ADHD symptoms consistently more than 1.5 *SD*s above the mean. Children in the ADHD group performed within normal limits on at least two of the three measures we used to assign DLD status.

ADHD + DLD Group

If participants met both ADHD and DLD inclusionary criteria, they were assigned to the ADHD + DLD group. All children assigned to the ADHD group received CBCL ADHD *T* scores of > 65, indicating parents rated the severity of their children's ADHD symptoms consistently more than 1.5 *SD*s above the mean.

Experimental Measures

An assessment battery consisting of standardized behavioral ratings scales and psycholinguistic tasks were used to examine potential group differences and to examine more closely associations among our participants'

ADHD symptoms and their verbal abilities. Key features of these measures are provided below.

ADHD Symptoms

The Conners Rating Scale represents one of the most used assessment systems for the evaluation of ADHD symptoms and related difficulties in children and adolescents. We used the inattention, hyperactivity/impulsivity, and executive functioning syndrome scales from the Conners Parent Scale–Third Edition (CPRS-3; Conners, 2009) to examine potential differences between our groups and associations with children's psycholinguistic abilities across these different sets of symptoms. The CPRS-3 provided alternative measures of children's specific ADHD symptoms than the one used during initial eligibility assessments. The CPRS-3 syndrome scales also allowed us to examine more clearly the relative shared and nonshared contributions of inattention, hyperactivity/impulsivity, and executive functioning symptoms on children's psycholinguistic abilities. The CPRS-3 uses a 4-point scale where parents indicate symptoms as either 0 = *not true at all*, 1 = *just a little true*, 2 = *pretty much true*, or 3 = *very much true* and, like the CBCL, reports norm-referenced values using T scores (M = 50, SD = 10). Internal consistency coefficients for these scales ranged from .92 to .94. Test–retest correlation coefficients for the Inattention, Hyperactivity/Impulsivity, and Executive Functioning scales are .88, .91, and .72, respectively. Parents of children receiving behavioral medications were instructed to rate their child's behaviors when they are not medicated.

Psycholinguistic Measures

Six verbal measures targeting our participants' abilities with recalling sentences, receptive vocabulary, grammaticality judgments, nonword repetition, and narratives were selected along with one standardized pragmatic behavioral rating measure.

Recalling sentences. Sentence recall is one of the most frequently used methods for identifying language disorders in children and adolescents and has been an abiding feature on omnibus language tests (Carrow, 1974; Lee, 1971). The Recalling Sentences (RS) subtest of the Clinical Evaluation of Language Fundamentals–Fifth Edition (CELF-5; Wiig et al., 2013) was administered to each participant providing an alternative measure of sentence recall abilities than the one used for determining eligibility. Internal consistency correlation coefficient for the RS for children ages 6–8 years ranges from .93 to .95. The test–retest adjusted correlation coefficient for the RS was .83. Performances on the CELF-5 RS are reported in scaled scores (M = 10, SD = 3).

Vocabulary. The Peabody Picture Vocabulary Test–Fourth Edition (PPVT-4; Dunn & Dunn, 2007) represents a standardized measure of receptive vocabulary commonly used by speech-language pathologists (Betz et al., 2013; Denman et al., 2021). Test–retest reliability for the PPVT-4 for children ages 6–8 years ranged from .92 to .93. Performances on the PPVT-4 are reported in standard scores (M = 100, SD = 15).

Grammaticality judgments. For monolingual General American English–speaking children in particular, tense-marking difficulties across a variety of testing formats represent one of the hallmark features of SLI/DLD (for reviews, see Leonard, 2014; Schwartz, 2009). Grammaticality judgments provide a receptive format that taps into acceptability levels associated with different tense-marking errors (Oetting et al., 2023; Rice et al., 1999, 2009, 2023). In this study, we administered the Grammaticality Judgment-Twenty (GJ20) protocol, an abridged version of the protocol developed by Rice et al. (2009). In their study of 405 twins aged 16 years, Dale et al. (2018) reported higher heritability estimates associated with low levels of performance on the GJ20 than other language measures considered (vocabulary, figurative language). Estimated test–retest reliability on the GJ20 items based on the Rice et al. (2009) study sample across a 1-year retest interval was r = .74 (Dale et al., 2018, p. 70). For our purposes, the GJ20 measure provided an alternative measure of children's morphosyntactic skills than the one we used for determining eligibility (TEGI). The GJ20 stimuli consist of 20 prerecorded *wh*-questions; half of the items are ungrammatical due to omitted obligatory finite forms (e.g., "Where you like to play?") and half are grammatically correct (e.g., "What do you like to do?"). Following previous studies of grammaticality judgments provided by individuals affected by language disorders, A' values were used to evaluate the capacity of each participant to correctly reject ungrammatical sentences and accept grammatical sentences. A' was calculated using the following formula provided by Grier (1971): $0.5 + [(y - x)(1 + y - x)]/4y\ (1 - x)$, where x = proportion of false alarms and y = proportion of hits. A' values at or close to 0.5 indicate chance levels of performance, and scores at or close to 1.00 indicate judgments that strongly align with the grammaticality of the sentence stimuli.

Nonword repetition. Difficulties with nonword repetition tasks have been demonstrated in a variety of pediatric language disorders (Graf Estes et al., 2007). Nonword repetition tasks are thought to measure children's phonological short-term memory capacities, although some debate exits regarding the specific mechanisms responsible for the observed deficits. Shriberg and Lohmeier's (2008) Syllable Repetition Task (SRT) was selected to measure children's ability to produce nonwords, providing an alternative measure of children's verbal working memory skills than the nonword repetition task used for determining eligibility. The SRT consists of 18 prerecorded nonwords and utilizes four voiced consonants /b/, /d/, /m/, and /n/ and the vowel /ɑ/ and its syllables from the early-eight speech sounds (Schriberg, 1993) and offers a potentially stronger estimate of working memory than other options because it does not penalize speakers with incomplete phonemic inventories. Items increase in complexity as the task goes onto repetitions of two-, three-, and four-syllable nonwords. Percent consonants correct were calculated for each participant. There are no normative data available for the SRT, but reported estimates of interjudge transcription agreement are 88%.

