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Understanding specific reading comprehension deficit: A review

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Abstract

A substantial population of children and adolescents struggle with reading comprehension despite adequate phonemic decoding (word-level reading) and intellectual ability. Individuals with this pattern of performance are considered to have specific reading comprehension deficit (S-RCD). Despite two decades of study on the profiles of behavioral performance associated with S-RCD, there is no current consensus on the causal mechanisms of the disorder. Recent progress in identifying such mechanisms includes studies that have utilized comprehension age match and longitudinal designs which have identified several comprehension subskills that are predictive of S-RCD development. However, disagreement persists over which deficits are core to S-RCD, which are comorbid and which are simply a consequence of poor comprehension. Further, almost no research on this disorder has sought to identify neurobiological endophenotypes that may enhance our understanding of causal mechanisms. Here, we offer a review of the literature on core language and higher-level language deficits associated with S-RCD, including studies that examine the neurobiological basis of this disorder. What emerges is a relatively consistent pattern of subclinical impairments across a range of comprehension subskills that may put pressure on the complex process of reading comprehension. These subskills include semantic and grammatical processing, inference making, and other higher-level language skills such as comprehension monitoring. This disorder also appears to have a neurobiological basis, though further study is needed to establish the precise disruption in neurocircuitry. Suggestions for further research include the continued use of online, temporally-sensitive measures such as eye-tracking and event-related potential, additional studies of the neurobiology of the disorder, as well as longitudinal tracking and identification of early behavioral and brain markers for S-RCD prior to formal schooling.

1 | INTRODUCTION

While many individuals who struggle with reading comprehension also have decoding difficulty, a sizable population (about 10% of children and adults) exhibit reading comprehension difficulties despite intact decoding skill (Catts, Hogan, & Fey, 2003; Landi, 2010; Nation & Snowling, 1998; Stothard & Hulme, 1995; Yuill & Oakhill, 1991). These children and adults are considered to have specific reading comprehension deficit (S-RCD) and are commonly referred to as specifically poor comprehenders or simply poor comprehenders. We use the term S-RCD here because the more commonly used "poor comprehenders" does not clearly indicate a deficit that is independent of other reading disabilities. Individuals with S-RCD have intelligence within the normal range, although some children with this profile score in the low-average range on both verbal and nonverbal IQ tasks (Nation, Clarke, & Snowling, 2002).

The idea that children and adults can and do struggle with comprehension of written text despite intact decoding ability is no longer new, with the earliest studies of S-RCD published over two decades ago (e.g., Oakhill, 1983; Oakhill, 1982; Garnham, Oakhill, & Johnson-Laird, 1982; Oakhill, 1984; Oakhill & Yuill, 1986). Indeed, *Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition* (American Psychiatric Association, 2013), the most recent version, has included an entry under specific learning disorder that specifies comprehension disorder as "Difficulty understanding the meaning of what is read (e.g., may read text accurately but not understand the sequence, relationships, inferences or deeper meanings of what is read)." However, the study of a comprehension disorder independent of lower-level word reading problems is still relatively new compared to the study of other reading and language disorders, such as dyslexia and specific language impairment (SLI or LI).

Reading comprehension requires the coordination of multiple levels of language and cognitive function, from lexical retrieval to syntactic parsing to the creation of a global representation of the text. Thus, it is not surprising that identification of causal mechanisms for S-RCD has been difficult. Although the identification of S-RCD is relatively recent, the idea that children and adults can have a deficit in comprehension that is not a byproduct of poor decoding is consistent with a widely accepted view of reading. Indeed, "The Simple View of Reading" (Gough & Tunmer, 1986) posits that reading comprehension is the product of decoding and listening comprehension. Consistent with this, individuals with S-RCD have problems with both spoken and printed comprehension, suggesting that S-RCD is a language, rather than a reading-specific impairment (e.g., Catts, Adlof, & Weismer, 2006; Hulme & Snowling, 2011).

One goal of the research on S-RCD is to identify causal mechanisms underlying this disorder and to dissociate these processes from other areas of cognitive and linguistic weakness that may simply be associated with poor comprehension. Areas of identified linguistic weakness for individuals with S-RCD include semantic processing, grammatical processing (syntax and morphology), and higher-level language skills such as inference and comprehension monitoring. Further, difficulties with nonlinguistic domain-general processes (e.g., executive function) can put pressure on the systems responsible for comprehension; indeed, some individuals with S-RCD show weaknesses in such domain-general processes. In the current review, we describe the relevant subskills and processes that contribute to successful reading comprehension and review studies of S-RCD in each of these domains. We also discuss the contributions that neurobiological investigations have made to the study of S-RCD and the importance of early intervention for remediation of S-RCD and provide some discussion of the next steps for research on S-RCD.

For the purposes of this review, we focus on studies that have considered decoding skill as a factor in the design, either through examination of children or adults with S-RCD and matched typically developing (TD) individuals or other comparison group or through examination of comprehension skill in a continuous fashion while also considering decoding skill. Please see Table A1 for a complete list of the studies reviewed and cited in this review. Table A1 includes information on how study groups were defined or whether a continuous analysis approach was used, as well as the study sample sizes, ages examined, and the study foci.

2 | DEFINING SPECIFIC READING COMPREHENSION DEFICIT

Before we turn to the psycholinguistic profiles of individuals with S-RCD, some discussion of the methods used for identifying S-RCD is warranted. The majority of studies define S-RCD using a cutoff-based approach, requiring a decoding score that is at or above average and a reading comprehension score that is below average (Adlof & Catts, 2015; Catts et al., 2006; Cragg & Nation, 2006). Some studies require an additional discrepancy between comprehension and decoding performance for each individual (Henderson, Snowling, & Clarke, 2013; Nation, Cocksey, Taylor, & Bishop, 2010). Other studies simply identify groups that differ significantly on comprehension but not decoding, without firm cutoffs or individual-level discrepancies between comprehension and decoding performance (Cain, Patson, & Andrews, 2005; Ehrlich, Remond, & Tardieu, 1999).

Another approach that has been employed more recently uses regression to predict comprehension skill from age, decoding, nonverbal IQ, and vocabulary. Using this approach, "Unexpected Poor Comprehenders" are defined as individuals whose actual comprehension scores fall below a 65–80% confidence interval of the fitted values. This approach also defines control participants, or "Expected Average Comprehenders," as those whose actual comprehension scores fall within a 15–25% confidence interval of the predicted values (Li & Kirby, 2014; Tong, Deacon, & Cain, 2013; Tong, Deacon, Kirby, Cain, & Parrila, 2011).

