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A meta-analytic review of comprehension deficits in students with dyslexia

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Abstract

Beyond the established difficulties of individuals with dyslexia in word recognition and spelling, it remains unclear how severe their difficulties in comprehension are. To examine this, we performed a meta-analytic review. A random-effects model analysis of data from 76 studies revealed a large deficit in reading comprehension in individuals with dyslexia compared to their chronological-age (CA) controls ($g = 1.43$) and a smaller one compared to their reading-level (RL) matched controls ($g = 0.64$). Individuals with dyslexia also differed significantly from their CA controls in listening comprehension ($g = 0.43$). Results further showed significant heterogeneity in the effect sizes that was partly explained by orthographic consistency (the deficits were larger in languages with low orthographic consistency) and vocabulary matching (the deficits were larger in studies in which the groups were not matched on vocabulary). These findings suggest, first, that individuals with dyslexia experience significant difficulties in both reading and listening comprehension, but the effect sizes are smaller than those reported in the literature for word reading and spelling. Second, our findings suggest that the deficits in reading comprehension are likely a combination of deficits in both decoding and oral language skills.

Keywords Comprehension · Dyslexia · Meta-analysis · Orthographic consistency · Reading · Writing system

Developmental dyslexia, defined as a persistent and unexpected difficulty in developing age- and experience-appropriate word reading skills, is one of the most common learning disabilities affecting 5–10% of all school-age children (Snowling et al., 2020b). Beyond the established difficulties of individuals with dyslexia in word reading skills and in spelling,

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researchers have argued that they may also experience difficulties in reading comprehension (often described as a secondary consequence of dyslexia; Simmons & Singleton, 2000). To date, even though a handful of meta-analyses have examined the difficulties of individuals with dyslexia in word/nonword reading skills (e.g., Melby-Lervåg et al., 2012; Parrila et al., 2020a; Reis et al., 2020; Swanson & Hsieh, 2009), to our knowledge, only one has examined the difficulties of individuals with dyslexia in reading comprehension and it included studies with adults. More specifically, Reis et al. (2020) estimated the average effect size in reading comprehension to be $d = 0.72$ (adults with dyslexia performing more poorly than their chronological-age controls), which was substantially lower than the one for word reading ($d = 1.81$), pseudoword reading ($d = 2.03$), and spelling ($d = 1.73$). In addition, no meta-analyses have been conducted on listening comprehension, even though there is substantial evidence to suggest that individuals with dyslexia—with or without comorbid developmental language disorders—have language deficits outside the phonological domain (see Adlof & Hogan, 2018, for a review). Thus, the purpose of this meta-analysis was twofold: (a) to replicate Reis et al.'s (2020) findings in studies with children and adolescents with dyslexia, and (b) to examine the extent to which individuals with dyslexia experience deficits also in listening comprehension.

Reading comprehension deficits in dyslexia

In one of the most popular theories of reading, the "Simple View of Reading," Gough and Tunmer (1986) proposed that reading comprehension (RC) is the product of decoding (D) and linguistic comprehension (LC), (RC = D X LC). They further classified three types of reading disorders (i.e., dyslexia, hyperlexia, and "garden variety" poor reading)[1] and suggested that all three types would result in poor reading comprehension, but for different reasons. In individuals with dyslexia, poor reading comprehension is thought to be a direct consequence of poor decoding, which, in turn, is a result of poor phonological skills (e.g., Bishop & Snowling, 2004; Vellutino et al., 2004). In contrast, reading comprehension in individuals with developmental language disorders is compromised by weaknesses in broader language skills (e.g., Bishop & Snowling, 2004; Nation et al., 2004). However, these reading disorders frequently co-occur with each other (e.g., Adlof et al., 2017; Bishop et al., 2009; Catts et al., 2005) and children with comorbid dyslexia and developmental language disorders often experience more severe comprehension difficulties than children with either dyslexia or developmental language disorders (e.g., Catts et al., 2005; Snowling et al., 2020a).

Longitudinal and cross-sectional studies that examined the role of decoding and linguistic comprehension in reading comprehension have also shown that their contribution changes over time (e.g., Adlof et al., 2006; Foorman et al., 2018; Tilstra et al., 2009; Torppa et al., 2016). Whereas decoding appears to exert a larger role in early grades, linguistic comprehension dominates the prediction of reading comprehension in later grades. On the basis of this, we would expect that the reading comprehension difficulties of children with dyslexia may decrease over time, while those of children with developmental

[1] We use the term "hyperlexia" here as it was used by Gough and Tunmer (1986). Today, researchers use the term developmental language disorders.

language disorders may increase over time. This may explain the moderate effect size of $d=0.72$ in adults with dyslexia reported by Reis et al. (2020).