Narratives. Comprehending and producing narratives represent well-established weaknesses of children with a variety of language disorders and has also been implicated in children with ADHD (Jepsen et al., 2022). The TNL-2 (Gillam & Pearson, 2017) assesses both narrative comprehension and production abilities across a series of tasks. The TNL-2 generates a composite standard score across these tasks, the Narrative Language Ability Index (NLAI; M = 100, SD = 15), providing a norm-referenced estimate of children's overall narrative proficiency. Internal consistency coefficients for the NLAI for children ages 6–9 years ranged from .90 to .94. The corrected test–retest correlation coefficient associated with the NLAI age interval that covers our participants was .94.

Pragmatics. Persistent difficulties in the use of verbal and nonverbal communication for social purposes are common across children affected by neurodevelopmental disorders. Several case–control studies have documented pragmatic deficits within study samples of children with DLD and study samples of children with ADHD (Carruthers et al., 2022; Norbury, 2014; Perkins, 2007). Elements of the CCC-2 (Bishop, 2006) have been frequently used by researchers to produce standardized measures of children's overall levels of pragmatic functioning. We used the Pragmatics Composite 5 (PC5; Ash et al., 2017; Ellis Weismer et al., 2021), representing the average of the scaled scores (M = 10, SD = 3) across the Coherence, Initiation, Scripted Language, Context, and Nonverbal Communication scales. Internal consistency coefficients associated with these scales range from .77 to .83. Test–retest reliability is not available for the PC5 or the individual scales that make up the PC5.

Procedure

The project manager scheduled and supervised administrations of the eligibility and experimental protocols to our participants and implemented our study's blinding procedures, ensuring that examiners were unaware of children's clinical status during testing. Test administrations were completed by 13 graduate research assistants in speech-language pathology. Of the 13 examiners, three were doctoral students who had their American Speech-Language-Hearing Association Certificate of Clinical Competence in Speech-Language Pathology. Examiners completed the Collaborative Institutional Training Initiative prior to beginning training on the measures. Training on the eligibility and experimental protocols took approximately 60 hr to complete, with all examiners meeting 85% reliability requirements on each measure before they began testing participants. Interrater scoring consistency was calculated on 20% of data collected. Correlations indicated overall high levels of interrater scoring consistency for our behavioral measures, CELF-5 RS, $r(18) = .989$, $p < .001$; PPVT-4, $r(18) = 1.00$, $p < .001$; SRT, $r(18) = .966$, $p < .001$; GJ20, $r(18) = 1.00$, $p < .001$; TNL-2, $r(18) = .992$, $p < .001$.

Completion of the eligibility and experimental protocols both typically required 2 hr of participants' time (4 hr in total). Parents in the ADHD and ADHD + DLD groups were instructed to suspend any stimulant or nonstimulant behavioral medications for the treatment of ADHD symptoms during both the eligibility and experimental assessments (77.8% and 52.9% of the ADHD and ADHD + DLD groups, respectively). Testing sessions took place either in person at the Child Language Laboratories at The University of Utah or remotely over Zoom. The inclusion of the Zoom-based protocol administrations was a necessary accommodation for COVID-19 restrictions that were in place during data collection. Standardized language testing results achieved through teletesting administrations have been highly consistent with in-person standardized testing results (e.g., Pratt et al., 2022; Waite et al., 2010). Similarly, teletesting administrations of cognitive, academic achievement, and verbal fluency measures have yielded similar results to in-person assessments of children with ADHD (McDermott et al., 2023).

Analysis Plan

Both categorical and dimensional analyses were used to address our research questions. First, potential group differences across the different psycholinguistic measures were evaluated using one-way analyses of variance (ANOVAs) with Sidak follow-up pairwise comparisons to determine if children's ADHD status was independently associated with lower levels of psycholinguistic performance. Next, we created a correlation heatmap displaying the strengths of unadjusted associations among our experimental measures for children with DLD (DLD and ADHD groups) and children without DLD (TD and ADHD groups) to better visualize the relative strengths of these relationships as a function of children's DLD status. Psycholinguistic measures and ADHD symptom checklists reflect different measurements schemes. Specifically, higher scores on psycholinguistic measures reflect better performance, whereas higher scores on ADHD symptom subscale reflect more severe behavioral symptoms or poorer performance. Consequently, a heatmap representation of these variables provides different colors for within-domain correlations (positive: red) and between-domains correlations (negative: violet).

Finally, we used the best subset regression method to determine which combination of ADHD symptom scales were the most predictive of children's performances across the psycholinguistic measures and if this varied by children's DLD status. The best subset regression is an exploratory model selection approach that consists of testing all possible combinations of the predictor variables and then selecting among them the best model using the Bayesian information criteria (BIC; Gelman et al., 2013). The BIC favors parsimonious models over more complex ones. The candidate predictors for our six psycholinguistic measures included DLD status as a binary group indicator (i.e., DLD and ADHD + DLD = 1 vs. TD and ADHD = 0) and interaction terms between DLD status–specific and ADHD symptom scale. The regression formula with all seven predictors consists of the following (where DLD = DLD status, Inattention = Conners Inattention Scale, HI = Conners Hyperactivity/Impulsivity Scale, and EF = Conners Executive Function scale):

$$\begin{aligned}&\text{Psycholinguistic Measure}\\&\quad = \beta_0 + \beta_1 * \text{Inattention} * \mathrm{I}(\text{DLD} = 1) + \beta_2\\&\quad * \text{Inattention} * \mathrm{I}(\text{DLD} = 0) + \beta_3 * \text{HI}\\&\quad * \mathrm{I}(\text{DLD} = 1) + \beta_4 * \text{HI} * \mathrm{I}(\text{DLD} = 0) + \beta_5\\&\quad * \text{EF} * \mathrm{I}(\text{DLD} = 1) + \beta_6 * \text{EF} * \mathrm{I}(\text{DLD} = 0)\\&\quad + \beta_7 * \text{DLD} + \text{residual}\end{aligned} \tag{1}$$

For each psycholinguistic measure, models consisting of all predictor combinations were generated for sets of one, two, three, four, five, six, and seven predictors. The BIC was then used to identify among the models generated the best model within each of these sets (e.g., the best predictor model consisting of four predictors). Then, separately for each measure, the BIC was used to further identify among these generated models which of them represented the overall best subset predictor model (e.g., the best four-predictor model for sentence recall vs. the other best sentence recall models consisting of the one-, two-, three-, etc.-predictor models). All analyses were performed using statistical analysis software R (Version 4.3.2).

