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Literacy-supporting skills in college students with specific reading comprehension deficit and developmental language disorder

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Abstract
Specific reading comprehension deficit (S-RCD) and developmental language disorder (DLD) are both commonly occurring developmental disorders of language. The ways in which these disorders do and do not overlap during childhood are a matter of debate (Nation & Norbury, 2005). Moreover, in both populations, the challenges faced by individuals in adulthood are understudied. Here, we combined data across cohorts of college students, and classified individuals with only S-RCD ($n = 20$), only DLD ($n = 55$), and co-occurring S-RCD and DLD ($n = 13$). Individuals with good language and reading skills, who matched those with S-RCD on decoding, comprised our typical language and reading group (TD; $n = 20$). Beyond the measures used for classification, group-level differences were identified in sentence-level reading fluency, phonological processing, verbal working memory, and rapid automatized naming. We found that skill profiles differed across groups; however, we found no evidence of weaknesses beyond the core deficit in reading comprehension observed in those with only S-RCD. In contrast, when S-RCD co-occurs with DLD, weaknesses are observed in phonological processing, as well as reading fluency and verbal working memory. These findings suggest that some adults with S-RCD have co-occurring DLD as a core weakness. These findings, as well as differences between individuals with S-RCD and DLD, are further discussed.

Keywords Comprehension · Developmental language disorder · Literacy · Specific reading comprehension deficit

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Introduction

Specific reading comprehension deficit (S-RCD) is a subtype of specific learning disability. Specific learning disability affects approximately 10–20% of individuals (Aaron, Joshi, & Williams, 1999; Catts, Hogan, & Fey, 2003; Hulme & Snowling, 2011), and occurs in the absence of intellectual disability or other explanatory diagnoses (DSM-V; APA, 2013). The deficits in reading comprehension are considered "specific" in that, for an individual to have S-RCD, decoding ability must be within normal limits (Adlof & Catts, 2015; Catts, Adlof, Ellis-Weismer, 2006; Cragg & Nation, 2006). Despite a prevalence rate that is similar to developmental dyslexia, S-RCD has been studied less, and is less understood (Hulme & Snowling, 2011).

During childhood, S-RCD is associated with sub-clinical weaknesses in broader language knowledge and skills (Nation, Snowling, & Clarke, 2007). Specifically, vocabulary knowledge (Colenbrander, Kohnen, Smith-Lock, & Nickels, 2016), lexico-semantic processing (Henderson, Snowling, Clarke, 2013; Landi & Perfetti, 2007), and learning of the semantic aspects of novel words (Saha, Del Tufo, & Cutting, 2019) have been noted as particular weaknesses for children with S-RCD. Other language skills implicated in S-RCD include grammatical and syntactic processing (Catts, et al., 2006; Nation, Clarke, Marshall, Durand, 2004); however, there is some debate as to whether these deficits are independent of problems in lexico-semantic processing (Goff, Pratt, & Ong, 2005). Notably, problems with word learning, grammar, and syntactic processing are hallmark characteristics of developmental language disorder (DLD), another commonly occurring specific learning disability subtype (Bedore & Leonard, 1998; Gray, 2003; McGregor, Arbisi-Kelm, Eden, & Oleson, 2020; McGregor, Newman, Reilly, Capone, 2002; Plante, Gomez & Gerken, 2002; Fonteneau & van der Lely, 2008). Such observations have prompted queries into whether the reading comprehension deficits found in individuals with S-RCD are similar to those observed in individuals with DLD, or if we should even consider these as distinct disorders at all (see Landi & Ryherd, 2017, for review).

Despite the many proposals put forward regarding the etiologies of S-RCD and DLD, the causal mechanisms of developmental and learning disorders are not well understood (Grigorenko et al., 2020). The growing evidence from neuroimaging techniques however suggests that the behavioral manifestation of S-RCD and DLD reflects brain-based differences in both structure and function. Children with S-RCD have been found to have a global neurobiological profile that is distinct from children with dyslexia and typically developing children, including aberrant task-based activity observed in the left IFG (Cutting et al., 2013), as well as reduced gray matter in the right prefrontal cortex (Bailey, Hoeft, Aboud, & Cutting, 2016). By contrast, a leading neurocognitive framework of DLD with growing empirical support suggests that behavioral manifestations of DLD may be explained by weaknesses in frontal-striatal structures (including the left IFG) that are critical for procedural memory (Ullman & Pierpont, 2005; Ullman et al., 2020). While the evidence from the neuroimaging literature largely suggests distinct neurobiological profiles between the two disorders, the left inferior frontal regions in both populations appear to differ from that of children with typical language. As there are relatively few comparisons between S-RCD and DLD in general, it remains unknown if the linguistic skills associated with the left IFG are similar in individuals with S-RCD and DLD.

In particular, there are various language-related skills that support reading comprehension that are implicated by the left inferior frontal lobe. Left inferior frontal regions are critical for verbal working memory, which is an important predictor of reading comprehension ability throughout development (Cain, Oakhill, & Bryant, 2004; Adams, Bourke, & Willis, 1999). Other component skills of reading comprehension that may be compromised by inferior frontal involvement includes phonological processing, rapid naming, and reading fluency (Klauda & Guthrie, 2008; Misra, Katzir, Wolf & Poldrack, 2004; Norton & Wolf, 2012; Poldrack et al., 1999; Siegel, 1993; Shaywitz et al., 2004). In other words, these are all skills that support reading comprehension that are potentially compromised in those with S-RCD and DLD. If those with S-RCD and DLD have a similar pattern of linguistic weaknesses that underlie reading comprehension performance, then there is a potential for unified approach to reading remediation across populations. If, however, the reading comprehension deficits in these populations arise from different strengths and weaknesses in component skills, this situation would call for a more tailored approach to intervention.

To our knowledge, there has not yet been a direct, empirical comparison of these two disorders. It should be noted that there are likely nonlinguistic skills that support reading comprehension (e.g., executive function) that are also affected in both of these populations. As a preliminary investigation into the adult behavioral manifestations of these disorders, however, we focused on the language-related skills that may elucidate specific intervention points within the scope of practice for reading specialists and speech language pathologists and/or lend themselves to accommodations in higher-education classrooms (as in Del Tufo & Earle, 2020).

In this study, we compared the profiles of language-related skills thought to be important for reading comprehension, between adults with S-RCD, DLD, those with both S-RCD and DLD, and adults with typical language skills (TD). Children with S-RCD (Nation and Snowling, 1997; 1998; Cain et al., 2001) and DLD (Potocki et al., 2013; Dawes et al., 2018) both struggle with oral language skills, specifically listening comprehension and morphosyntax (Nation et al., 2004), with the latter considered a hallmark of DLD (Leonard et al., 1997; Rice, 2016). We reasoned that if problems in reading comprehension in adults with S-RCD arise from weaknesses in oral language that is similar to that of adults with DLD (Nation & Norbury, 2005), we may observe similarities between S-RCD and DLD in the other skills that support reading comprehension. However, it is also possible that problems in reading comprehension in adults with S-RCD arise from comprehension-supporting skills that are separate and unique from those with DLD. If this is the case, we would expect to see a dissociation in skill profiles. Pinpointing the nature of the reading comprehension deficits observed in these disorders is a first step toward providing more tailored support for struggling readers throughout their educations.