Although there are good theoretical reasons to expect significant deficits in reading comprehension in individuals with dyslexia, evidence from empirical studies is mixed. On the one hand, some studies have shown that individuals with dyslexia experience significant difficulties in reading comprehension (e.g., Caravolas et al., 2005; Constantinidou & Stainthorp, 2009; Ferrer et al., 2015; Swanson & Ashbaker, 2000). On the other hand, some studies have shown that individuals with dyslexia perform equally well as their controls in reading comprehension (e.g., Fletcher et al., 1994; Goulandris et al., 2000; Miller-Shaul, 2005a, b; Parrila et al., 2020b).

Moderators

In view of the mixed findings regarding the presence of reading comprehension deficits in individuals with dyslexia, it is reasonable to expect significant heterogeneity in the effect sizes, which then requires an examination of the role of possible moderators. For the purpose of this meta-analysis, we examined the role of four moderators (i.e., grade level, writing system, orthographic consistency, and selection criteria/vocabulary matching) that have been found in previous meta-analyses on dyslexia to account for some of the observed heterogeneity (e.g., Araújo & Faísca, 2019; Melby-Lervåg et al., 2012; Parrila et al., 2020a; Reis et al., 2020) as well as the role of two moderators that are more closely related to reading comprehension outcomes (i.e., type of response and reading mode).

Grade level

Because the contribution of decoding to reading comprehension declines over time (e.g., Adlof et al., 2006; Foorman et al., 2018), it is possible to observe differences in the effect sizes depending on the grade level of the participants. More specifically, the effect sizes might be larger in earlier grades (i.e., Grades 1 to 5) than in later grades (i.e., Grades 6 to 12). However, it is also possible that the declining effects of decoding on reading comprehension might be offset by the exacerbated difficulties of children with dyslexia in broader language skills (e.g., vocabulary). Because older students with dyslexia find reading more effortful, they read less and, consequently, have less exposure to academic vocabulary. This, in turn, would negatively impact their reading comprehension. If this is the case, then grade level would not be a significant moderator.

Writing system and orthographic consistency Effect sizes may also vary as a function of the writing system (alphabetic vs. non-alphabetic) or degree of orthographic consistency (high, medium, and low) among the alphabetic orthographies. In regard to writing system, we know that children learning to read Chinese (a non-alphabetic orthography) must learn approximately 3000 characters by the end of elementary school in order to be fluent readers (Hanley, 2005). In addition, because there is little systematic relationship between the graphic symbols (i.e., characters) and their pronunciation, Chinese children must learn most characters by heart. In light of this, it should be harder for Chinese children (with or without dyslexia) to comprehend text compared to children learning to read an alphabetic orthography. In addition, Chinese characters represent meaning. Thus, if a character is not recognized correctly, both reading accuracy and comprehension will be affected. In contrast, in alphabetic orthographies where letters are used to represent sounds, even if a word is not read entirely correctly, an individual can still gain access to the meaning by relying on partial cues within the word (e.g., Pedersen et al., 2016; Tobia & Bonifacci, 2015).

In regard to orthographic consistency, one would expect larger deficits in reading comprehension in children learning to read an opaque orthography (e.g., English, French) than a transparent orthography (e.g., Finnish, Greek). Again, this may relate to how efficient children can decode words, which allows them to reallocate cognitive resources for reading comprehension. Drawing on the "Simple View of Reading" (Gough & Tunmer, 1986), if decoding is a significant predictor of reading comprehension and decoding poses larger difficulties for dyslexic children learning to read an opaque orthography than a transparent orthography (see Carioti et al., 2021, for evidence from a recent meta-analysis), then we should also expect larger deficits in reading comprehension for children with dyslexia in opaque orthographies.

Sample selection criteria and vocabulary matching

An important issue identified in previous meta-analyses is how participants with dyslexia are selected (e.g., Melby-Lervåg et al., 2012; Parrila et al., 2020a). For example, some researchers selected their participants with dyslexia on the basis of a former diagnosis (e.g., Bazen et al., 2020; Grant et al., 2007; Re et al., 2011). In contrast, some researchers selected their participants following screening with standardized reading/spelling tasks (e.g., Ghelani et al., 2004; Layes et al., 2015; Meng et al., 2011a, 2011b). Depending on the approach used there might be different implications for the nature and severity of the reading difficulties, particularly when viewed in conjunction with reading intervention. Typically, children with a diagnosis of dyslexia receive targeted reading intervention. Assuming reading interventions have positive effects on children's reading performance (see Gersten et al., 2020; Scammacca et al., 2015, for evidence from meta-analyses), then the reading difficulties of these children may not be as severe compared to those who do not have such diagnosis and have not possibly received targeted reading intervention.