Results

Complete data were available for all participants. Table 1 displays our participants' demographic characteristics, along with the group means, standard deviations, and ranges associated with our eligibility and descriptive measures. Groups were similar in their gender ratios, racial/ethnic compositions, and overall levels of maternal education. As expected, significant group differences were observed on the language measures, and follow-up pairwise comparisons confirmed the TD and ADHD groups were performing significantly higher than the DLD and ADHD + DLD groups, which were not significantly different from each other. The *DSM* ADHD syndrome scale mean *T* scores from the CBCL (Achenbach & Rescorla, 2001) indicated similar levels of overall symptom severity among the ADHD and ADHD + DLD groups, and both were significantly higher than the TD and DLD groups. Although observed means for the DLD group on the CBCL ADHD ratings were higher than the TD group, this difference failed to reach statistical significance. Significant group differences were also observed across groups on their performances on our test of nonverbal abilities (Naglieri, 2003), indicating lower levels of performance in our DLD and ADHD + DLD groups relative to our TD and ADHD groups.

Group Differences on ADHD Symptom Subscales and Psycholinguistic Measures

Means, standard deviations, and planned follow-up pairwise comparisons for the nine experimental measures (three ADHD symptom subscales and six psycholinguistic measures) are reported for each group in Table 2. A one-way ANOVA identified differences between mean values associated with the ADHD symptom scales and psycholinguistic measures across the TD, ADHD, DLD, and ADHD + DLD groups. The *F* values from the ANOVA ranged from $F(3, 74) = 8.71$ to 23.24 (all $p\text{s} < .001$). Follow-up Sidak post hoc analyses were conducted to identify pairwise comparisons that reached the significance level of $p < .05$. Mean values differed between the TD and ADHD groups on the Conners ADHD symptom scales, with the ADHD group scoring higher on *T* scores across the three measures, indicating more severe levels of difficulty in these areas (all $p\text{s} < .001$). Differences between the TD and ADHD groups were also seen on the CCC-2 Pragmatic 5 composite, with the TD group receiving higher ratings of their pragmatic abilities than the ADHD group ($p < .001$). There were no significant differences between the TD and ADHD groups on the other psycholinguistic measures (SRT, $p = 1.0$; PPVT-4, $p = .884$; GJ20, $p = .698$; GJ20, $p = .350$; CELF-5 RS, $p = .799$; TNL-2 NLAI, $p = .801$; TNL-2 Comprehension, $p = .801$; TNL-2 Production, $p = .343$).

Sidak post hoc analyses found mean value differences between the DLD and ADHD + DLD groups on

Table 1. Means (standard deviations) and ranges for demographics variables and eligibility measures.

Variable	Combined sample *N* = 78	TD *n* = 24	ADHD *n* = 18	DLD *n* = 19	ADHD + DLD *n* = 17	Chi-square/ ANOVA *p* values
Sex	33% girls	33% girls	39% girls	32% girls	29% girls	.941
	67% boys	67% boys	61% boys	68% boys	71% boys	
Race, ethnicity	79% White	79% White	78% White	95% White	76% White	
	4% PI/NH	8% PI/NH	6% PI/NH	11% Hispanic	24% Hispanic	Person of color vs. White
	17% Hispanic	17% Hispanic	17% Hispanic	1% Missing		.943
Age	89.46 (10.57)	90.92 (11.22)	90.72 (9.83)	85.00 (11.47)	91.06 (8.66)	.149
	72–107	73–107	72–103	72–107	78–103	
Mother's education[a]	3.81 (0.88)	3.92 (0.97)	4.06 (0.64)	3.68 (1.06)	3.53 (0.72)	.240
	1–5	2–5	3–5	1–5	2–5	
CBCL ADHD	63.13 (10.29)	54.08 (5.66)	72.44 (4.73)	58.74 (9.59)	70.94 (5.27)	< .001
	50–80	50–69	66–80	50–77	66–80	
NNAT	104.80 (12.96)	110.67 (9.69)	108.50 (11.35)	99.16 (15.83)	99.88 (10.60)	.013
	76–136	91–123	88–134	76–136	78–125	
TEGI	66.71 (41.87)	99.08 (22.80)	85.39 (32.69)	38.00 (37.17)	33.29 (29.49)	< .001
	1–114	1–112	1–114	1–106	1–78	
Nonword Repetition	87.38 (23.65)	103.92 (12.94)	100.44 (14.06)	65.16 (20.83)	75.06 (20.05)	< .001
	40–124	74–120	71–124	40–111	40–110	
Sentence Recall	87.30 (22.08)	104.71 (11.23)	100.78 (12.64)	70.26 (14.31)	67.47 (18.51)	< .001
	41–122	75–119	79–122	41–89	44–104	

Note. TD = neurotypical development; ADHD = attention-deficit/hyperactivity disorder; DLD = developmental language disorder; ANOVA = analysis of variance; PI = Pacific Islander; NH = Native Hawaiian; CBCL ADHD = Child Behavior Checklist *DSM-5* ADHD Syndrome Scale, *T* score (M = 50, SD = 10; higher values indicate elevated levels of attention/impulsivity difficulties); NNAT = Naglieri Nonverbal Achievement Test; TEGI = Test of Early Grammatical Impairment standard score (M = 100, SD = 15); Nonword Repetition = standard score (M = 100, SD = 15; Dollaghan & Campbell, 1998); Sentence Recall = standard score (M = 100, SD = 15; Redmond, 2005).

[a]1 = *some high school*, 5 = *some graduate school/graduate degree*.

the Conners hyperactive–impulsive *T* score ($p < .05$) and the Conners inattentive *T* score ($p < .01$), with children in the ADHD + DLD group having higher mean scores indicating more severe symptom than children in the DLD group. Differences between the DLD and ADHD + DLD groups approached significance on the Conners executive functioning *T* score ($p = .055$). There were no significant differences between these groups on the CCC-2 Pragmatic 5 composite ($p = .177$). Additionally, there were no significant differences on the other psycholinguistic measures between the DLD and ADHD + DLD groups (SRT, $p = .938$; PPVT-4, $p = .758$; GJ20, $p = .704$; CELF-5 RS, $p = 1.0$; TNL-2 NLAI, $p = .747$; TNL-2 Comprehension, $p = .556$; TNL-2 Production, $p = .882$).

Table 3 summarizes the pairwise comparisons between our TD and ADHD groups and between our DLD and ADHD + DLD groups. These comparisons were motivated by predictions generated for the premise that ADHD status represents an independent risk for children's psycholinguistic development. For completeness, we include the outcomes of follow-up pairwise comparisons between our TD and DLD groups and between ADHD and ADHD + DLD groups below.