With respect to selecting appropriate control comparisons, cutoff-based designs typically use average comprehenders matched on age, IQ, and decoding. The regression-based approach uses participants who are expected to be average comprehenders (defined above). Another approach (Comprehension Age Match, or CAM) includes a second control group of comprehension-matched younger children (Cain, 1999, 2003, 2006; Cain, Oakhill, & Lemmon, 2004b; Cataldo & Oakhill, 2000; Nation, Marshall, & Snowling, 2001; Yuill & Joscelyne, 1988). The inclusion of a comprehension-matched group is one way to determine whether subskills that are impaired in S-RCD are a cause or a consequence of poor comprehension ability. For example, if the younger comprehension-matched readers outperform those with S-RCD, the observed weaknesses in S-RCD cannot be a consequence of comprehension ability.

Within each of these identification approaches there exists substantial variability across studies in the exact assessments used to measure comprehension, decoding, IQ, and other covariates, when used. Further, the exact values used for cutoffs, discrepancy scores, and confidence intervals (in the case of the regression based approach) also vary considerably from study to study. Recent studies by Keenan and Meenan (2014) and Keenan et al. (2014) demonstrate that variability in classification method can have an impact on which individuals are identified as having S-RCD and on how the groups compare on some comprehension subskills, such as vocabulary and working memory. Thus, researchers must be clear in discussing their method for classification and be mindful of the method used when interpreting their findings and comparing across studies.

Finally, it should be noted that some children identified as having S-RCD may also meet criteria for LI. However, for most children with S-RCD, language weaknesses are not severe enough to meet criteria for LI. There has been discussion of whether S-RCD may be a milder form of LI, but the significant heterogeneity among children with LI leads to some children with LI demonstrating deficits that are not consistent with S-RCD profiles (e.g., phonological problems, articulatory problems, word-level reading impairments). Further, for children with LI who do not have phonological level deficits (receptive or expressive), grammatical processing appears to be the primary deficit and vocabulary is relatively spared, whereas, children with S-RCD appear to have more prominent vocabulary deficits (discussed below). Research reports on S-RCD should include thorough characterization of participants' language profiles as well as the percentage of children in the sample that would meet criteria for LI.

3 | IDENTIFIED IMPAIRMENTS IN S-RCD: LANGUAGE FUNDAMENTALS

3.1 | Vocabulary and Lexical Semantic Processing

Both reading comprehension and spoken language comprehension are highly correlated with vocabulary skill. These relationships hold even when lower-level skills such as decoding are taken into account (Braze, Tabor, Shankweiler, & Mencl, 2007; Catts, Fey, & Zhang, 1999; Landi, 2010; Muter, Hulme, Snowling, & Stevenson, 2004; Ouellette, 2006; Roth, Speece, & Cooper, 2002; Share, Jorm, Maclean, & Matthews, 1984; Share & Leikin, 2004; Spencer, Quinn, & Wagner, 2014; Stanovich, Cunningham, & Feeman, 1984; Vellutino & Scanlon, 1987). Thus, it is not surprising that poor vocabulary knowledge has been consistently associated with S-RCD (Cain & Oakhill, 2006; Henderson et al., 2013). Moreover, studies using longitudinal designs to retrospectively examine children with S-RCD before they began literacy instruction have found early deficits in vocabulary (Catts et al., 2006). These findings suggest that poor vocabulary is causally related to S-RCD rather than a consequence of poor comprehension skill.

Given that performance on vocabulary assessments requires intact phonology and semantics, many studies have explicitly compared semantic and phonological processing of single words (including both speed and accuracy measures) in children with S-RCD. Comparisons of lexical–semantic processing and phonological processing in individuals with S-RCD have consistently identified a dissociation in these skills, with individuals with S-RCD showing impaired performance on semantic but not phonological tasks. For example, Nation et al. (2001) found that while children with dyslexia, who have phonological processing difficulties, are less accurate in naming pictures with longer versus shorter names ("ring" vs. "banana"), children with S-RCD do not show this effect. However, children with S-RCD are slower and less accurate than controls to name pictures with low-frequency names, a skill that is associated with semantic impairments (Woollams, Ralph, Plaut, & Patterson, 2007). Relatedly, children with S-RCD are slower and less accurate when reading low-frequency and exception words, which require more support from semantics, but they perform similarly to controls when reading phonologically complex words (Nation & Snowling, 1998). Further, individuals with S-RCD are slow and error-prone when asked to determine whether two low-imageable spoken words are synonyms (again requiring support from semantic knowledge) but are unimpaired when asked to judge whether two spoken words rhyme. Children with S-RCD also generate fewer semantic associates than controls when given a category, such as "types of work;" however, they have no difficulty listing rhyme associates, such as producing "chair" when given "hair" (Nation & Snowling, 1998).

Additional evidence for lexical–semantic processing weaknesses in S-RCD comes from studies of priming. Nation and Snowling (1999) found that individuals with S-RCD show typical patterns of semantic priming to functionally related pairs such as "*broom–floor*" as well as category coordinates with high association strength like "*cat–dog*." However, they fail to show priming for category coordinate pairs with low association strength, such as "*sheep–cow*." These findings suggest that individuals with S-RCD have rather shallow conceptual semantic representations leading to lexical priming that is disproportionately driven by co-occurrence or functional relationships.

Following up on this work, Landi and Perfetti (2007) examined event-related potentials to targets preceded by either semantically related or phonologically related primes (semantic primes were either categorically related or associatively related). These studies found that skilled adult comprehenders exhibited large N200 and N400 effects to a target preceded by a semantically unrelated prime relative to a target preceded by a related prime (either associatively related or categorically related). Critically, these effects were much smaller in adults with S-RCD, particularly for the categorically associated condition. However, when N200 and N400 responses to rhyme-primed targets were compared, no difference between the two groups was observed. These findings replicate the behavioral priming findings, suggesting impoverished semantic, but not phonological, access in S-RCD.

Vocabulary and lexical–semantic knowledge have been consistently identified as areas of weakness, making these hallmarks of S-RCD. This relationship holds for both standardized and experimental measures and remains after controlling for general cognitive ability. Further, retrospective longitudinal studies suggest that vocabulary weaknesses are present in young children who will go on to become poor comprehenders, suggesting that vocabulary weakness is a cause rather than a consequence of poor comprehension. One open question, and a current area of focus in our ongoing research, is whether these deficits are language-specific (weak links between verbal labels and concepts) or amodal and present at the level of conceptual representations (weak links among concepts). Findings from Nation and Snowling (1999) and Landi and Perfetti (2007) suggest differential priming effects in S-RCD as a function of the conceptual relation between prime and target (associated vs. categorically related vs. functionally related) providing some suggestion that concept-level knowledge may be impaired. However, limited direct study of nonlinguistic concept knowledge in S-RCD restricts further discussion of this claim.