Methods

Participants

To address these research questions, we analyzed data collected at the University of Connecticut (UConn) and the University of Delaware (UD). Datasets were collected under studies advertising for participants within the age range of 18–35, with normal hearing and normal-to-corrected vision, with no history of neurological or socio-emotional disorders. Recruitment materials for both studies included language welcoming individuals with a history of language and reading difficulties, to collect samples with greater than normal representation by individuals with language-based disabilities. The total sample of participants who completed the study included 352 participants at UConn, and 207 participants at UD. In the current paper, we report data from the subset of participants from this sample who met criteria for DLDand/or S-RCD. We selected a subset of typically developing (TD) readers who most closely matched to the S-RCD sample on decoding ability as in Nation et al. (2007) and Saha, Del Tufo, and Cutting (2019). For the present paper, we removed data from individuals obtaining nonverbal intelligence quotients below normal limits (scores greater than 1.5 standard deviations below the mean), and individuals who were not monolingual speakers of English. This included a total sample of 108 participants (mean age 20.54 [1.95]; 27 M, 81 F, 1 declined to answer; [4 Hispanic, 104 not Hispanic, 85 White, 12 Black, 1 Asian, 10 Multiracial]).

Procedures

Prior to participation, all participants provided informed consent in accordance with procedures approved by the UConn and UD Institutional Review Boards. Participants completed a questionnaire regarding demographic information, language background, and language and reading development. Participants then completed 2 h of standardized and experimental assessments (see description below). All testing was conducted by one of the two authors, or trained laboratory personnel. Raw score sheets were scored by two independent laboratory personnel, and inter-scorer agreement was above 95% at both sites. All discrepancies in scoring were resolved by one of the two authors.

Assessments for group classification

Standardized assessments included measures of nonverbal cognition (Wechsler, 1999, 2011), timed and untimed real- and pseudo-word-level reading (Woodcock, 2011; Torgeson, Rashotte, & Wagner, 1999; Torgesen, Wagner, Rashotte, 2012), and reading comprehension (Woodcock, 2011). All assessments are described below. For all assessments, we report normed ages and reliability metrics.

Nonverbal cognition Nonverbal cognitive ability is a composite score from the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) and Wechsler Abbreviated Scale of Intelligence-II (WASI-II; Wechsler, 2011). It is comprised of the “Block Design” and “Matrix Reasoning” subtests which together yield a “Performance Intelligence” score. During the Block Design subtest, participants were asked to arrange colored blocks to match the design in the stimulus book as quickly as possible. During the Matrix Reasoning subtest, participants were asked to view an incomplete series or a design matrix and select the response option that best completes the pattern. Both versions of the WASI are normed for ages 6 through 89. The reliability of the WASI nonverbal cognitive ability composite is excellent; the test-retest reliability correlation was 0.94. The WASI-II was normed for age 6 through 90. Test-retest reliability of the WASI-II for adults (17–90) was good-to-excellent, ranging from 0.83 to 0.94 for the subtests, and excellent for the composite scores (0.90 to 0.96).

Real- and pseudo-word reading Untimed real- and pseudo-word reading scores were obtained from subtests of the Woodcock Reading Mastery Test, Third Edition (WRMT-III; Woodcock, 2011). This included the “Word Identification” and “Word Attack” subtests of the WRMT-III. During the Word Identification subtest, participants were asked to name real words of increasing difficulty. During the Word Attack subtest, participants were asked to read pseudo-words (also increasing in difficulty) that follow the alphabetic and syllabic rules of American English. The split-half reliability of the two subtests was high (Word Identification = 0.92 and Word Attack = 0.88). Timed real- and pseudo-word reading scores were obtained from subtests of the Test of Word Reading Efficiency (TOWRE; Torgesen, et al., 1999) and the Test of Word Reading Efficiency-2 (TOWRE-2; Torgesen, et al., 2012). This included the "Sight Word Efficiency" and "Phonemic Decoding Efficiency" subtests of the TOWRE and TOWRE-2. During the Sight Word Efficiency and Phonemic Decoding Efficiency subtests, participants were given 45 seconds (s) to read as many real words and pseudo-words, respectively, as possible. The TOWRE and TOWRE-2 are both normed for individuals from 6 through 24 years old. Both versions of this assessment had good-to-excellent reliability. TOWRE test-retest reliability correlations ranged from 0.82 to 0.97. TOWRE-2 test-retest reliability correlations ranged from 0.89 to 0.93.

Reading comprehension The reading comprehension score was obtained from the "Passage Comprehension" subtest of the WRMT-III. The Passage Comprehension subtest is frequently used to assess reading comprehension abilities in adults. During the Passage Comprehension subtest, participants were asked to read a passage and provide the missing word. The Passage Comprehension subtest uses a modified cloze format, and is normed for ages 4–79 years. This subtest has a split-half reliability coefficient of mean .86.

Experimental assessments Experimental assessments included a 15-word spelling test and a modified token test as described by Fidler, Plante, and Vance (2011). In the 15-word spelling test, the participant is instructed to write down the target word as a trained experimenter reads the word once, then again in a sentence, then repeats the target word once more. The target words in the list are *realtor, trailer, tiresome, miracle, conscience, bouquet, carriage, predominantly, accommodation, immortalize, necessitate, cupboard, peculiar, faucet,* and *analysis*. Raw scores are calculated as a sum total of whole words spelled correctly. In the modified token test, participants are seated in front of a set of brightly colored shapes varying in size. They are instructed to follow the directions that are presented to them by a voice on the computer (e.g., "Touch the large red circle and the small blue square"). There are 44 items, progressing in difficulty over the course of the tasks. Raw scores are calculated as a sum total of items performed correctly.

Assessments for group comparison of skill profiles

Assessments included in the literacy-supporting skill profiles included measures of reading fluency (Woodcock, Mather, McGrew, 2001), verbal working memory (Wechsler, 2014), phonological awareness, and phonological processing (Wagner, Torgesen, & Rashotte, 1999), as well as rapid automatized naming (Wolf & Denckla, 2005).

Reading fluency The reading fluency score was from the "Sentence Reading Fluency" subtest of the Woodcock-Johnson Tests of Achievement, Third Edition (WJ-III; Woodcock, Mather & McGrew, 2001). Participants were asked to read grammatically correct sentences and make a semantic (yes or no) judgment regarding each sentence. Participants had 3-min to read and respond to as many questions as possible. The WJ-III is normed for ages 2 through 90+, though test administration is recommended for ages 5 and up. Test reliability is reported to be at least .80.