There were no significant differences between the TD and DLD groups on the three ADHD measures from the Conners (Executive Functioning, $p = .112$; *DSM-5* ADHD Hyperactive–Impulsive, $p = .929$; Inattentive, $p = .098$). In contrast, as expected, significant differences were found between the TD and DLD groups on all of the psycholinguistic measures (SRT, $p \leq .001$; PPVT-4, $p \leq .001$; GJ20, $p \leq .001$; CELF-5 RS, $p \leq .001$; TNL-2 NLAI, $p < .001$; TNL-2 Comprehension, $p \leq .001$; TNL-2 Production, $p < .001$; CCC-2 PC5, $p < .001$).

Sidak post hoc comparisons between the ADHD and ADHD + DLD groups indicated there were no significant differences between the groups on measures of ADHD symptoms on the three measures from the Conners (Executive Functioning, $p = .895$; *DSM-5* ADHD Hyperactive–Impulsive, $p = .539$; Inattentive, $p = .951$). Similarly, there were no significant difference between the ADHD and ADHD + DLD groups on the CCC-2 Pragmatic 5 composite ($p = .901$) or the GJ20 ($p = .662$). Significant differences, however, were present on the other psycholinguistic measures (SRT, $p = .005$; PPVT-4, $p \leq .001$; CELF-5 RS, $p \leq .001$; TNL-2 NLAI, $p \leq .001$; TNL-2 Comprehension, $p \leq .001$; TNL-2 Production, $p = .014$).

Table 2. Means (standard deviation) and ranges for experimental measures.

Variable	Combined sample *N* = 78	TD *n* = 24	ADHD *n* = 18	DLD *n* = 19	ADHD + DLD *n* = 17	ANOVA *p* values
Conners Executive Function	63.59 (15.26)	51.67 (9.35)	75.44 (10.51)	60.53 (15.48)	71.29 (12.77)	< .001
	40–90	41–76	59–90	40–84	41–90	
Conners Hyperactive	66.13 (17.92)	54.88 (14.11)	81.44 (10.46)	59.00 (16.74)	73.76 (15.87)	< .001
	40–90	40–90	61–90	40–90	45–90	
Conners Inattentive	66.78 (16.35)	53.25 (8.60)	80.17 (8.83)	62.37 (17.42)	76.65 (12.39)	< .001
	40–90	40–69	61–90	40–90	48–90	
SRT	83.74 (12.45)	89.92 (8.86)	90.33 (7.77)	74.84 (13.94)	78.00 (10.75)	< .001
	48–100	66–100	66–100	48–98	56–94	
PPVT-4	107.09 (15.96)	118.13 (12.79)	114.11 (15.62)	98.68 (11.03)	93.47 (8.74)	< .001
	70–146	92–145	87–146	80–127	70–109	
GJ20	0.71 (0.17)	0.82 (0.11)	0.73 (0.17)	0.60 (0.14)	0.66 (0.18)	< .001
	0.20–1.00	0.57–1.00	0.42–1.00	0.25–0.90	0.20–0.88	
CELF-5 RS	9.35 (3.56)	12.08 (2.39)	11.06 (2.94)	6.79 (2.57)	6.53 (2.35)	< .001
	1–16	8–16	7–16	1–10	3–13	
CCC-2 Pragmatic 5	8.49 (2.66)	11.13 (1.31)	7.23 (1.61)	8.01 (2.66)	6.58 (2.11)	< .001
	1.80–13.20	9.00–13.20	4.40–10.00	1.80–11.00	3.00–11.60	
TNL-2 NLA Index	96.71 (14.90)	106.79 (11.70)	102.33 (11.18)	89.58 (11.24)	84.47 (13.77)	< .001
	64–127	86–127	78–124	69–108	64–111	

Note. TD = neurotypical development; ADHD = attention-deficit/hyperactivity disorder; DLD = developmental language disorder; ANOVA = analysis of variance; Conners = Conners Rating Scale, three subscales *T* score (*M* = 50, *SD* = 10; higher values indicate elevated symptoms); SRT = Syllable Repetition Task percent correct; PPVT-4 = Peabody Picture Vocabulary Test–Fourth Edition; GJ20 = Grammaticality Judgment-Twenty (Dale et al., 2018) *A′* scores; CELF-5 RS = Clinical Evaluation of Language Fundamentals–Fifth Edition Recalling Sentences score (*M* = 10, *SD* = 3); CCC-2 Pragmatic 5 = Pragmatic Composition from the Children's Communication Checklist–Second Edition; TNL-2 NLA = Test of Narrative Language–Second Edition Narrative Language Ability (*M* = 100, *SD* = 15).

Associations Among Children's ADHD Symptoms and Their Psycholinguistic Abilities

Figure 1 displays the results of zero-order correlations among our experimental measures as a function of children's DLD status: The upper wedge presents a matrix based on measures taken from children in the DLD and ADHD + DLD groups combined, and the lower wedge presents the matrix for the combination of children in the TD and ADHD groups. For children with and without DLD, positive intercorrelations among the ADHD symptom measures were comparable and consistently in the moderate to very strong range (.48–.83). In contrast, positive associations among the psycholinguistic measures were affected by children's DLD status. For children without DLD, positive intercorrelations among the psycholinguistic measures ranged from moderate to strong (.50–.72), whereas for children with DLD, these abilities were less integrated and included some weak/very weak intercorrelations. Specifically, associations between the grammaticality judgment and the pragmatic measures and the other psycholinguistic for children with DLD measures were very limited (−0.1 to 0.31). This outcome among our psycholinguistic measures is not entirely unexpected but rather is consistent with some long-standing models of disorder within developmental processes. Instead of representing general delays, language disorders likely consist of more complex asynchronous growth patterns. In this sense of the term *disorder*, disruptions of the otherwise orderly integration of psycholinguistic subsystems that occurs under unaffected development are present (cf. Rice, 2004).

Negative intercorrelations were expected between our ADHD symptom measures and our psycholinguistic measures because their scales are inverted. Specifically, a high language test score indicates better performance, whereas high ratings on an ADHD checklist indicates more severe symptoms or worse performance. Negative intercorrelations between the ADHD and psycholinguistic measures were affected by children's DLD status. For children without DLD, moderate negative associations among their ADHD symptoms and vocabulary, recalling sentences, and pragmatics abilities were observed (−0.33 to −0.51). In contrast, for children with DLD, there was little evidence that ADHD symptoms were associated with their psycholinguistic abilities. The one noteworthy exception being the presence of moderate negative associations

Table 3. Follow-up pairwise comparisons for eligibility and experimental measures: neurotypical development (TD) versus attention-deficit/hyperactivity disorder (ADHD) and developmental language disorder (DLD) versus ADHD + DLD.