3.2 | Grammatical processing

Studies of grammatical processing in S-RCD have been equivocal, with some studies finding clear deficits and others failing to do so. Evidence for weaknesses in grammatical processing comes from several reports. Catts et al. (2006) found that 8th grade children with S-RCD had deficits on measures of syntactic processing, measured with the Clinical Evaluation of Language Fundamentals (Semel, Wiig, & Secord, 1995), and that these deficits were present in kindergarten, grade 2, and grade 4 (when analyzed retrospectively), relative to both typically developing readers and poor decoders. Nation, Clarke, Marshall, and Durand (2004) also found poorer performance in 3rd and 4th graders with S-RCD relative to typically developing readers during recall and comprehension of syntactically complex sentences as well as in past tense elicitation (again, measured using the Clinical Evaluation of Language Fundamentals). However, other studies have not found differences. Cain and Oakhill (2006) found no significant difference between children with S-RCD and age-matched controls in receptive grammar, measured with the Test for Receptive Grammar (TROG; Bishop, 2003) despite differences in receptive vocabulary. Stothard and Hulme (1994) also failed to find deficits in receptive grammar (measured with the TROG) for children with S-RCD when compared to younger comprehension-matched controls. Further, Oakhill, Cain, and Bryant (2003) found correlations between receptive grammar (measured with the TROG) and reading comprehension, but this relationship did not hold after measures of IQ and vocabulary were included in their analysis.

These null findings raise the possibility that problems with grammatical processing may be mediated by word knowledge or other cognitive skills. To explore these relations, Goff, Pratt, and Ong (2005) examined grammatical comprehension in 9- to 11-year old children. After controlling for working memory, they found clear, albeit small, contributions of grammatical knowledge (measured with the TROG) to comprehension. Tong et al. (2013) also found that unexpected poor comprehenders performed more poorly than TD controls after controlling for vocabulary knowledge on a sentence correction task, which asked the children to produce a grammatically correct sentence after hearing an ungrammatical sentence, and in a morphological word analogy task (e.g., providing *pushed*, given *push*).

The inconsistency in findings on grammatical processing in S-RCD appears to be at least partially driven by the level of grammatical processing being assessed. Specifically, some tasks require only adequate comprehension of grammatically complex sentences, whereas others involve explicit (meta)knowledge of syntactic or morphological structure. The latter is considerably more difficult. To some degree, the literature bears this distinction out; studies that have failed to find differences are typically those that only require understanding of syntactic structures (e.g., matching a picture to a spoken sentence that correctly depicts the agent and patient), not meta-analytic knowledge of syntactic structure. However, some studies that require only understanding have found differences as well (Catts et al., 2006; Goff et al., 2005; Nation et al., 2004; Silva & Cain, 2015). Further, some studies that have been noted in previous reviews as not supporting deficits in grammatical processing for children with S-RCD require only basic comprehension of relatively simple spoken sentences (e.g., Florit, Roch, & Levorato, 2011). This variability in task difficulty across studies makes it difficult to evaluate which specific aspects of grammatical processing are impaired in S-RCD.

In sum, research suggests that individuals with S-RCD perform more poorly than typically developing children on tasks of grammatical processing when grammatical processing is clearly being tested (i.e., on tests of explicit knowledge of grammatical structure or application of grammatical rules, as in morphological analogy). Further, early grammatical deficits are associated with S-RCD in later grades. Future research examining grammatical processing in S-RCD should be explicit about the type and level of grammatical knowledge being assessed.

4 | IDENTIFIED IMPAIRMENTS IN S-RCD*:* HIGHER-LEVEL LANGUAGE SKILLS

In addition to the fundamental language skills discussed above, several “higher-level language” skills such as the ability to organize a text or discourse representation also play a role in reading comprehension and have been found to be impaired in S-RCD. For the purposes of this review, we consider these higher-level language skills to be (a) knowledge of text structure, (b) inference making, and (c) comprehension monitoring (c.f., Perfetti, Landi, & Oakhill, 2005; Hogan, Bridges, Justice, & Cain, 2011; Cain, Oakhill & Bryant, 2004a; Oakhill & Cain, 2012).

4.1 | Knowledge of Text Structure

Knowledge of story structure does account for significant variance in comprehension skill in childhood (Cain et al., 2004a). Indeed, when asked to produce a narrative based on a wordless picture book, children with S-RCD produce narratives with less global structure than typically developing children, both in written and spoken format (Cragg & Nation, 2006). Children with S-RCD exhibit a greater benefit in comprehension and recall relative to skilled comprehenders from the provision of information that supports structure knowledge (e.g., titles and pictures) when reading a text (Yuill & Joscelyne, 1988). Further, when given more detailed prompts, including informative titles and picture sequences, children with S-RCD produce more structured narratives than when given just a simple topic prompt, although they perform worse than TD children regardless of the information provided (Cain, 2003). However, children with S-RCD produce less structured narratives than comprehension-age-matched controls when given only a topic but similarly to comprehension-age-matched controls when given a picture sequence (Cain & Oakhill, 1996).

These results suggest that comprehension skill alone cannot account for story structure deficits in children with S-RCD when provided information is minimal. However, with more explicitly provided information, children with S-RCD can understand and produce passages in a more structured manner. This is potentially because children with S-RCD need this information to prioritize, organize, and integrate information in a way that comes more naturally to skilled comprehenders.

4.2 | Inference-Making

In addition to explicitly stated information, readers obtain significant implied information by integrating meaning presented across statements and incorporating prior knowledge. This ability to make inferences is a critical component of comprehension. Although some researchers have argued that deficits in vocabulary and grammar alone account for impaired comprehension in S-RCD (Hulme & Snowling, 2011), others have argued that inference making contributes independently to comprehension skill (Florit et al., 2011; Oakhill & Cain, 2012; Silva & Cain, 2015). For example, Oakhill and Cain (2012) found that inference-making ability at ages eight to nine significantly predicts reading comprehension ability at ages 10 to 11 over and above word reading, vocabulary, IQ, and earlier measurements of comprehension. When looking at younger children, inference-making skill at ages four and five directly predicts subsequent listening comprehension at age six (Lepola, Lynch, Laakkonen, Silven, & Niemi, 2012). Moreover, children with S-RCD show poorer inference-making performance than younger comprehension-matched controls, suggesting further that inference-making ability is not simply a consequence of poor comprehension (Cain & Oakhill, 1999; Oakhill & Cain, 2000).

These findings suggest that other aspects of processing critical to comprehension may be tapped by inference tasks. Namely, inference making may require the use of higher-order semantic knowledge networks to activate information not explicitly present in text, tapping into spreading activation mechanisms. In addition, inference tasks may be revealing individual differences in the integration of semantic information across portions of text. Further, aspects of grammatical knowledge such as relational devices (because, therefore, and before) may be better tapped by inference tasks than tasks of explicit grammatical knowledge.