A related issue is what measures of general cognitive ability researchers use to match their groups (see Deacon et al., 2008, for a detailed discussion). For the purpose of this meta-analysis, we focused on the role of verbal IQ (usually measured with a vocabulary test). This is important in light of evidence that many children with dyslexia have broader language difficulties that can also lead to reading comprehension difficulties (e.g., Adlof & Hogan, 2018; Bishop & Snowling, 2004). Arguably, matching groups on vocabulary should reduce group differences in reading comprehension.

Reading comprehension outcomes

We now have ample evidence to suggest that the type of reading comprehension task used in a given study may influence the results (e.g., Calet et al., 2020; Colenbrander et al., 2017; Das & Georgiou, 2016; Keenan & Meenan, 2014). Researchers have argued that reading comprehension tests do not necessarily assess the same array of cognitive processes (e.g., Cutting & Scarborough, 2006; Fletcher, 2006). In addition, factors such as presentation structure (e.g., whether the text is available while answering the questions, text length, and question type) and response format (e.g., multiple choice, open ended questions, cloze tasks, picture matching may produce different comprehension scores (see Collins et al., 2018, for a review). For example, in Woodcock-Johnson Passage Comprehension (Woodcock et al., 2001)—a cloze format task—children are asked to read a sentence or a short passage and then provide the missing word that accurately completes the meaning of the sentence; in this case, accurate decoding is essential in providing the correct answer. In contrast, other formats that use longer texts do not depend as much on decoding skills.[2] The effect of response format has been documented in Collins et al.'s (2018) meta-analysis with children with and without reading difficulties.[3] They reported significantly larger differences between groups in picture matching (Hedges' $g = -1.80$) than in retell (Hedges' $g = -0.60$). Beyond response format, we examined here whether individuals performed the comprehension tasks following oral reading or silent reading. We expected larger differences between groups in comprehension tasks completed after oral reading because this adds another layer of complexity to the task—motor programming—in which dyslexics have been found to experience difficulties (e.g., Bertucci et al., 2003; Catts, 1989; Fawcett & Nicolson, 2002).

The present study

The present study aimed to answer the following two questions:

1. To what extent do individuals with dyslexia experience difficulties in reading and listening comprehension? Based on the findings of Reis et al. (2020), we expected large deficits in reading comprehension. At the same time, because children with dyslexia may also experience broader language deficits (Adlof & Hogan, 2018), we also expected to find significant deficits in listening comprehension (but perhaps not a pronounced as in reading comprehension because not all children with dyslexia experience oral language difficulties; see Catts et al., 2005).
2. To what extent effect sizes may vary as a function of grade level, writing system, orthographic consistency, selection criteria, type of response, reading mode, and vocabulary matching? We expected that the effect sizes would be moderated by writing system (effects sizes being larger in non-alphabetic orthographies), orthographic consistency (effect sizes being larger in languages of low orthographic consistency), and vocabulary matching (effect sizes being larger in studies in which groups were not matched on vocabulary). We did not formulate any specific hypotheses for the other moderators because of the mixed findings of previous studies.

Because studies on dyslexia may include not only samples of chronological-age (CA) controls but also samples of reading-level (RL) controls (i.e., younger, typipically-developing children matched to older children with dyslexia on reading ability), we also examined in this meta-analysis if there are differences between children with dyslexia and their

[2] We acknowledge though that the type of comprehension task may differ according to the age of the participants. Cloze tasks and picture matching tasks are more frequently used in studies with younger participants and multiple choice or open-ended question tasks are more frequently used in studies with older participants. In addition, even within the same task (e.g., Woodcock-Johnson Passage Comprehension), ítems for younger ages include pictures that give hints to the answer, but ítems for older children do not include pictures.

[3] Notice that Collins et al. (2018) did not use only studies with dyslexic children. Their sample of studies included also struggling readers, children at-risk for reading difficulties, and low achievers in reading.