Variable	TD vs. ADHD Sidak *p* values	DLD vs. ADHD + DLD Sidak *p* values
Eligibility measures		
CBCL ADHD	.001	.001
NNAT	.993	1.000
TEGI	.634	.998
Nonword Repetition	.987	.416
Sentence Recall	.941	.992
Experimental measures		
Conners Executive Function	.001	.055
Conners Hyperactive	.001	.050
Conners Inattentive	.001	.010
SRT	.084	1.000
PPVT-4	.698	.758
GJ20	.350	.704
CELF-5 RS	.799	.938
CCC-2 Pragmatic 5	.001	.177
TNL-2 NLA Index	.801	.742
TNL2 Production	.801	.882
TNL2 Comprehension	.343	.556

Note. CBCL ADHD = Child Behavior Checklist *DSM-5* ADHD Syndrome Scale; NNAT = Naglieri Nonverbal Achievement Test; TEGI = Test of Early Grammatical Impairment; Nonword Repetition = standard score (Dollaghan & Campbell, 1998); Sentence Recall = standard score (Redmond, 2005); Conners = Conners Rating Scale, three parent scales (Executive Function, Hyperactive/Impulsivity, Inattention); SRT = Syllable Repetition Task (Shriberg & Lohmeier, 2008); PPVT-4 = Picture Peabody Vocabulary Test–Fourth Edition; GJ20 = Grammaticality Judgment-Twenty (Dale et al., 2018); CELF-5 RS = Clinical Evaluation of Language Fundamentals–Fifth Edition Recalling Sentences subscale; CCC-2 Pragmatic 5 = Pragmatic Composition from the Children's Communication Checklist–Second Edition; TNL-2 = Test of Narrative Language–Second Edition; NLA = Narrative Language Ability.

among ADHD symptoms and pragmatic skills for children affected by DLD.

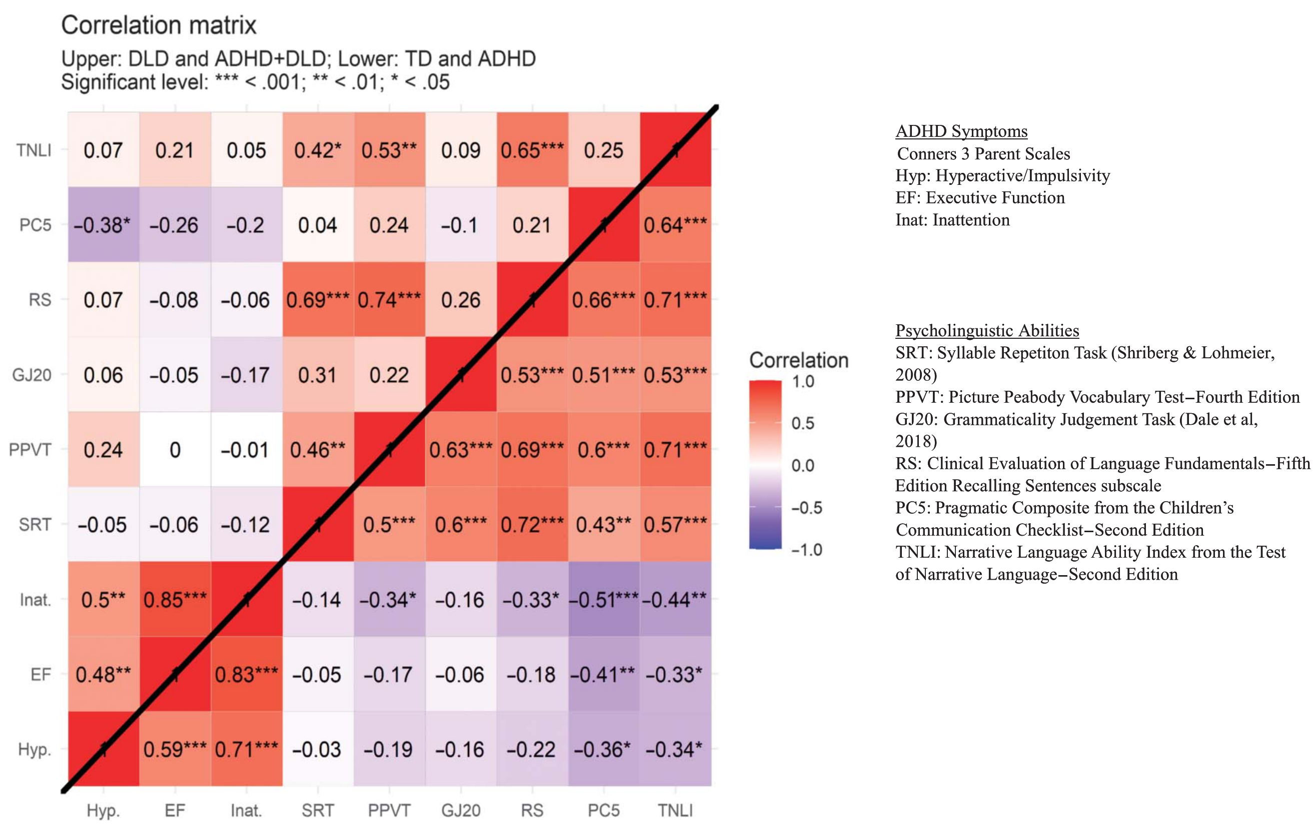
Best Subsets Regression Analyses

We used the best subsets regression procedure to determine which combination of ADHD scales (inattention, hyperactivity/impulsivity, and executive functions) best predicted children's psycholinguistic abilities and to further confirm these associations were influenced by children's DLD status. Table 4 presents the best one-, two-, three-, four-, five-, six-, and seven-predictor models for each psycholinguistic measure. Table 5 displays the final models (i.e., the best subset) for each psycholinguistic measure after using the BIC to compare among the best one-, two-, three-, four-, five-, six-, and seven-predictor models. We found that four of our six psycholinguistic measures could be significantly predicted by at least one of the ADHD symptoms after adjusting for the DLD group indicator. The amount of variation in the psycholinguistic measures explained by our predictor models was modest (< 17%) with one exception. The model for our pragmatic measure, PC5, accounted for 55% of the variance in parental rating of children's pragmatic abilities, and it included two ADHD scale predictors (Inattention and Hyperactivity/Impulsivity) for those with and without DLD. For children with DLD (DLD and ADHD + DLD groups), Hyperactivity/ Impulsivity was a significant predictor of children's pragmatic abilities, whereas for children without DLD (TD and ADHD groups), Inattention was a significant predictor for PC5 and three other psycholinguistic measures: TNL, PC5, RS, and PPVT. None of the ADHD symptom scales significantly predicted children's performances on the SRT or GJ20 tasks.