Verbal working memory Scores for verbal working memory were obtained from the Wechsler Adult Intelligence Scale (WAIS-IV; Wechsler, 2014). Subtests assessing verbal working memory included "Digit Span Forward," "Digit Span Backward," and "Digit Span Sequencing." During the Digit Span Forward subtest, participants were asked to listen then repeat back an increasing series of numbers in the same order. During the Digit Span Backward subtest, participants were asked to listen to an increasing series of numbers and then repeat back those numbers in the reverse order. During Digit Span Sequencing subtest, participants were asked to listen to a series of numbers and letters increasing with each trial. After each trial, participants were asked to repeat back those numbers and letters in numerical and alphabetical order beginning with the lowest number and the first letter of the alphabet (e.g., 1, 3, 8, A, G). The WAIS-IV is normed for ages 16 through 90. Cronbach's alpha for these subtests ranged from acceptable to very good, Digit Span Forward = 0.84, Digit Span Backwards 0.78, Digit Span Sequencing = 0.89.

Phonological awareness and processing Phonological processing performance was measured using the "Elision," "Blending," and "Nonword Repetition" subtests of the Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, & Rashotte, 1999), and CTOPP-2 (Wagner, et al., 2013). During the Elision subtest, participants were asked to repeat back a word and then to repeat the same word with a phoneme segment removed to produce a new word. During the Blending words subtest, participants were asked to combine phoneme segments to create a word. During the Nonword Repetition subtest, participants were asked to repeat back a made-up word that follows the alphabetic and syllabic rules of American English. The CTOPP is normed for individuals from 5 through 24, with good reliability (CTOPP: .68–.87 for all subtests; CTOPP-II: Elision, $R = .93$, Blending Words, $R = .79$; Nonword Repetition, $R = .99$).

Rapid automatized naming and sequencing Rapid automatized naming and sequencing were assessed via the Rapid Automatized Naming and Rapid Alternating Stimulus Test (RAN/RAS; Wolf & Denckla, 2005). Rapid automatized naming was assessed using the "Number Naming" and "Letter Naming" subtests. Rapid automatized sequencing was assessed using the "2-set" subtest. During the Number Naming subtest, participants were asked to name a series of numerically represented numbers as quickly as possible. During the Letter Naming subtest, participants were asked to name a series of alphabetic letters as quickly as possible. During the 2-set subtest, participants were asked to name a series of numerically represented numbers and alphabetic letters as quickly as possible. The raw score of each subtest indicates the amount of time needed to name all of the characters presented. The RAN/RAS is normed for individuals from 5 through 18 years and 11 months old. Test-retest reliability was 0.65 for RAN and 0.81 for RAS.

Classification of S-RCD and DLD status

While data collection is ongoing for the UD study, the data presented in this manuscript includes all participants in the two datasets that met the classification criteria for S-RCD only, DLD only, or as having both S-RCD and DLD, as of 2019. This resulted in samples of 20 individuals with S-RCD, 55 with DLD, and 13 with both S-RCD and DLD. Additionally, we selected a subset of 20 individuals with good language and reading ability, matched to our S-RCD participants on age and decoding ability (as measured by the Word Attack subtest of the WRMT-III and the Phonemic Decoding Efficiency subtest of the TOWRE/TOWRE-II), to comprise our comparison group of TD readers. A descriptive summary of raw scores obtained on the measures used for classification is provided in Table 1.

Means and standard deviations (in parentheses) are expressed for raw scores. Under 'Site', UConn is entered as '1', and UD is entered as '2.' Nonverbal cognition used subtests of the Weschler Abbreviated Scale of Intelligence (WASI; Weschler, 1999) at UConn and WASI-II (Weschler, 2011) at UD. Untimed reading was assessed using subtests of the WRMT-III (Woodcock, 2011), and timed reading was assessed using TOWRE at UConn, and TOWRE-2 at UD (Torgesen, et al., 1999, 2012). The index for identifying developmental language disorder was calculated from the modified token test and spelling tests described in Fidler, Plante, and Vance (2013). Scores are presented by collection site for Nonverbal cognition and timed word reading, which were assessed using different versions of the same test by site.

S-RCD Given the complex nature of reading comprehension, it is perhaps unsurprising that several different reading comprehension measures have been used as part of the classification index of S-RCD (e.g., Catts et al., 2003, 2006; Shankweiler et al., 1999; Leach, Scarborough & Rescorla, 2003). While a number of childhood studies have shown that reading comprehension assessments vary in the skills that they access (e.g., Cutting & Scarborough, 2006), this difference has been shown to diminish with increased age (Keenan, Betjemann, & Olson, 2008). Therefore, in the current study, an assessment of passage comprehension was chosen based on the criteria of adult standardization. To be classified as having S-RCD, individuals obtained a score falling below the 25th percentile on the Passage Comprehension subtest, in addition to word-level reading ability above the 35th percentile on the Word Identification and

Table 1 Descriptive summary of performance on skills used for participant classification

Skill area	Site	DLD $N = 55$	S-RCD $N = 20$	S-RCD + DLD $N = 13$	TD $N = 20$
Nonverbal cognition					
Block Design	1	48.78 (14.61)	56.5 (11.26)	33.6 (12.50)	47.17 (6.62)
	2	42.89 (11.13)	39.5 (8.27)	39.75 (9.22)	50.57 (9.30)
Matrix Reasoning	1	27.25 (3.09)	27.67 (2.34)	27.8 (4.09)	25.33 (4.72)
	2	21.15 (3.89)	21 (3.57)	28.13 (16.97)	21.71 (3.34)
Untimed reading					
Word Identification		40.05 (2.36)	41.35 (1.90)	39.69 (2.53)	42.7 (1.89)
Word Attack		21.45 (3.10)	22.35 (2.48)	22 (3.14)	23.3 (1.75)
Passage Comprehension		32.31 (2.64)	27.35 (1.04)	26.77 (1.17)	33.4 (2.08)
Timed word reading					
Sight Word Efficiency	1	91.22 (6.97)	94.33 (7.45)	99.2 (3.19)	97.5 (4.45)
	2	89.32 (8.58)	93.36 (8.96)	94.25 (4.74)	94.21 (7.97)
Phonemic Decoding	1	48.19 (8.09)	53.5 (7.50)	59.8 (2.68)	54.33 (4.27)
	2	52.42 (6.15)	59.29 (4.23)	56 (6.26)	58.14 (5.22)
Fidler, Plante, Vance (2011)					
Modified Token Test		34.44 (5.08)	38.6 (2.96)	32.77 (7.22)	39.05 (3.71)
Spelling		7.51 (2.37)	11.15 (1.81)	7.46 (2.47)	12.25 (2.05)
Index		.49 (.44)	−.87 (.51)	.70 (.83)	−1.17 (.54)

Word Attack subtests. These procedures are consistent with the classification of S-RCD described by Cain and Oakhill (2006).

DLD A methodological hurdle in conducting research on adults with DLD is that many standardized assessments by which DLD is diagnosed do not provide normative information in adults. To address this need, Fidler, Plante, and Vance (2011) devised an experimental method for the identification of adults with DLD. According to this method, the spelling test and the modified token test are administered to the examinee (described above under Experimental Assessments) and the raw scores are entered into the equation $y = 6.5727 + \text{spelling} * -.2184 + \text{token} * -.1298$. Resultant values, when positive, indicate the presence of a language disorder. Therefore, to be classified as having DLD, individuals obtained raw values on the modified token test and spelling test such that, when entered into the above equation, yielded a positive value. Our previous work has shown that DLD can co-occur with developmental dyslexia in college-age students (Del Tufo & Earle, 2020). Individuals with DLD who had co-occurring developmental dyslexia were excluded from the current study to focus only on the relationship between DLD and S-RCD. The exclusionary criteria for co-occurring dyslexia (specifically, obtaining a standard score of 85 or less on two or more of the timed/untimed word-level reading subtests) were consistent with previous work (e.g., Christodoulou et al., 2014; Cutting et al., 2013).