Evidence that inference-making difficulties in S-RCD may be tied to semantic integration mechanisms rather than basic semantic knowledge comes from a unique study that trained children with S-RCD and controls on a common knowledge base. After training, children with S-RCD were impaired in answering questions about the text that involved the integration of knowledge from the prior training. Analyses controlled for memory of the newly learned knowledge base, and thus reduced inference-making performance seen in children with S-RCD must be due to factors other than literal knowledge of the new information (Cain, Oakhill, Barnes, & Bryant, 2001).

Further suggestion that differences in semantic knowledge alone do not cause inference failure in S-RCD comes from the fact that individuals with S-RCD can make relevant inferences when they are alerted to their erroneous answers to inference-based questions. Indeed, individuals with S-RCD improve their performance on inferential questions when they are asked to attempt the task again and allowed to look back at the text (Cain & Oakhill, 1999). These findings suggest that the inference-making deficits observed in S-RCD are less about the ability to make an inference and instead more about the lack of automatically doing so (again suggesting deficits in automatic integration or spreading activation mechanisms).

Although the integrative and constructive skills required for inference making clearly have a strong influence on overall comprehension and are impaired in S-RCD, some difficulties remain in determining whether inference making is an independent causal factor for comprehension weakness. Using inference-making performance to understand comprehension-specific deficits remains difficult because many measures of inference making are very similar in nature to those measures used to define S-RCD in children. Indeed, some standardized measures of comprehension (e.g., KTEA, Kaufman & Kaufman, 2004) include inferential and literal knowledge subscores. Further, inference-making tasks require the processing of lexical knowledge, the combination of meanings across sentences, and knowledge of grammatical structure as well as experience with text structure. As such, the unique contributions of inference making to the prediction of comprehension in some studies may simply reflect an over-additive effect of each of these skills' contributions.

4.3 | Comprehension Monitoring

Comprehension monitoring refers to an individual's ability to evaluate his or her own understanding during comprehension. As such, it requires meta-knowledge of a reader's relationship with the text. Many studies of monitoring ask children to identify inconsistencies or pieces of text that do not integrate well into the global text. For example, when asked to underline any parts of a written passage that "did not make sense," children with S-RCD identified fewer pieces of inconsistent text than controls (Cain & Oakhill, 2006; Oakhill, Hartt, & Samols, 2005). Using an online, self-paced reading task, Ehrlich et al. (1999) found that children with S-RCD did not slow down their reading when they encountered an inconsistency in text, unlike skilled comprehenders. Further, they found that skilled comprehenders but not children with S-RCD looked back to previous text more frequently when given an inconsistency. Children with S-RCD also explicitly report lower comprehension of passages and indicate detection of inconsistencies less frequently. These findings provide evidence for both reduced implicit awareness of inconsistencies and explicit evaluation and revision skill.

Two recent eyetracking studies provide online support for these monitoring problems. That TD children showed slower reading times for disambiguating information following an ambiguous word, indicating detection and reparation of the ambiguity was found by van der Schoot, Vasbinder, Horsley, Reijntjes, and van Lieshout (2009). They did not show the same slowing when the disambiguating information preceded the ambiguous word. In contrast, individuals with S-RCD showed similar reading times for the disambiguating context regardless of its position relative to the ambiguous word, suggesting a failure to detect or remediate the ambiguity of the sentence.

A second recent study by Van Dyke, Matsuki, and Landi (2016, March) found that although reading times for individuals with S-RCD were slower overall, individuals with S-RCD were also less sensitive to semantic and syntactic distractors when reading sentences that required long distance dependency formation. Consider the following three sentences:

1. The father with the very colorful shirt smiled proudly during the entire game.
2. The father who the colorful shirt pleased smiled proudly during the entire game
3. The father who the colorful clown pleased smiled proudly during the entire game.

Poor comprehenders showed similar fixation durations to the verb "smiled" across all conditions despite the presence of syntactic (2) and both syntactic and semantic (3) competitors. In contrast, skilled comprehenders showed increased fixations to the verb for (2) and (3) as compared to (1). Individuals with S-RCD also showed similar performance in comprehension question accuracy for distractor and no-distractor sentences, despite overall accuracy lower than skilled comprehenders (Van Dyke et al., 2016, March). From these results, we concluded that individuals with S-RCD were not bothered by these competitors, given that slowing at the verb when diagnosticity is low (i.e., with increased competitors) is only expected if the reader notices the error. These findings suggest that children with S-RCD are not as concerned with making sure that incoming information fits with the text model they are constructing.

As with inference-making skill, researchers ask if comprehension monitoring is a specific skill unto itself, if it results from good lower-level language skills such as rapid and fluid access to meaning and knowledge of appropriate grammatical structure, or if it is the product of basic levels of linguistic processing and more domain-general processes associated with attention, executive function or even motivation. Indeed, some studies have found evidence for domain-general deficits in attention, working memory (Cain, Oakhill, & Bryant, 2004a; Sesma, Mahone, Levine, Eason, & Cutting, 2009; Strasser & del Río, 2013), and executive function (Cutting, Materek, Cole, Levine, & Mahone, 2009) in children with S-RCD. Research utilizing online techniques which can track moment-to-moment integration (such as eyetracking) holds promise for further investigation of comprehension monitoring and its related subskills in S-RCD. Further, studies of monitoring need to adequately evaluate domain-general functions and include these in their analytic models.

5 | NEUROBIOLOGICAL MECHANISMS IN SPECIFIC READING COMPREHENSION DEFICIT

Few studies to date have specifically investigated the neurobiological underpinnings of individuals with S-RCD. However, to date, neurobiological studies generally confirm the broad profile of S-RCD, that is, intact decoding paired with semantic weaknesses. For example, a recent study by Cutting et al. (2013) used functional magnetic resonance imaging (fMRI) to investigate functional activation during single-word reading in individuals with S-RCD, individuals with dyslexia, and TD children. Activation to both low- and high-frequency words as well as nonwords during a lexical decision task was compared. Behaviorally, there were no group differences in reaction time. However, consistent with existing literature, children with S-RCD showed lower sensitivity (A' values[1]) for low- but not high-frequency words, whereas children with dyslexia had lower sensitivity for both high- and low-frequency words.