Discussion

Millions of U.S. students are impacted by ADHD and DLD—two conditions with well-documented risks for academic, social, and vocational outcomes. In addition to their presence as relatively common neurodevelopmental disruptions, ADHD and DLD also commonly co-occur on clinical caseloads. Despite the importance of understanding the links between ADHD and DLD for optimizing clinical services, these associations remain poorly understood. In this report, we implemented a relatively underutilized four-group design (TD, ADHD, DLD, and ADHD + DLD) to examine further the potential impacts of ADHD symptoms on six different aspects of children's psycholinguistic development: recalling sentences, receptive vocabulary, grammaticality judgments, nonword repetition, narratives, and pragmatics. Based on previous reports, we predicted children with ADHD would underperform relative to children with TD, even though both groups would likely perform within the normal range across our different psycholinguistic measures. Similarly, we predicted children with co-occurring ADHD + DLD would display more severe psycholinguistic deficits than children in our DLD group. These outcomes would be consistent with a characterization of ADHD status as an independent contributor to psycholinguistic risk. A corollary prediction is that children with the most severe ADHD symptoms should be at higher risk for diminished psycholinguistic performance. However, because both psycholinguistic ability and ADHD symptoms represent multidimensional constructs, we expected associations to vary across our clinical measures. Specifically, we expected the unique contributions of inattention symptoms to be relatively more pronounced than hyperactivity/impulsivity and

Figure 1. Correlation heatmap. DLD = developmental language disorder; ADHD = attention-deficit/hyperactivity disorder; TD = typical development.



executive functioning on measures of semantics, pragmatics, and narratives relative to measures of grammatical competence and verbal memory. In our analyses, we also considered the possibility that links among children's ADHD symptoms and psycholinguistic abilities might be different for children with and without DLD, a relatively unexplored premise but one with implications for phenotypic models and differentiated treatment of these two common neurodevelopmental conditions.

Our results provided mixed support for our predictions. Some outcomes aligned with the characterization of ADHD as an independent contributor to psycholinguistic risk whereas others did not. Starting with details from our ADHD and TD groups, the presence of statistically significant negative associations (r range: −.34 to −.51) among children's ADHD symptoms and some of our language measures (receptive vocabulary, narratives, pragmatics) indicated that lower levels of performance were generally associated with more severe ADHD symptoms. These results aligned well with previous reports from case–control studies, suggesting ADHD status contributes to compromised psycholinguistic development (Green et al., 2014; Jepsen et al., 2022; Korrel et al., 2017; Westby & Watson, 2021). However, other outcomes of our study suggest the situation might be more complicated. For example, despite these associations, follow-up pairwise group mean comparisons revealed for the most part our ADHD group's psycholinguistic performances were not significantly different than our TD group's means. The one exception among our measures being parental ratings of children's pragmatic abilities.

ADHD and TD comparisons provide only one test of the contributions of ADHD symptoms to psycholinguistic development. The inclusion of a fourth group of cases of ADHD + DLD into our design allowed us to examine the possibility of potential additive/interaction effects on children's psycholinguistic abilities. The absence of significant mean differences between our DLD and our ADHD + DLD groups suggests that there were no additive/interactive effects across our psycholinguistic measures—an outcome previously reported by Redmond et al. (2015). The absence of group effects between our cases of TD and ADHD and between our cases of DLD and ADHD + DLD in the presence of significant correlations among children unaffected by DLD provides mixed signals that present a challenge to the view of ADHD as a

Table 4. Summary of best model for each psycholinguistic measure given predefined number of predictors.

Psycholinguisticability model	Effect of ADHD symptom for DLD			Effect of ADHD symptom for non-DLD			DLD group		
	Effect estimate (*SE*)			Effect estimate (*SE*)			Effect estimate (*SE*)		
Best 1-predictor model for	**Inattention**	**HI**	**EF**	**Inattention**	**HI**	**EF**		**BIC**	R^2
TNLI							–5.53 (3.36)	652.1	.03
PC5		–0.04 (0.01)***						349.9	.33
RS			–0.01 (0.01)					430.3	.02
PPVT			–0.07 (0.05)					663.3	.03
GJ20	0 (0)							–41.5	.01
SRT				–0.04 (0.05)				625.9	.01
Best 2-predictor model for									
TNLI				–0.52 (0.15)**			–35.56 (9.36)***	645.3	.16
PC5		–0.11 (0.01)***		–0.09 (0.02)***				329.1	.52
RS				–0.12 (0.04)**			–7.52 (2.29)**	425.5	.13
PPVT				–0.4 (0.17)*			–28.47 (10.43)**	662.1	.1
GJ20	0 (0)			0 (0)				–39.6	.04
SRT			–0.17 (0.1)	–0.24 (0.12)*				627.1	.05
Best 3-predictor model for									
TNLI			0.2 (0.2)	–0.52 (0.15)**			–50.14 (17.6)**	648.6	.17
PC5		–0.06 (0.02)**		–0.12 (0.02)***			–5.06 (2.17)*	327.9	.55
RS				–0.19 (0.08)*		0.09 (0.09)	–6.8 (2.38)**	428.6	.14
PPVT				–0.83 (0.37)*		0.51 (0.39)	–24.51 (10.81)*	664.7	.12
GJ20	–0.01 (0)		0.01 (0.01)	0 (0)				–36.5	.05
SRT			–0.16 (0.1)	–0.35 (0.3)		0.13 (0.31)		631.3	.05
Best 4-predictor model for									
TNLI	–0.28 (0.45)		0.42 (0.41)	–0.52 (0.15)**			–44.57 (19.82)*	652.6	.18
PC5		–0.06 (0.02)**		–0.11 (0.03)***	–0.02 (0.03)		–5.28 (2.19)*	331.7	.56
RS				–0.22 (0.09)*	0.03 (0.05)	0.1 (0.09)	–6.49 (2.46)*	432.7	.14
PPVT		0.22 (0.19)		–0.83 (0.37)*		0.51 (0.39)	–41.3 (18.34)*	667.7	0.13
GJ20	–0.01 (0)		0.01 (0.01)	–0.01 (0)		0 (0)		–33.1	0.06
SRT			–0.15 (0.1)	–0.41 (0.34)	0.07 (0.18)	0.13 (0.31)		635.4	0.06
Best 5-predictor model for									
TNLI	–0.3 (0.45)	0.07 (0.19)	0.41 (0.41)	–0.52 (0.16)**			–47.22 (21.23)*	656.8	0.18
PC5		–0.06 (0.02)*	–0.01 (0.03)	–0.11 (0.03)***	–0.02 (0.03)		–4.58 (2.63)	335.7	0.56
RS	0.08 (0.11)		–0.09 (0.1)	–0.19 (0.08)*		0.09 (0.09)	–6.84 (4.91)	436.5	0.15
PPVT		0.22 (0.19)		–0.99 (0.42)*	0.18 (0.22)	0.53 (0.39)	–39.21 (18.58)*	671.4	0.14
GJ20	–0.01 (0.01)	0 (0)	0.01 (0.01)	–0.01 (0)		0 (0)		–28.9	0.07