Analyses and results

All analyses were conducted using R (version 3.4.2, https://www.r-project.org). The R package psych (version 1.9.12, http://personality-project.org/r/psych) was used for descriptive data analyses. The R packages car (3.0, https://cran.r-project.org/web/packages/car/), MASS (7.3-51.3, https://cran.project.org/web/packages/MASS/), mvoutlier (2.0.9, https://cran.r-project.org/web/packages/mvoutlier/), mvnormtest (0.1-9, https://cran.r-project.org/web/packages/mvnormtest/), pastecs (1.3.21, https://cran.r-project.org/web/packages/pastecs/), reshape2 (1.4.3, https://cran.r-project.org/web/packages/reshape2/), WRS2 (1.0-0, https://cran.r-project.org/web/packages/WRS2/), and heplots (1.3-5, http://datavis.ca/R/index.php#heplots) were used to support and conduct the MANOVA analyses. The R packages ggplot 2 (3.2.1, https://ggplot2.tidyverse.org), tidyr (0.8.3, https://tidyr.tidyverse.org), and plyr (1.8.4, http://had.co.nz/plyr/) were used to restructure data and create figures. The code used for data analysis and a spreadsheet of the data have been made publicly available (https://github.com/fsearle/S-RCD_DLD_AD).

Preliminary analysis

See descriptive summary of raw scores in Table 2. Literacy-supporting skills, beyond those used for participant classification, were re-scaled to ensure that the data was treated on commensurate scales across measures in our statistical models. Data was scaled using the Proximity-to-Maximum Scaling method (POMS; Moeller, 2015). Of our four dependent literacy support skill assessments, only the CTOPP version differed across data collection sites. An independent sample t test was run between each of the CTOPP subtests by site (and ergo version). Only the "Nonword Repetition" subtest (UConn: M = 13.08, SD = 2.67 & UD:

Table 2 Descriptive summary of performance on literacy-supporting skills

Skill area	Site	DLD $N = 55$	S-RCD $N = 20$	S-RCD + DLD $N = 13$	TD $N = 20$
Phonological processing					
Elision	1	16.84 (2.97)	17.67 (1.03)	15.6 (4.88)	18.83 (.45)
	2	30.05 (2.07)	30.69 (1.49)	27.33 (4.32)	30.64 (1.22)
Blending	1	16.6 (2.19)	17.2 (2.77)	16.8 (2.05)	16.67 (3.44)
	2	26.05 (3.12)	28.15 (2.76)	26.67 (3.72)	27.93 (3.22)
Nonword repetition	1	12.87 (2.29)	12.67 (4.13)	13.4 (.55)	14.33 (4.44)
	2	17.84 (2.95)	19.31 (3.43)	19.17 (.98)	18.64 (1.95)
Rapid automatized naming					
Numbers		19.11 (4.40)	17.5 (3.03)	16.15 (3.44)	18.1 (4.24)
Letters		18.87 (3.86)	16.95 (2.78)	15.85 (3.02)	17.4 (3.63)
2-set		20.64 (3.89)	18.45 (3.41)	18.85 (4.71)	19.15 (3.65)
Verbal working memory					
Forwards		9.89 (2.58)	11.35 (2.35)	10.62 (1.50)	11.35 (2.41)
Backwards		7.48 (1.41)	9.21 (1.62)	8.23 (1.30)	9.3 (2.60)
Sequencing		8.23 (1.51)	8.8 (1.15)	8.62 (1.61)	8.95 (1.47)
Reading fluency					
Sentence reading fluency		83.02 (13.69)	92.17 (5.84)	80.92 (9.46)	88.85 (8.64)

M = 18.58, SD = 2.70) was found to differ ($t^{(96)} = 4.36$, $p < .001$), and was thus removed from further literacy-supporting skills analyses. We also found "Digit Span Sequencing" performances to differ by site. To test differences between groups rather than by site, we took the following steps. First, we removed Digit Span Sequencing as an outcome variable from our omnibus MANOVA. Additionally, we entered site as a covariate to account for smaller, insignificant variance attributable to testing site. A *post hoc* power analysis can be found in the supplementary methods.

Scores are expressed in means and standard deviations (in parentheses) of the raw scores obtained on the respective assessments by group. Phonological processing was assessed using subtests of the CTOPP/CTOPP-II (Wagner, et al., 1999, 2013), and was expressed in the number of whole items correct. Rapid Automatized Naming was assessed using subtests of the RAN/RAS (Wolf & Denckla, 2005), and raw scores are expressed in seconds. Verbal working memory was assessed using subtests of the WAIS-IV (Wechsler, 2014), and is expressed in the number of items correct. Reading fluency was assessed using a subtest of the WJ-III (Woodcock, Mather, & McGrew, 2001), and is expressed as number of items correct. Means are provided by site for phonological processing, which was assessed using different versions of the same test across sites.

MANOVA assumptions

The assumptions of the MANOVA were assessed. We found that dependent variables (collectively) were not normally distributed (violated multivariate normality) within each group DLD (*Shapiro-Wilk* = 0.74, $p < .001$), S-RCD (*Shapiro-Wilk* = 0.52, $p < .001$), S-RCD and DLD (*Shapiro-Wilk* = 0.61, $p < .001$), and TD (*Shapiro-Wilk* = 0.83, $p < .01$). Visual examination revealed that multivariate normality was not violated due to outliers, but rather skewed data, not unexpectedly given the populations of interest. Comparisons of the variance-covariance matrices for each group revealed that dependent variable variances by group are roughly equal (homogeneity of variance) and that the correlation between any two dependent variables is similar in all groups. Specifically, Box's Test of Equality of Covariance Matrices was significant (*Box's M* = 252.0, $p < .01$), but is sensitive to departures from normality. As an additional check of the diagonals of the covariance matrices, we ran Levene's tests. Levene's test revealed that only the Elision subtest of the CTOPP was significant *Levene's* = 2.28, $p < .05$. The removal of the Elision subtest resulted in a *Box's M* = 128.33, $p = .10$, indicating that only for the Elision subtest are variances across samples unequal.