With respect to patterns of functional neural activation, S-RCD and TD children showed similar activation to words in the occipitotemporal (OT) region, which was reduced in children with dyslexia, suggesting typical word-level processing in children with S-RCD. For pseudowords, again children with S-RCD and TD children showed similar patterns of activation in the OT as well as in the supramarginal gyrus, suggesting intact grapheme-to-phoneme decoding. Functional connectivity analyses for the low-frequency versus high-frequency contrast revealed abnormal interactions for children with S-RCD between the inferior frontal gyrus and several subcortical regions including the hippocampus, suggesting anomalies in connectivity between language and declarative memory regions. These connectivity results are consistent with observed deficits in semantic memory for children with S-RCD. In contrast, children with dyslexia showed atypical connectivity (relative to TD children) between the inferior frontal gyrus and OT. Taken together, these findings mirror behavioral findings of TD–S-RCD and TD–dyslexia comparisons, which suggest disrupted lexical–semantic processing in children with S-RCD and disrupted decoding in children with dyslexia.

A second recent functional magnetic resonance imaging study by Ryherd and colleagues (Ryherd et al., under review) measured brain activation in skilled comprehenders and adolescents with S-RCD during naturalistic processing of spoken and printed passages as well as during processing of spoken and printed single words. This study investigated how comprehension ability would affect the involvement of particular neural systems in language processing across processing level (word vs. passage) and modality (spoken vs. printed). Using partial least squares analysis, we found increased activation for skilled comprehenders relative to individuals with S-RCD in areas commonly associated with semantic processing (e.g., middle temporal gyrus, anterior temporal pole) for both spoken and printed passages. Individuals with S-RCD, on the other hand, showed greater activation in areas involved in effortful retrieval, including the anterior cingulate cortex, insula, and hippocampus. Critically, this pattern held across the different presentation modalities, suggesting that comprehension skill affects the neural circuits involved in spoken and printed passage comprehensions in similar ways. For our comparisons of word- and passage-level processing, we observed similar results, with greater semantic involvement for skilled comprehenders for both single words and passages and greater effortful processing for both single words and passages in individuals with S-RCD. These results suggest that individuals with S-RCD are not engaging in semantic processing in the same way as skilled comprehenders regardless of modality or processing level and require increased effort to process real words and passages (Ryherd et al., under review).

The paucity of studies examining the neural circuitry associated with S-RCD makes conclusions about neurobiological anomalies premature at this point. However, neurobiological findings thus far are consistent with behavioral findings, indicating intact decoding and poor lexical–semantic processing as well as atypical circuitry for processing of longer texts for individuals with S-RCD. Further, our findings suggest that comprehension skill may impact circuits for spoken and printed passages similarly, consistent with behavioral findings suggesting that S-RCD is not a disorder of reading per se but of language comprehension.

6 | INTERVENTION

Ultimately, studies that contribute to better characterization of S-RCD should influence educational practice. The majority of comprehension-focused intervention work has focused on enhancing the story structure provided or on teaching strategies to improve performance. For example, an early intervention study by Yuill and Joscelyne (1988) found that providing story titles that describe the main theme of a story (e.g., “Billy's Sandcastle Gets Broken by the Wave”) rather than simply the characters (“Billy and his Mother”) improves comprehension in children with S-RCD. In this study, Yuill & Joscelyne also found that children with S-RCD benefited from the provision of a short instruction on inference making prior to answering comprehension questions that required an inference.

Other interventions have focused on the use of strategies such as imagery to assist in comprehension. Oakhill and Patel (1991) trained children to “think in pictures” and found an increase in comprehension performance for children with S-RCD. In a related approach, Johnson-Glenberg (2000) compared a strategy-building intervention to one focused on verbalization and visualization. The strategy training included four subareas: summarization, clarification, prediction, and question generation. The verbalization and visualization intervention focused on teaching children to create mental and physical visual summaries of words, phrases, and sentences. Both of these strategies for focused summarization produced comprehension gains in children with S-RCD.

More recently, Clarke, Snowling, Truelove, and Hulme (2010) developed three types of interventions for S-RCD that were informed by research that has identified early oral language weaknesses in children with S-RCD (reviewed above). Their interventions included a focus on text comprehension (TC), a focus on oral language (OL), and a combination of the two (COM). The TC intervention focused on printed text comprehension and had separate modules on metacognition and inferencing, whereas the OL group had modules on vocabulary and figurative language. The COM group received all modules with the same amount of total intervention time. Results revealed that all three approaches produced significant gains in comprehension over time, although the greatest gains were seen for OL intervention. These gains were also mediated by children's vocabulary knowledge (Clarke et al., 2010). These findings highlight the importance of training in oral comprehension subskills and vocabulary in particular in children with S-RCD. Following up on this line work, Carretti and colleagues (Carretti, Caldarola, Tencati, & Cornoldi, 2014) noted differences in the training materials used by Clarke and colleagues across the TC and OL conditions and designed an intervention with matched materials to be delivered in both the oral and printed domains. Although the specific training targets used in this study (metacognition and working memory) differ from those used by Clarke et al. (2010), and the children in this study did not have S-RCD, of note is that the impact of training in the printed domain produced larger gains in reading and listening comprehension outcomes, suggesting that the relative impact of oral language- versus text-based training may vary as a function of the specific training targets.

Finally, McMaster et al. (2012) looked at the effects of different interventions in two subgroups of children with S-RCD defined by their inference-making abilities. The subgroups included "elaborators," who made inferences at the same rate as TD individuals but mostly made invalid inferences, and "paraphrasers," who produced fewer inferences overall, preferring instead to paraphrase or repeat parts of text. Findings from this study revealed that providing questions related to causality during reading helped elaborators make more valid causal inferences, whereas asking general connecting questions helped paraphrasers increase their recall beyond the immediate sentence. This work provides some support for identification of individualized approaches based on subclassification of children with S-RCD.

Intervention at multiple levels appears to support improved comprehension performance in children with S-RCD. The results of the Clarke et al. (2010) study are particularly provocative because they suggest an approach (oral language enrichment) that could be used with very early readers and even pre-readers, which could eliminate or greatly reduce the need for strategy-based approaches in the later grades. That said, many children with early oral language risk will continue to go unidentified, and strategy- and inference-focused approaches can produce significant gains in older children. Further, findings reported by McMaster et al. (2012) support identification of specific weaknesses that can be targeted for individuals or groups of students.

7 | CONCLUSION & IMPLICATIONS

There is strong evidence for a set of skills that is impaired in S-RCD, but this picture still leaves some areas underexplored and others unexplored. With demonstrated weaknesses in areas such as semantic processing, some aspects of grammatical knowledge, inference-making, and comprehension monitoring, S-RCD remains a multifaceted heterogeneous disorder.