(*table continues*)

Table 4. *(Continued).*

Psycholinguisticability model	Effect of ADHD symptom for DLD			Effect of ADHD symptom for non-DLD			DLD group		
	Effect estimate (*SE*)			Effect estimate (*SE*)			Effect estimate (*SE*)		
Best 1-predictor model for	**Inattention**	**HI**	**EF**	**Inattention**	**HI**	**EF**		**BIC**	R^2
SRT	–0.07 (0.36)		–0.09 (0.37)	–0.41 (0.34)	0.07 (0.18)	0.13 (0.32)		639.8	0.06
Best 6-predictor model for									
TNLI	–0.3 (0.46)	0.07 (0.19)	0.41 (0.41)	–0.57 (0.23)*	0.06 (0.21)		–46.54 (21.48)*	661	0.18
PC5	0.03 (0.06)	–0.06 (0.03)*	–0.03 (0.05)	–0.11 (0.03)***	–0.02 (0.03)		–5.03 (2.83)	339.9	0.56
RS	0.08 (0.11)		–0.09 (0.1)	–0.22 (0.09)*	0.03 (0.05)	0.1 (0.09)	–6.53 (4.97)	440.6	0.15
PPVT	0.54 (0.5)	0.22 (0.21)	–0.57 (0.45)	–0.83 (0.37)*		0.51 (0.39)	–42.91 (23.51)	674.7	0.15
GJ20	–0.01 (0.01)	0 (0)	0.01 (0.01)	–0.01 (0)	0 (0)	0 (0)		–24.6	0.07
SRT	–0.09 (0.4)		–0.09 (0.37)	–0.41 (0.35)	0.07 (0.18)	0.13 (0.32)	2.53 (18.3)	644.1	0.06
Best 7-predictor model for									
TNLI	–0.3 (0.46)	0.07 (0.19)	0.41 (0.42)	–0.55 (0.39)	0.06 (0.21)	–0.03 (0.36)	–46.76 (21.83)*	665.4	0.18
PC5	0.03 (0.06)	–0.06 (0.03)*	–0.03 (0.05)	–0.12 (0.05)*	–0.02 (0.03)	0.02 (0.05)	–4.89 (2.87)	344.1	0.56
RS	0.08 (0.11)	0.02 (0.05)	–0.09 (0.1)	–0.22 (0.09)*	0.03 (0.05)	0.1 (0.09)	–7.1 (5.31)	444.8	0.15
PPVT	0.54 (0.5)	0.22 (0.21)	–0.57 (0.45)	–0.99 (0.42)*	0.18 (0.23)	0.53 (0.39)	–40.82 (23.72)	678.3	0.16
GJ20	–0.01 (0.01)	0 (0)	0.01 (0.01)	–0.01 (0)	0 (0)	0 (0)	0.03 (0.27)	–20.3	0.07
SRT	–0.09 (0.41)	–0.01 (0.17)	–0.09 (0.37)	–0.41 (0.35)	0.07 (0.19)	0.13 (0.33)	2.83 (19.58)	648.5	0.06

Note. ADHD = attention-deficit/hyperactivity disorder; DLD = cases with developmental language disorder status (DLD and ADHD + DLD groups); non-DLD = cases without developmental language disorder (TD and ADHD groups); HI = Conners Parent Rating Scale Hyperactivity/Impulsivity; EF = Conners Parent Rating Scale Executive Function; BIC = Bayesian information criterion; TNLI = Test of Narrative Language–Second Edition Narrative Language Ability Index; PC5 = Children's Communication Checklist–Second Edition Pragmatic Composite; RS = Clinical Evaluation of Language Fundamentals–Fifth Edition Recalling Sentences; PPVT = Picture Peabody Vocabulary Test–Fourth Edition; GJ20 = Grammaticality Judgment Task; SRT = Syllable Repetition Task.

**p* value < .05. ***p* value < .01. ****p* value < .001.

Table 5. Final best subset model for each psycholinguistic measure.

Psycholinguistic measure	ADHD symptoms for DLD and ADHD + DLD			ADHD symptoms for TD and ADHD			DLD status	R^2
	Effect estimate (*SE*)			Effect estimate (*SE*)			Effect estimate (*SE*)	
	Inattention	HI	EF	Inattention	HI	EF		
TNLI				−0.524 (0.154)			−35.56 (9.361)	.1638
PC5		−0.062 (0.022)		−0.121 (0.021)			−5.064 (2.166)	.5526
RS				−0.116 (0.037)			−7.521 (2.289)	.1259
PPVT				−0.402 (0.046)			−28.466 (10.429)	.0954

Note. No significant ADHD symptom predictors were identified for children's performance on the Grammaticality Judgment or Syllable Repetition Tasks. ADHD = attention-deficit/hyperactivity disorder; DLD = developmental language disorder; TD = neurotypical development; HI = Conners Parent Rating Scale Hyperactivity/Impulsivity; EF = Conners Parent Rating Scale Executive Function; TNLI = Test of Narrative Language–Second Edition Narrative Language Ability Index; PC5 = Pragmatic Composite from the Children's Communication Checklist–Second Edition; RS = Clinical Evaluation of Language Fundamentals–Fifth Edition Recalling Sentences subtest.

contributing or aggravating factor to psycholinguistic deficits.