MANOVA results

First, to determine if any of our measures of literacy-supporting measures differed based on group membership, we conducted an initial Multivariate Analysis of Variance Analysis (MANOVA) on the scaled Elision, Blending, RAN (Numbers, Letters, and 2-set), Digit Span (Forwards and Backwards), and Reading Fluency scores, with Group as the independent variable, and site (UConn vs. UD) as a covariate. The MANOVA was statistically significant for group category membership ($F^{(24, 249)} = 2.22$, $p < .01$, *Pillai's Trace* = .528), a result that remained when the Elision subtest was not included ($F^{(21, 252)} = 2.06$, $p < .01$, *Pillai's Trace* = .440). There was no effect of data collection site. We tested the source of this group effect by running separate univariate ANOVAs on each of our literacy measures, with group membership as the independent variable. This revealed significant effects of group for Elision ($F^{(3,88)} = 4.13$, $p < .01$, Cohen's $d = .36$), RAN Letters ($F^{(3,88)} = 3.22$, $p < .05$, Cohen's $d = .55$), Digit Span Forward ($F^{(3,88)} = 3.15$, $p < .05$, Cohen's $d = .58$), Digit Span Backward ($F^{(3,88)} = 7.16$, $p < .001$, Cohen's $d = 1.20$), and Reading Fluency ($F^{(3,88)} = 4.37$, $p < .01$, Cohen's $d = .83$). RAN 2-Set was marginally significant for group ($F^{(3,88)} = 2.33$, $p = .08$, Cohen's $d = .60$). No significant effects were found for Blending and RAN Numbers. See Fig. 1 for a graphical summary of these results.

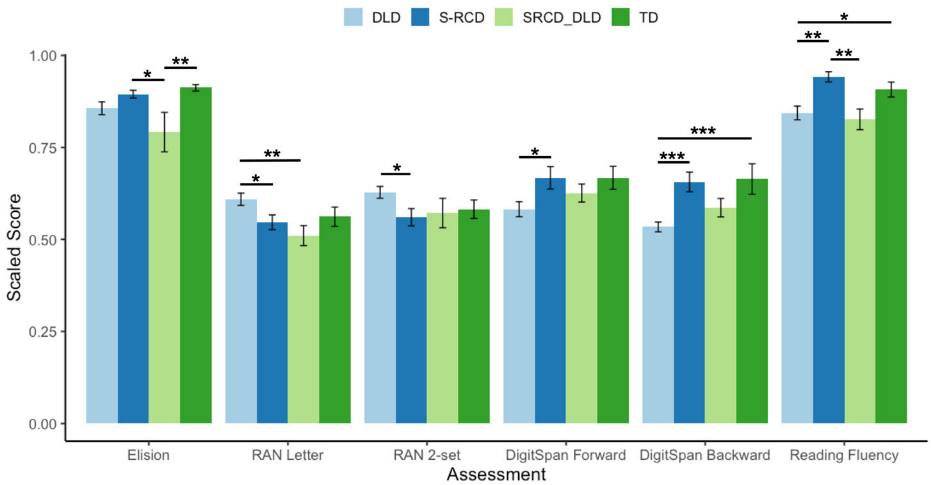

Fig. 1 Graphical summary of literacy-supporting skill profiles across groups. Performance scores (*y*-axis) on the Elision (CTOPP/CTOPP-2; Wagner et al., 1999, 2013), RAN Letter and 2-set (RAS/RAS; Wolf & Denckla, 2005), Digit Span Forward and Backward (WAIS-IV; Weshler, 2014), and Reading Fluency (WJ-III; Woodcock et al., 2001) scores are expressed in proximity-to-maximum scaled (Moeller, 2015) values. Error bars denote standard error of the mean. Single asterisk denotes statistical significance at .05, Two asterisks at .01, and three asterisks at .001 levels

To determine which group membership differences drove our findings, we ran separate linear regressions predicting each significant literacy-supporting measure. For Elision, group effects were driven by significantly lower performance by those with both S-RCD & DLD ($B = -0.12$, SE = .04, $t = 2.93$, $p < .01$) and albeit marginally significant, the lower performance of those with DLD ($B = -0.06$, SE = .03, $t = 1.91$, $p = .059$) as compared to TD. As well as, group effects driven by the significantly higher performance of those with S-RCD ($B = 0.10$, SE = .04, $t = 2.50$, $p < .05$) and the marginally significantly higher performance of those with DLD ($B = 0.07$, SE = .04, $t = 1.79$, $p = .08$) as compared to those with both S-RCD & DLD. In sum, those with S-RCD & DLD performed worse than those with S-RCD or DLD alone on the Elision measure of phonological processing.

For Digit Span Forward, group effects were driven by the significantly lower performance of those with DLD compared to those with S-RCD ($B = -0.09$, SE = .04, $t = 2.32$, $p < .05$). Similarly, for Digit Span Backward, group effects were driven by the significantly lower performance of those with DLD compared to those with S-RCD ($B = -0.12$, SE = .03, $t = 3.77$, $p < .001$). They were, however, also driven by the significantly lower performance of those with DLD and as compared to TD ($B = -0.13$, SE = .03, $t = 4.08$, $p < .001$), as well as the marginally significant lower performance of those with S-RCD & DLD as compared to TD ($B = -0.08$, SE = .04, $t = 1.79$, $p = .08$). Thus, those with DLD performed worse than those with S-RCD and TD on two measures of verbal working memory.

For RAN Letter, group effects were driven by significantly longer duration needed by those with DLD compared to those with S-RCD ($B = 0.06$, SE = .03, $t = 2.10$, $p < .05$) and those with S-RCD & DLD ($B = 0.10$, SE = .04, $t = 2.81$, $p < .01$). For RAN 2-set which was marginally significant across group, we found the effect was driven by the significantly longer duration needed for those with DLD compared to those with S-RCD ($B = 0.07$, SE = .03, $t = 2.20$, $p < .05$). Thus, those with DLD performed slower than those with S-RCD on RAN Letter and RAN 2-set, and slower than those with S-RCD & DLD on RAN Letter.

For sentence-level Reading Fluency, group effects were driven by the significantly lower performance of those with DLD compared to those with S-RCD ($B = -0.10$, SE = .03, $t = 3.19$, $p < .01$) and as compared to TD ($B = -0.06$, SE = .03, $t = 2.15$, $p < .05$). Moreover, those with S-RCD performed significantly better than those with S-RCD & DLD ($B = 0.12$, SE = .04, $t = 2.18$, $p < .01$), and those with TD performed better than those with S-RCD & DLD ($B = 0.08$, SE = .04, $t = 1.98$, $p = .051$). As such, individuals with S-RCD performed better than individuals with DLD, and those with S-RCD & DLD on sentence-level reading fluency.

Discussion

Summary and interpretation

The purpose of the current study was to examine the language-related skills that support literacy. Specifically, we focused on comparing performance on comprehension-supporting skills in individuals with S-RCD and DLD, against individuals with TD and both S-RCD and DLD, and finally, we directly compare the two subtypes of specific learning disabilities. Largely, our findings indicate a dissociation in skill profiles that suggests that comprehension issues in subtypes of specific learning disabilities may occur due to differences in supporting skills.

When we examined differences between individuals with TD and those with S-RCD, no differences beyond those used for classification were found. This is consistent with work on children with S-RCD, who demonstrate normal phonological processing (e.g., Stanovich, 2000), rapid automatized naming (Tong et al., 2011), and verbal working memory (Cain & Oakhill, 2006; De Beni & Palladino et al., 2000; Georgiou & Das, 2016; Stothard & Hulme, 1992). This may suggest that problems in reading comprehension in adults with S-RCD do not stem from linguistic skills that support reading comprehension. Taken together with previous literature on the neural profiles of children with S-RCD (e.g., Cutting et al., 2013), that many of the linguistic skills that support reading appears to be intact may suggest that problems with reading in the majority of the S-RCD population stems from domain-general abilities (e.g., executive function) that assist with reading comprehension.