It is clear that more research is needed across each of the domains discussed in this paper. Although weaknesses in vocabulary and lexical–semantic processing are consistent, future research is needed to refine our understanding of the nature of the deficit, including explorations of nonverbal conceptual representations. In the area of grammatical processing, studies thus far have failed to definitively identify whether grammatical deficits in S-RCD reflect difficulties in understanding complex syntactic structures or in metalinguistic knowledge of syntax and morphological structure. Further, it is unclear whether null reports present in the literature have adequately tested grammatical knowledge competence. With respect to higher-level comprehension processes, some dispute remains in two key areas: first, whether or not inference and comprehension monitoring tasks are measuring something more than the sum of their parts; and second, if they are independent of domain-general skills such as attention. Moreover, studies of S-RCD are inconsistent in use of covariates (IQ, working memory, and vocabulary), in the approach used to classify S-RCD, and in the selection of control populations, making cross-study comparisons difficult.

To date, there are very few studies exploring the neurobiological basis of S-RCD and no studies on the genetic basis of this disorder, leaving the underlying neurobiological basis of this disorder largely unknown. More work in this area could help to distinguish S-RCD from disorders that have overlapping behavioral profiles, such as LI, and further refine our understanding of the component skills involved in some of the observed behavioral deficits.

With respect to intervention, gains have been made in identifying several approaches to improve comprehension. Although strategy-based approaches have been prominent, findings from the studies of Clarke et al. (2010) and Clarke, Truelove, Hulme, and Snowling (2013) suggest an oral-language-based approach that could be utilized with very young children at risk for S-RCD, on the basis of early language profiles. Such an approach, if effective early, could reduce the need for top-down approaches in the later grades.

Finally, there is a clear need for more work on the developmental trajectory of S-RCD. Although a few longitudinal studies have examined children with S-RCD retrospectively and have identified early oral language weaknesses (e.g., Catts et al., 2006; Florit et al., 2011; Kim, 2015; Nation et al., 2010), these studies rely almost exclusively on standardized assessments. Further, although studies utilizing comprehension match and longitudinal designs have shed light on potential causal relations between comprehension subskills and S-RCD, more studies that utilize an early longitudinal approach and include neurobiological measures will support the identification of causal mechanisms associated with S-RCD and potentially identify early biomarkers, which could further inform early treatment approaches.

ENDNOTE

[1] A' is a nonparametric measure used for recognition memory that compares correct and incorrect answers (see Pollack & Norman, 1964; Zhang & Mueller, 2005).