One way to resolve this apparent contradiction would be to show that the influence of ADHD symptoms on children's psycholinguistic development was subject to threshold effects. That is, the impact of ADHD symptoms was qualitatively different at the nonclinical, borderline clinical, and clinical levels of linguistic proficiency. Our results provide some support for the contention that links between children's ADHD symptoms and their psycholinguistic abilities were different for children with and without DLD. First, our heatmap display of zero-order correlations among our experimental measures indicated significant associations among children's ADHD symptoms, and their psycholinguistic abilities were primarily limited to our participants without DLD (i.e., the TD and ADHD groups). Furthermore, while zero-order correlations among ADHD symptoms were robust and comparable for children with and without DLD, suggesting the underlying trait structure of ADHD was the same regardless of DLD status, associations among our psycholinguistic measures were not. The presence of smaller and several nonsignificant associations in our DLD and ADHD + DLD groups suggests language disorders of the sort associated with our eligibility criteria represent unexpected developmental asynchronies across language subcomponents. Limited coherence among psycholinguistic performances within our DLD and ADHD + DLD cases probably contributed to weaker associations between ADHD symptoms and their psycholinguistic abilities.

When we reassigned our four groups into two composite groups based on children's DLD status ([DLD, ADHD + DLD], [TD, ADHD]), our best subset regression analyses confirmed further that the links among ADHD symptoms and psycholinguistic abilities were different for children based on their DLD status. Inattention symptoms were primarily responsible for the links between children's ADHD symptoms and their performances on receptive vocabulary, and narratives (as predicted) and recalling sentences (not predicted), accounting for 9%–16% of the variance. However, this only applied to children without DLD. For children with DLD, the impacts of inattention symptoms on their psycholinguistic abilities were nonsignificant. Links between parental ratings of children's pragmatic skills and their ADHD symptoms provided the strongest evidence within our data of the presence of qualitatively different associations between children with and without DLD. Our model, which included DLD status as a predictor, accounted for 55% of the overall variance in parental ratings of children's pragmatic skills. For children with DLD, elevated symptoms of hyperactivity/impulsivity were responsible for the association of ADHD symptoms with lower ratings of pragmatic skills, whereas for children without DLD, inattention symptoms were primarily responsible. This outcome suggests children experience pragmatic difficulties for a variety of reasons, and the potential impact of ADHD symptoms on children's development in this area is multifaceted.

Limitations and Future Directions

Our results represent the first wave of outcomes associated with our ongoing longitudinal project. It is possible that the small, nonsignificant differences we observed between our TD and ADHD groups and between our DLD and ADHD + DLD groups will further compound over time, eventually revealing significant additive/interactive effects we were unable to detect initially. Another limitation is although the demographics of our study sample were representative of the communities and clinical populations it was drawn from, more diverse samples are needed to determine if our results carry over into other communities. Likewise, a variety of diagnostic criteria and measures have currency among researchers when they assign either DLD or ADHD status to their participants and explore potential associations among clinical symptoms. Additional research is needed to determine if our results would apply to other study samples with groups defined differently and/or with different dependent measures. Much of our data were collected from our participants while they were experiencing restrictions during the COVID-19 pandemic period requiring adjustments to standard assessment practices. Although there is some evidence to support the integrity of our assessment protocols when they are delivered via telehealth, the possibility remains that either our psycholinguistic measurements or the parental ratings we collected or the links we observed between children's ADHD symptoms and their psycholinguistic abilities might have been different outside the pandemic period. For example, recent reports indicate that wide-spread increases in students' ADHD symptoms occurred during the pandemic period (Rogers & MacLean, 2023). Indeed, within our TD and DLD groups, there were cases presenting with elevated ADHD symptoms who were not identified as having ADHD or receiving services. Additional research is needed to verify that our results hold under more conventional conditions.

Given the current state of research in the area, our regression procedures were necessarily exploratory with the aim of arriving at a useful subset of ADHD symptom predictors on variation in children's psycholinguistic abilities. Additional confirmatory analyses with independent study samples are needed to verify the models generated as well as consider other possibilities. Associations of the sort captured by our correlation and regression analyses are potentially bidirectional. In this report, we did not expand our analyses to examine the potential complimentary effects of DLD status or low psycholinguistic performance on the progression of children's inattention, hyperactivity/impulsivity, and executive function symptoms. We plan to address this gap in a separate report when our longitudinal outcomes arrive.

Other limitations should be considered when interpreting our results. For example, our research questions focused on the impacts of ADHD on the verbal abilities of children with and without DLD, and we did not consider other impacts ADHD might have had on our participants' broader development/well-being. Even though language disorders represent a risk factor for compromised functioning, there can be limited associations between the severity of children's psycholinguistic deficits, as measured by standardized tests, and the disabilities they experience in their play, interpersonal, or coping skills (McGregor et al., 2023). It is possible that the disabling contributions of co-occurring ADHD are most pronounced on these aspects of functioning for children with DLD than their underlying vocabulary, grammatical, or verbal memory development.

Conclusions and Implications

Despite their various limitations, we believe our results help advance our understanding of links between two of the most common neurodevelopmental disorders. In addition to clarifying how ADHD symptoms impact aspects of psycholinguistic development differently in the presence and absence of DLD, our results extend to some provisional implications for clinical practice. For example, the absence of robust associations between the difficulties our children with DLD were experiencing with inattention, hyperactivity/impulsivity, and executive functions and most of our psycholinguistic measures suggests interventions targeting these difficulties, without additional refinements, are not likely to yield significant improvements in children's psycholinguistic deficits. In other words, treatment of psycholinguistic deficits for children with co-occurring ADHD + DLD may not need to be differentiated from the treatment provided to children with DLD. The one possible exception to this generalization was pragmatic abilities. Our results, along with those provided by previous reports, suggest interventions directed at improving the social/pragmatic skills of children with or without ADHD should first take their DLD status into account. Additional research is needed to determine the best approaches for addressing the links between hyperactivity/impulsivity and pragmatic difficulties in children with DLD and the links between inattention and pragmatic difficulties in children with ADHD.

Data Availability Statement

The data sets generated and/or analyzed over the course of this study are not publicly available due to pending arrangements for deposit in a public repository.

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