When we examined differences between individuals with TD and those with DLD, we found that those with DLD performed worse on the verbal working memory subtest, digit span backward, and reading fluency. Additionally, those with only DLD performed marginally worse on phonological processing than their TD peers. While there are fewer descriptions of the phonological processing of adults with DLD, this finding is consistent with prior literature that has identified phonological processing as a weakness for children with DLD (Bishop & Adams, 1990). This may suggest that when individuals with DLD experience problems with reading comprehension, these problems may be secondary to the linguistic symptoms commonly observed in DLD that support reading comprehension.

When we examined differences between individuals with TD and those with S-RCD & DLD, we found that individuals with co-occurring S-RCD and DLD performed significantly worse on phonological processing, and marginally worse on digit span backward and reading fluency. Taken together, we see that when individuals have co-occurring S-RCD and DLD, they present with a skill profile that includes issues beyond those accounted for by S-RCD alone. Specifically, in addition to the core deficits associated S-RCD, those with both conditions also exhibit weaknesses common to individuals with DLD (poor phonological processing, marginally poor verbal working memory, and reading fluency; Conti-Ramsden et al., 2001; Miller & Wagstaff, 2011), which are generally (including in the present paper) found to be relatively intact for individuals with S-RCD alone (Cutting et al., 2009; Nation et al., 2004). The results of the current manuscript, in adults with S-RCD and DLD, are consistent with the childhood S-RCD literature, which reports a minority of children with S-RCD performing poorly enough on measures of language skills to have an additional classification of DLD (Bishop, 1997). In other words, our findings suggest that some individuals with S-RCD have co-occurring DLD as a core weakness, one that likely contributes to poorer reading comprehension. An alternative interpretation may be that those with both S-RCD and DLD are members of a “broad spectrum” disorder, in which language comprehension deficits are present in both spoken and written modalities (although see below on RAN performance in those with S-RCD and DLD as compared to DLD alone).

As individuals with specific reading comprehension deficit have normal word recognition abilities, it has often been predicted that their underlying problems stem from language comprehension. This view is consistent with the simple view of reading, in which reading comprehension is composed of two parts: word recognition and language comprehension (Gough & Tunmer, 1986; Hoover & Gough, 1990). Across studies, evidence indicates that children with S-RCD struggle with oral language skills, including listening comprehension (Nation and Snowling, 1997;1998; Cain et al., 2001) and morphosyntax (Nation et al., 2004). The results of the current manuscript indicate that individuals with S-RCD who have co-occurring DLD suffer from issues with reading comprehension that may stem, in part, from comprehension-supporting skills that are known to be problematic in DLD. These findings may furthermore indicate that those presenting with both S-RCD and DLD may be distinct in etiology from those with S-RCD alone.

As the challenges faced by individuals with S-RCD and DLD are understudied, we also examined assessment performance differences between the two subgroups directly. Individuals with DLD had significantly more difficulty with verbal working memory, reading fluency, and rapid automatized naming and switching than individuals with S-RCD. These findings are consistent with previous observations that individuals with DLD have problems with verbal working memory and reading fluency (Miller & Wagstaff, 2011). While the finding that those with DLD perform more slowly on RAN is also consistent with the previous literature, here we found that those with co-occurring S-RCD performed faster on this task than those with DLD alone. Similarly, none of the skills assessed here provided evidence that individuals with DLD performed better than those with S-RCD. This may indicate that the nature of the language deficit in those with S-RCD and DLD do not stem from problems with processing speed (as has been argued is the case for those with DLD alone, Leonard et al., 2007). This may also point to a compensation strategy available to those with co-occurring S-RCD and DLD who achieve entry into college. Please see our discussion on the study limitations below.

Limitations

There are several important limitations and decision points to acknowledge in the current study. We chose to study two commonly occurring specific learning disabilities, S-RCD and DLD, in adulthood. We did this for two reasons. First, we wanted to ensure that the skill profiles did not reflect large-scale differences in developmental maturation. Second, we know comparatively little about the sequelae of these conditions in adulthood. An alternate option would have been to investigate the relationship between these specific learning disabilities longitudinally during development or at specific developmental time points. Additionally, the adults recruited in the current study were primarily college-attending adults, likely representing the better performing end of the S-RCD and DLD spectra. The assessment battery itself may also be considered a limitation. The study was based on extant data that contained adequate sample sizes of individuals with S-RCD and DLD, as well as broad measures of comprehension-supporting skills, and a single measure of comprehension. In addition to a clear need to determine if reading comprehension tests vary in the skills they assess during adulthood, future studies that investigate the skill profiles of S-RCD and DLD may include broader measures of language skills, such as those supporting spoken language or listening comprehension.

Conclusions and implications

In summary, we found that skills that support reading comprehension differed between adults with different specific learning disability subtypes and those with typical language and reading. In this preliminary investigation, we found no evidence of weaknesses in the specific literacy-supporting linguistic skills examined here in adults with S-RCD beyond their core deficit in comprehension. The exception to this was that in adults with S-RCD and with co-occurring DLD. In this group, skills known to be problematic in childhood DLD were observed to be weaknesses. Therefore, for a small subset of individuals with S-RCD, a co-occurrence of DLD might be considered an additional core weakness.

The current work may have potentially important clinical implications. For example, reading comprehension in those with both S-RCD and DLD may benefit from intervention in areas commonly associated with DLD that is integrated with those targeting reading comprehension alone. Furthermore, those with S-RCD alone that do not appear to have linguistic weaknesses in literacy-supporting skills prompt future queries into the role of nonlinguistic deficits, such as executive function, in comprehension deficits in S-RCD. More broadly, our work joins a small, but emerging literature that suggests that deficits associated with specific learning disabilities in childhood persist into adulthood. Understanding the weakness associated with specific learning disabilities in adulthood is a first step toward providing adequate accommodations to allow these individuals the opportunity to succeed academically.

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Data availability A subset of the key data presented in this manuscript has been made publically available in .csv format (https://github.com/fsearle/S-RCD_DLD_AD). To protect confidentiality of our participants, we have removed age, gender, and collection site.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

Ethics approval All study procedures were approved by Institutional Review Boards (IRBs) at the University of Connecticut and the University of Delaware.

Consent to participate All participants provided informed consent prior to participation in this study according to IRB-approved procedures.

Consent for publication All authors have agreed to publication of the manuscript in its present form.

Code availability The code used for statistical analyses has been made publicly available (https://github.com/fsearle/S-RCD_DLD_AD).

References

Aaron, P. G., Joshi, M., & Williams, K. A. (1999). Not all reading disabilities are alike. *Journal of Learning Disabilities, 32*(2), 120–137.

Adams, A. M., Bourke, L., & Willis, C. (1999). Working memory and spoken language comprehension in young children. *International Journal of Psychology, 34*(5–6), 364–373.

Adlof, S. M., & Catts, H. W. (2015). Morphosyntax in poor comprehenders. *Reading and Writing, 28*(7), 1051–1070.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington: American Psychiatric Association.