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APPENDIX

TABLE A1 Study details

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Adlof and Catts (2015)	morphosyntax	9–10	16 S-RCD, 24 TD	cutoffs	reading comprehension (GRADE), reading fluency (TOWRE), nonverbal intelligence (TONI), language (CELF), vocabulary (PPVT), phonological memory (CTOPP)
Braze et al. (2007)	vocabulary	16–24	44	continuous	reading comprehension (PIAT, GORT), decoding (WJ, GORT), pseudohomophones, spelling, phonological awareness, vocabulary (PPVT, WASI), working memory (sentence span), oral comprehension (PIAT), visual memory (Corsi blocks), nonverbal IQ (WASI), print experience
Cain (1999)	strategy use	6–8	43 S-RCD, 36 TD, 39 CAM	CAM; cutoffs	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Cain (2003)	narrative	6–8	14 S-RCD, 12 TD, 12 CAM	CAM; cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM), listening comprehension (NARA)
Cain (2006)	executive function; working memory	9–10	13 S-RCD, 13 TD	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), digit span (WMTB-C)
Cain and Oakhill (2006)	S-RCD profile	7–11*	time 1: 23 S-RCD, 23 TD; time 2: 19 S-RCD, 17 TD	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM, BVPS), working memory (listening span, digit reading), grammar (TROG), IQ (WISC)
Cain and Oakhill (1996)	narrative	6–8	16 S-RCD, 12 TD, 15 CAM	CAM; cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Cain and Oakhill (1999)	inference making	6–8	29 S-RCD, 24 TD, 27 CAM	CAM; cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Cain, Oakhill, & Bryant (2004a)	working memory; inference making; comprehension monitoring	7–8	102	continuous	reading comprehension (NARA), decoding (NARA), vocabulary (GM, BVPS), verbal ability (WISC-verbal), working memory (digit span, sentence span), inference making, comprehension monitoring, story knowledge
Cain, Oakhill, & Lemmon (2004b)	lexical semantics	9–10	exp 1: 25 S-RCD, 24 TD, 12 weak vocabulary	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Cain et al. (2001)	inference making	7–8	13 S-RCD, 13 TD	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Cain et al. (2005)	syntax	7–9	18 S-RCD, 17 TD	group differences	listening comprehension (NARA), vocabulary (BVPS), decoding (BAS), grammar (TROG)
Carretti et al. (2014)	intervention	9–11	159	group differences	reading comprehension (Cornoldi & Colppo), listening comprehension (Carretti et al.), metacognition, working memory (updating), integration
Cataldo and Oakhill (2000)	strategy use	10–11	12 S-RCD, 12 TD	cutoffs	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Catts et al. (2006)	S-RCD profile	5–14	57 S-RCD, 98 TD, 27 DYS	cutoffs	reading comprehension (WRMT, GORT, QRI), decoding (WRMT), IQ (WISC), language comprehension (PPVT, TOLD, CELF, QRI), phonological processing (phoneme deletion, pig Latin, nonword rep)
Catts et al. (1999)	S-RCD profile	5–8*	421 good readers, 183 poor readers	cutoffs	reading comprhension (WRMT), phonological processing (deletion, rapid naming), oral language (TOLD), word recognition (WRMT), IQ (WISC, PPVT)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Catts et al. (2003)	S-RCD profile	5–9	183	cutoffs	reading comprehension (GORT, DAB), decoding (WRMT), listening comprehension (TOLD, PPVT, CELF), phonological processing (deletion, RAN), nonverbal IQ (WPPSI)
Clarke et al. (2010)	intervention	8–9	84 S-RCD, 76 TD	discrepancy	reading comprehension (NARA, WIAT), reading fluency (TOWRE), vocabulary (WASI), arithmetic (WIAT)
Cragg and Nation (2006)	narrative	9–11	11 S-RCD, 19 TD	cutoffs	reading comprehension (NARA), decoding (NARA), reading fluency (TOWRE), grammar (TROG), nonverbal IQ (WASI), spelling (WORD), narrative (ERRNI)
Cutting et al. (2013)	S-RCD profile; neurobiology	10–14	12 S-RCD, 19 TD, 20 DYS	cutoffs, discrepancy	reading comprehension (GORT, GM, SDRT, GAB), decoding (WRMT), reading fluency (TOWRE), vocabulary (PPVT), grammar (TOLD), working memory (spatial span, ToL)
Cutting et al. (2009)	executive function	9–14	17 S-RCD, 21 TD, 18 DYS	cutoffs	reading comprehension (WRMT, GORT), decoding (WRMT), reading fluency (TOWRE, GORT), oral language (PPVT, TOLD, TLC), IQ (WISC), executive function (Tower of London, mazes, digit span), Attention Deficit Hyperactivity Disorder (ADHD) symptomology
Ehrlich et al. (1999)	syntax	9–10	23 S-RCD, 23 TD	cutoffs, group difference	reading comprehension (INETOP), decoding (LPELR), vocabulary (CST)
Florit et al. (2011)	oral comprehension	4–6	162	continuous	listening comprehension (TOR, PVCL), verbal IQ (WPPSI), vocabulary (PPVT), verbal working memory (backward word span)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Garnham et al. (1982)	narrative	7–8	12 S-RCD, 12 TD	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Goff et al. (2005)	working memory	8–12	180	continuous	reading comprehension (PAT), decoding (WRMT, irregular/nonword reading, NARA), nonverbal IQ (Raven's), exposure to print (TRT), vocabulary (PPVT), grammar (TROG), memory (RAVLT, WISC, Corsi blocks, triplet block span)
Henderson et al. (2013)	lexical semantics	7–11	17 S-RCD, 17 TD, 17 CAM	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA, BAS, GNRT), nonverbal ability (BAS), vocabulary (BPVS), working memory (WMTB-C)
Johnson-Glenberg (2000)	intervention	7–10	58	cutoffs	reading comprehension (GM), vocabulary (WISC), decoding (WRAT), following instructions (DTLA), working memory (sentence span, WISC)
Keenan and Meenan (2014)	S-RCD profile	8–18	995	cutoffs	reading comprehension (GORT, QRI, PIAT, WJ), decoding (TORSW, PIAT), IQ (WISC, WAIS), ADHD symptomology, working memory (sentence span, counting span, digit span)
Keenan et al. (2014)	S-RCD profile	8–19	1522	cutoffs, discrepancy	reading comprehension (PIAT, WJPC, GORT, QRI), decoding (TORSW, PIAT, Olson), listening comprehension (WJ, QRI, KNOW-IT), IQ (WAIS, WISC), ADHD symptomology, WM (sentence span, counting span, digit span)
Kim (2015)	high and low-level skills	5–6	148	continuous	reading comprehension (WJ), decoding (accuracy & fluency), listening comprehension (Carrow-Woolfolk), vocabulary (PPVT), syntax (error detection, error correction, completion), theory of mind (1st and 2nd order false belief), comprehension monitoring (inconsistency detection), WM (listening span)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Landi (2010)	high and low-level skills	18–49	928	continuous	reading comprehension (ND), decoding (pseudohomophone), vocabulary (ND), print exposure (ART), spelling (Baroff), nonverbal IQ (Raven's)
Landi and Perfetti (2007)	lexical semantics	college	30	median split	reading comprehension (ND), decoding (TOWRE), nonverbal IQ (Raven's)
Lepola et al. (2012)	inference making	3–5	130	continuous	listening comprehension (Rilven & Rubinov), phonological awareness (rhyme, alliteration), vocabulary (WISC), sentence memory (developmental neuropsychological assessment), inference making (Paris & Paris)
Li and Kirby (2014)	English as a Second Language	13–14	33 UPC, 28 EAC, 30 UGC	regression	reading comprehension (GM), reading fluency (TOWRE), listening comprehension (WJ), nonverbal IQ (Raven's), vocabulary (GM, Ouelette's depth, multiple-meaning, base identification), inference, summary writing
McMaster et al. (2012)	intervention	9–10	56 struggling, 129 average, 59 good comprehenders	cutoffs	reading comprehension (CMB maze, GM)
Muter et al. (2004)	vocabulary; syntax	4–7*	101	continuous	reading comprehension (NARA), decoding (BAS, NARA), phonological processing phonological abilities test, BPVS, Hatcher), syntax (word order correction, morphological generation)
Nation and Snowling (1998)	lexical semantics	8–10	16 S-RCD, 16 TD	cutoffs, group difference	reading comprehension (NARA), decoding (GNRT, NARA), nonverbal IQ (matrix analogies), vocabulary (TOWK)
Nation and Snowling (1999)	lexical semantics	9–10	16 PC, 16 TD	cutoffs, group difference	reading comprehension (NARA), decoding (GNRT, NARA), nonverbal IQ (matrix analogies), vocabulary (TOWK)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Nation et al. (2004)	S-RCD profile	7–9	25 S-RCD, 23 TD	cutoffs, group difference	reading comprehension (NARA), decoding (NARA), listening comprehension (WISC, TLC), nonverbal IQ (BAS), phonological skills (nonword rep, rhyme, phoneme deletion), semantics (BAS), morphosyntax (CELF, past tense elicitation, TROG)
Nation et al. (2010)	S-RCD profile	5–8*	15 S-RCD, 15 TD	cutoffs, discrepancy	reading comprehension (NARA, YARC), decoding (sight words reading, TOWRE, NARA), phonological skills (CTOPP), language (WPPSI, WASI; CELF, NARA, TROG)
Nation et al. (2001)	lexical semantics	8–9	10 S-RCD, 10 TD	cutoffs, group difference	reading comprehension (NARA), decoding (GNRT, NARA)
Oakhill (1982)	memory	7–8	13 S-RCD, 13 TD	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Oakhill (1983)	lexical semantics	7–8	12 S-RCD, 12 TD	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Oakhill (1984)	inference making	7–8	12 S-RCD, 12 TD	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Oakhill and Cain (2012)	S-RCD profile	7–11*	102	continuous	reading comprehension (NARA), decoding (NARA), vocabulary (BVPS, GM), phonological awareness (phoneme deletion, odd-one-out), working memory (digit span, listening span), grammar (TROG), IQ (WISC), inference, comprehension monitoring, story knowledge
Oakhill and Patel (1991)	intervention	9–10	22 S-RCD, 22 TD	group differences	reading comprehension (NARA), vocabulary (GM)
Oakhill and Yuill (1986)	inference making	7–8	26 S-RCD, 26 TD	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Oakhill et al. (2003)	comprehension monitoring	7–8	102	continuous	reading comprehension (NARA), decoding (NARA), vocabulary (BVPS, GM), phonological awareness (phoneme deletion, odd-one-out), working memory (digit span, listening span), grammar (TROG), IQ (WISC), inference, comprehension monitoring, story knowledge
Oakhill et al. (2005)	comprehension monitoring	9–11	12 S-RCD, 12 TD	group differences	reading comprehension (NARA), decoding (NARA), vocabulary (GM)
Ouellette (2006)	vocabulary	9–10	60	continuous	reading comprehension (WRMT), decoding (WJ), word recognition (Adams & Huggins), nonverbal IQ (TONI), vocabulary (TOWK)
Roth et al. (2002)	vocabulary	5–6	88	continuous	reading (TERA), vocabulary (PPVT, TOLD, Boston Naming), grammar (CELF), phonological awareness (blending, elision), metasemantic skill (TLC), narrative, race, gender, SES, nonverbal IQ (Raven's), family literacy
Ryherd et al. (under revision)	S-RCD profile; neurobiology	13–18	32	continuous	reading comprehension (KTEA), decoding (WJ), nonverbal IQ (WASI)
Sesma et al. (2009)	executive function	9–15	10 S-RCD, 16 DYS, 34 TD (9-15 yrs)	cutoffs	reading comprehension (WIAT), decoding (WRMT, WIAT), fluency (GORT), vocabulary (PPVT), IQ (WISC), executive function (ToL), attention (BASC)
Share and Leikin (2004)	high and low-level skills	5	543	continuous	reading comprehension (NARA), decoding (sight words, story words, pseudowords, NARA), oral language (PPVT, NSS, sentence repetition), phonological awareness (phoneme segmentation), IQ (CMMS)