Bailey, S., Hoeft, F., Aboud, K., & Cutting, L. (2016). Anomalous gray matter patterns in specific reading comprehension deficit are independent of dyslexia. *Annals of Dyslexia, 66*(3), 256–274.

Bedore, L. M., & Leonard, L. B. (1998). Specific language impairment and grammatical morphology: a discriminant function analysis. *Journal of Speech, Language, and Hearing Research, 41*(5), 1185–1192.

Bishop, D. V. (1997). Cognitive neuropsychology and developmental disorders: Uncomfortable bedfellows. *The Quarterly Journal of Experimental Psychology, Section A, 50*(4), 899–923.

Bishop, D. V., & Adams, C. (1990). A prospective study of the relationship between specific language impairment, phonological disorders and reading retardation. *Journal of Child Psychology and Psychiatry, 31*(7), 1027–1050.

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. *British Journal of Educational Psychology, 76*(4), 683–696.

Cain, K., Oakhill, J., & Bryant, P. (2004). Children's reading comprehension ability: concurrent prediction by working memory, verbal ability, and component skills. *Journal of Educational Psychology, 96*(1), 31–42.

Cain, K., Oakhill, J. V., Barnes, M. A., & Bryant, P. E. (2001). Comprehension skill, inference-making ability, and their relation to knowledge. *Memory and Cognition, 29*, 850–859.

Catts, H. W., Adlof, S. M., & Weismer, S. E. (2006). Language deficits in poor comprehenders: a case for the simple view of reading. *Journal of Speech, Language, and Hearing Research, 49*(2), 278–293.

Catts, H. W., Hogan, T. P., & Fey, M. E. (2003). Subgrouping poor readers on the basis of individual differences in reading-related abilities. *Journal of Learning Disabilities, 36*(2), 151–164. https://doi.org/10.1177/00222194030360020.

Christodoulou, J. A., Del Tufo, S. N., Lymberis, J., Saxler, P. K., Ghosh, S. S., Triantafyllou, C., Whitfield-Gabrieli, S., & Gabrieli, J. D. E. (2014). Brain bases of reading fluency in typical reading and impaired fluency in dyslexia. *PLoS One, 9*(7), e100552.

Colenbrander, D., Kohnen, S., Smith-Lock, K., & Nickels, L. (2016). Individual differences in the vocabulary skills of children with poor reading comprehension. *Learning and Individual Differences, 50*, 210–220.

Conti-Ramsden, G., & Botting, N. (2001). Psycholinguistic markers for specific language impairment (SLI). *Journal of Child Psychology and Psychiatry, 42*(6), 741–748.

Cragg, L., & Nation, K. (2006). Exploring written narrative in children with poor reading comprehension. *Educational Psychology, 26*(1), 55–72.

Cutting, L. E., Clements-Stephens, A., Pugh, K. R., Burns, S., Cao, A., Pekar, J. J., Davis, N., & Rimrodt, S. L. (2013). Not all reading disabilities are dyslexia: distinct neurobiology of specific comprehension deficits. *Brain Connectivity, 3*(2), 199–211.

Cutting, L. E., Materek, A., Cole, C. A. S., Levine, T. M., & Mahone, E. M. (2009). Effects of fluency, oral language, and executive function on reading comprehension performance. *Annals of Dyslexia, 59*, 34–54.

Cutting, L. E., & Scarborough, H. S. (2006). Prediction of reading comprehension: Relative contributions of word recognition, language proficiency, and other cognitive skills can depend on how comprehension is measured. *Scientific Studies of Reading, 10*(3), 277–299.

Dawes, E., Leitão, S., Claessen, M., & Kane, R. (2018). A profile of the language and cognitive skills contributing to oral inferential comprehension in young children with developmental language disorder. *International Journal of Language & Communication Disorders, 53*(6), 1139–1149.

De Beni, R., & Palladino, P. (2000). Intrusion errors in working memory tasks: Are they related to reading comprehension ability? *Learning and Individual Differences, 12*(2), 131–143.

Del Tufo, S. N., & Earle, F. S. (2020). Skill profiles of college students with a history of developmental language disorder and developmental dyslexia. *Journal of Learning Disabilities, 53*(3), 228–240.

Fidler, L. J., Plante, E., & Vance, R. (2011). Identification of adults with developmental language impairments. *American Journal of Speech-Language Pathology, 20*(1), 2–13.

Fidler, L. J., Plante, E., & Vance, R. (2013). Erratum: Identification of adults with developmental language impairments. *American Journal of Speech-Language Pathology, 22*, 577.

Fonteneau, E., & van der Lely, H. K. (2008). Electrical brain responses in language-impaired children reveal grammar-specific deficits. *PLoS One, 3*(3), e1832.

Georgiou, G. K., & Das, J. P. (2016). What component of executive functions contributes to normal and impaired reading comprehension in young adults? *Research in Developmental Disabilities, 49*, 118–128.

Goff, D. A., Pratt, C., & Ong, B. (2005). The relations between children's reading comprehension, working memory, language skills and components of reading decoding in a normal sample. *Reading and Writing, 18*(7–9), 583–616.

Gough, P. B., & Tunmer, W. E. (1986). Decoding, reading, and reading disability. *Remedial and Special Education, 7*(1), 6–10.

Gray, S. (2003). Word-learning by preschoolers with specific language impairment. *Journal of Speech, Language, and Hearing Research, 46*, 56–67.

Grigorenko, E. L., Compton, D. L., Fuchs, L. S., Wagner, R. K., Willcutt, E. G., & Fletcher, J. M. (2020). Understanding, educating, and supporting children with specific learning disabilities: 50 years of science and practice. *American Psychologist, 75*(1), 37.

Henderson, L., Snowling, M., & Clarke, P. (2013). Accessing, integrating, and inhibiting word meaning in poor comprehenders. *Scientific Studies of Reading, 17*(3), 177–198.

Hoover, W. A., & Gough, P. B. (1990). The simple view of reading. *Reading and Writing, 2*(2), 127–160.

Hulme, C., & Snowling, M. (2011). Children's reading comprehension difficulties: nature, causes and treatments. *Current Directions in Psychological Science, 20*(3), 139–142. https://doi.org/10.1177/0963721411408673.

Keenan, J. M., Betjemann, R. S., & Olson, R. K. (2008). Reading comprehension tests vary in the skills they assess: Differential dependence on decoding and oral comprehension. *Scientific Studies of Reading, 12*(3), 281–300.

Klauda, S. L., & Guthrie, J. T. (2008). Relationships of three components of reading fluency to reading comprehension. *Journal of Educational Psychology, 100*(2), 310–321.

Landi, N., & Perfetti, C. A. (2007). An electrophysiological investigation of semantic and phonological processing in skilled and less-skilled comprehenders. *Brain and Language, 102*(1), 30–45.

Landi, N., & Ryherd, K. (2017). Understanding specific reading comprehension deficit: a review. *Lang & Ling Compass, 11*(2), e12234.

Leach, J. M., Scarborough, H. S., & Rescorla, L. (2003). Late-emerging reading disabilities. *Journal of Educational Psychology, 95*(2), 211.