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Share et al. (1984)	decoding	5	543	continuous	reading comprehension (NARA), decoding (sight words, story words, pseudowords, NARA), oral language (PPVT, NSS, sentence repetition), phonological awareness (phoneme segmentation), IQ (CMMS)
Silva and Cain (2015)	inference making	4–6	82	continuous	reading comprehension (NARA), vocabulary (BVPS), grammar (TROG), nonverbal IQ (WPPSI), verbal memory (digit span)
Spencer et al. (2014)	S-RCD profile	5–8	424,430	cutoffs	reading comprehension (Stanford), word fluency (DIBELS), vocabulary (PPVT, GMRT)
Stanovich et al. (1984)	high and low-level skills	6–9	74	continuous	reading comprehension (MAT), decoding (word/pseudoword naming), listening comprehension (DRS), vocabulary (PPVT), nonverbal IQ (Raven's), phonological awareness (strip initial, oddity)
Stothard & Hulme (1995)	working memory	6–8	14 S-RCD, 14 TD, 14 CAM	discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (BVPS), listening comprehension (NARA), grammar (TROG), working memory (digit span, sentence span)
Strasser and del Río (2013)	high and low-level skills	4–6	257	continuous	story comprehension (wordless book), story recall (WM), vocabulary (PPVT, WPPSI), executive function (pencil-tapping, LIPS), working memory (backward digit span, word span), comprehension monitoring, inference making, theory of mind
Tong et al. (2013)	morphosyntax	9–10	15 UPC, 15 EAC	regression	reading comprehension (GM, WRMT), decoding (WRMT), vocabulary (PPVT), nonverbal IQ (WASI), morphological awareness, syntactic awareness, phonological awareness

(*Continues*)

TABLE A1 (Continued)

Reference	Study Focus	Ages Sampled	Sample Size	S-RCD identification method	Assessments
Tong et al. (2011)	morphosyntax	7–10	18 UPC, 18 EAC	regression	reading comprehension (WRMT), decoding (WRMT), reading fluency (TOWRE), nonverbal IQ (WASI), vocabulary (WASI), naming (RAN), phonological awareness (CTOPP), orthographic processing
van der Schoot et al. (2009)	comprehension monitoring	10–12	32 S-RCD, 32 TD	cutoffs; discrepancy	reading comprehension (CITO), decoding (Dutch word reading test), IQ (WISC), vocabulary (CITO)
Van Dyke et al. (2016, March)	comprehension monitoring	13–19	16 S-RCD, 16 TD	cutoffs	reading comprehension (KTEA), decoding (WJ), nonverbal IQ (WASI)
Yuill and Joscelyne (1988)	narrative	7–8	22 S-RCD, 22 TD	cutoffs; discrepancy	reading comprehension (NARA), decoding (NARA)
Yuill and Oakhill (1991)	S-RCD profile	7–8	96 S-RCD, 96 TD	cutoffs, discrepancy	reading comprehension (NARA), decoding (NARA), vocabulary (GM)

*indicates a longitudinal study with multiple time points

Note. ART = Author Recognition Test; BAS = British Ability Scales; BASC = Behavioral Assessment System for Children; BVPS = British Picture Vocabulary Scales; CBM = Curriculum-Based Measurement; CELF = Clinical Evaluation of Language Fundamentals; CITO = Test for Reading Comprehension of the Dutch National Institute for Educational Measurement; CMMS = Columbia Mental Maturity Scale; CST = California Synonym Test; CTOPP = Comprehensive Test of Phonological Processing; DAB = Diagnostic Achievement Battery; DIBELS = Dynamic Indicators of Basic Early Literacy Skills; DRS = Diagnostic Reading Scales; DTLA = Detroit Test of Learning Aptitude; ERRNI = Expression, Reception, and Recall of Narrative Instrument; GM = Gates–MacGinitie Vocabulary Test; GORT = Gray Oral Reading Test; GNRT = Graded Nonword Reading Test; GRADE = Group Reading Assessment and Diagnostic Evaluation; INETOP = Test de Lecture Silencieuse; KTEA = Kaufmann Test of Educational Achievement; LIPS = Leiter International Performance Scale; LPELR = La pipe et le rat; MAT = Metropolitan Achievement Tests; NARA = Neale Analysis of Reading Ability; ND = Nelson–Denny Reading Test; NSS = Northwestern Syntax Screening Test; PAT = Progressive Achievement Test in Reading Comprehension; PIAT = Peabody Individual Achievement Test; PPVT = Peabody Picture Vocabulary Test; PVCL = Prova di Valutazione della Comprensione Linguistica; QRI = Qualitative Reading Inventory; RAN = Rapid Automatized Naming; RAVLT = Rey Auditory Verbal Learning Task; SDRT = Stanford Diagnostic Reading Tests; TERA = Test of Early Reading Achievement; TLC = Test of Language Competence; TOLD = Test of Language Development; TONI = Test of Nonverbal Intelligence; ToL = Tower of London; TOR = Test for Listening Comprehension; TOWK = Test of Word Knowledge; TORSW = Timed Oral Reading of Single Words; TOWRE = Test of Word Reading Efficiency; TROG = Test for Reception of Grammar; TRT = Title Recognition Test; WAIS = Wechsler Adult Intelligence Scale; WASI = Wechsler Abbreviated Scales of Intelligence; WIAT = Wechsler Individual Achievement Test; WISC = Wechsler Intelligence Scale for Children; WMTB-C = Working Memory Test Battery for Children; WJ = Woodcock–Johnson Tests of Achievement; WPPSI = Wechsler Preschool and Primary Scale of Intelligence; WRAT = Wide Range Achievement Test; WRMT = Woodcock Reading Mastery Tests; YARC = York Assessment of Reading Comprehension; TD = typically developing