Leonard, L., Eyer, J., Bedore, L., & Grela, B. (1997). Three accounts of the grammatical morpheme difficulties of English—speaking children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 40*(4), 741–753.

Leonard, L. B., Weismer, S. E., Miller, C. A., Francis, D. J., Tomblin, J. B., & Kail, R. V. (2007). Speed of processing, working memory, and language impairment in children. *Journal of Speech, Language, and Hearing Research, 50*(2), 408–428.

Misra, M., Katzir, T., Wolf, M., & Poldrack, R. A. (2004). Neural systems for rapid automatized naming in skilled readers: unraveling the RAN-reading relationship. *Scientific Studies of Reading, 8*(3), 241–256.

McGregor, K. K., Arbisi-Kelm, T., Eden, N., & Oleson, J. (2020). The word learning profile of adults with developmental language disorder. *Autism & Developmental Language Impairments, 5*, 2396941519899311.

McGregor, K. K., Newman, R. M., Reilly, R. M., & Capone, N. C. (2002). Semantic representation and naming in children with specific language impairment. *Journal of Speech, Language, and Hearing Research, 45*(5), 998–1014.

Miller, C. A., & Wagstaff, D. A. (2011). Behavioral profiles associated with auditory processing disorder and specific language impairment. *Journal of Communication Disorders, 44*, 745–763.

Moeller, J. (2015). A word on standardization in longitudinal studies: don't. *Frontiers in Psychology, 6*, 1389.

Nation, K., Clarke, P., Marshall, C. M., & Durand, M. (2004). Hidden language impairments in children. *Journal of Speech, Language, and Hearing Research, 47*(1), 199–211.

Nation, K., & Norbury, C. F. (2005). Why reading comprehension fails: insights from developmental disorders. *Topics in Language Disorders, 25*(1), 21–32.

Nation, K., & Snowling, M. J. (1997). Assessing reading difficulties: the validity and utility of current measures of reading skills. *British Journal of Educational Psychology, 67*, 359–370.

Nation, K., & Snowling, M. J. (1998). Semantic processing and the development of word recognition skills: evidence from children with reading comprehension difficulties. *Journal of Memory and Language, 39*(1), 85–101. https://doi.org/10.1006/jmla.1998.2564.

Nation, K., Snowling, M. J., & Clarke, P. (2007). Dissecting the relationship between language skills and learning to read: semantic and phonological contributions to new vocabulary learning in children with poor reading comprehension. *Advances in Speech Language Pathology, 9*(2), 131–139.

Norton, E. S., & Wolf, M. (2012). Rapid automatized naming (RAN) and reading fluency: Implications for understanding and treatment of reading disabilities. *Annual Review of Psychology, 63*, 427–452.

Plante, E., Gomez, R., & Gerken, L. (2002). Sensitivity to word order cues by normal and language/learning disabled adults. *Journal of Communication Disorders, 35*(5), 453–462.

Poldrack, R. A., Wagner, A. D., Prull, M. W., Desmond, J. E., Glover, G. H., & Gabrieli, J. D. (1999). Functional specialization for semantic and phonological processing in the left inferior prefrontal cortex. *Neuroimage, 10*(1), 15–35.

Potocki, A., Ecalle, J., & Magnan, A. (2013). Narrative comprehension skills in 5-year-old children: correlational analysis and comprehender profiles. *The Journal of Educational Research, 106*(1), 14–26.

R Core Development Team (2016). R: a language and environment for statistical computing. Version 3.4.2.

Rice, M. L. (2016). Specific language impairment, nonverbal IQ, attention-deficit/hyperactivity disorder, autism spectrum disorder, cochlear implants, bilingualism, and dialectal variants: defining the boundaries, clarifying clinical conditions, and sorting out causes. *Journal of Speech, Language, and Hearing Research, 59*(1), 122–132.

Saha, N. M., Del Tufo, S. N., & Cutting, L. E. (2019). Learning lexical information depends upon task, learning approach, and reader subtype. *Journal of Learning Disabilities, 52*(6), 442–455.

Shankweiler, D., Lundquist, E., Katz, L., Stuebing, K. K., Fletcher, J. M., Brady, S., Fowler, A., Dreyer, L. G., Marchione, K. E., Shaywitz, S. E., & Shaywitz, B. A. (1999). Comprehension and decoding: Patterns of association in children with reading difficulties. *Scientific Studies of Reading, 3*(1), 69–94.

Shaywitz, B. A., Shaywitz, S. E., Blachman, B. A., Pugh, K. R., Fulbright, R. K., Skudlarski, P., et al. (2004). Development of left occipitotemporal systems for skilled reading in children after a phonologically-based intervention. *Biological Psychiatry, 55*(9), 926–933.

Siegel, L. S. (1993). Phonological processing deficits as the basis of a reading disability. *Developmental Review, 13*(3), 246–257.

Stanovich, K. E. (2000). *Progress in understanding reading: Scientific foundations and new frontiers*. Guilford Press.

Stothard, S. E., & Hulme, C. (1992). Reading comprehension difficulties in children. *Reading and Writing, 4*(3), 245–256.

Torgesen, J. K., Rashotte, C. A., & Wagner, R. K. (1999). *TOWRE: Test of word reading efficiency*. Austin: Pro-ed.

Torgesen, J. K., Wagner, R., & Rashotte, C. (2012). Test of word reading efficiency:(TOWRE-2). **Pearson Clinical Assessment**.

Tong, X., Deacon, S. H., Kirby, J. R., Cain, K., & Parrila, R. (2011). Morphological awareness: A key to understanding poor reading comprehension in English. *Journal of Educational Psychology, 103*(3), 523.

Ullman, M. T., & Pierpont, E. I. (2005). Specific language impairment is not specific to language: the procedural deficit hypothesis. *Cortex, 41*(3), 399–433.

Ullman, M. T., Earle, F. S., Walenski, M., & Janacsek, K. (2020). The neurocognition of developmental disorders of language. *Annual Review of Psychology, 71*(1), 389–417.

Wagner, R. K., Torgesen, J. K., Rashotte, C. A., & Pearson, N. A. (1999). *Comprehensive test of phonological processing: CTOPP*. Austin: Pro-ed.

Wagner, R., Torgesen, J., Rashotte, C., Pearson, N. A., Wiig, E., & Secord, W. (2013). *CTOPP-2: comprehensive test of phonological processing–second edition*. Austin: Pro-ed.

Wechsler, D. (1999). *Wechsler abbreviated scale of intelligence*. San Antonio: Harcourt Assessment.

Wechsler, D. (2011). WASI-II: Wechsler abbreviated scale of intelligence. **PsychCorp**.

Wechsler, D. (2014). *Wechsler adult intelligence scale–fourth edition (WAIS–IV)*. San Antonio: Psychological Corporation.

Wolf, M., & Denckla, M. B. (2005). *RAN/RAS: rapid automatized naming and rapid alternating stimulus tests*. Austin: Pro-ed.

Woodcock, R. W. (2011). Woodcock reading mastery tests: WRMT-III. **Pearson**.

Woodcock, R. W., Mather, N., & McGrew, K. S. (2001). Woodcock-Johnson III tests of achievement:(WJ-III). **Riverside Pub**.