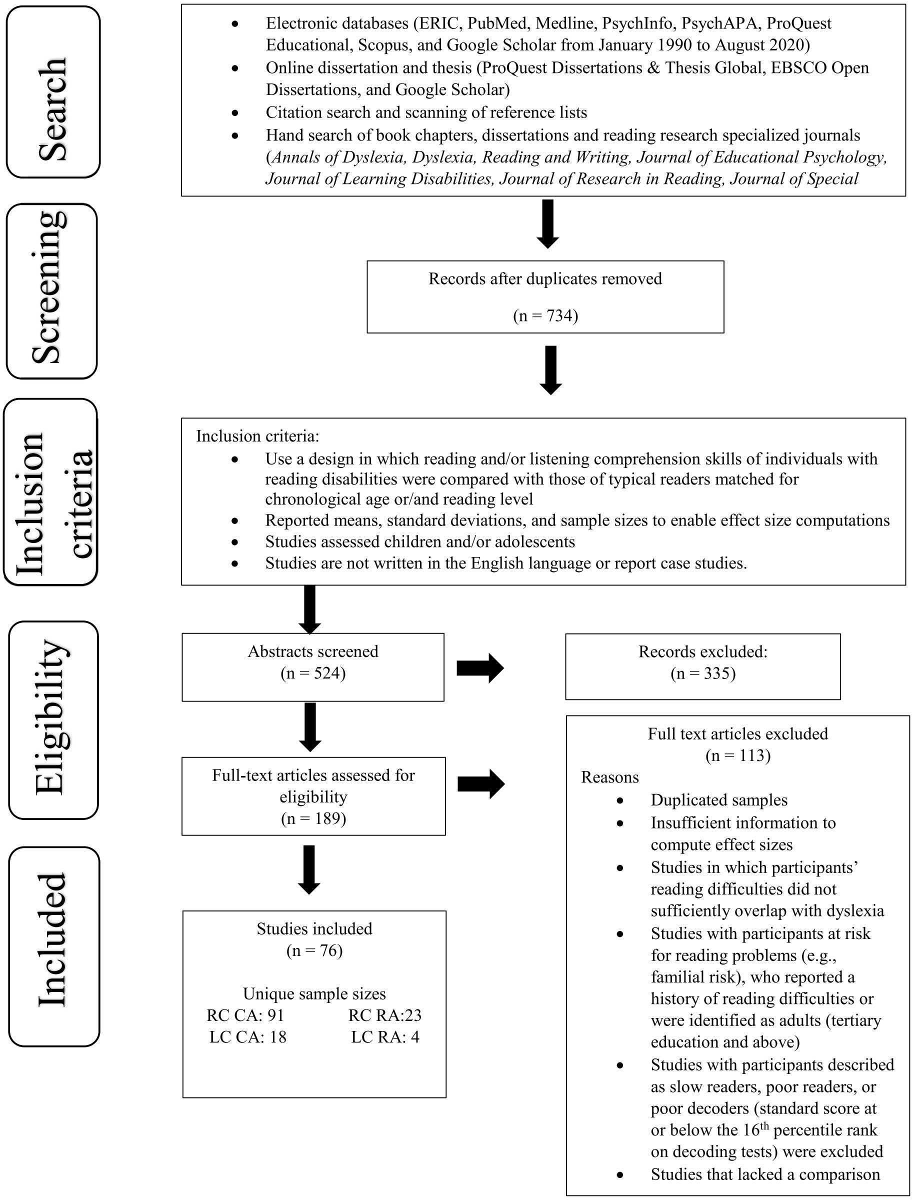

Fig. 1 Flow diagram for the search and inclusion on studies

RL-matched controls in reading and listening comprehension. This is interesting in light of recent evidence showing that matching children with dyslexia to their RL controls in one reading task does not mean that they are also matched on other reading tasks (Parrila et al., 2020a; see also Zoccolotti, 2020).

Methods

Study selection and inclusion/exclusion criteria

The data collection, coding, and selection process are summarized in Fig. 1. To identify the studies for the meta-analysis, we first searched electronic databases (i.e., ERIC, PubMed, Medline, PsycINFO, ProQuest Educational, Scopus, and Google Scholar) for publications in English from January 1990 to August 2020. To identify the initial pool of studies a combination of terms related to reading disabilities (*reading disability(ies)* OR *learning disability(ies)* OR *reading difficulty(ies)* OR *poor reader(s)* OR *at-risk reader(s)* OR *dyslexia* OR *special education*) crossed with terms related to reading and listening comprehension (*reading comprehension* OR *listening comprehension*) was used as a first step.

Additionally, nine journals that specialize in the study of reading and learning disabilities were searched by hand: *Annals of Dyslexia*, *Dyslexia*, *Reading and Writing*, *Journal of Educational Psychology*, *Journal of Learning Disabilities*, *Journal of Research in Reading*, *Journal of Special Education*, *Learning Disabilities Research & Practice*, and *Scientific Studies of Reading*. For all journal articles that met inclusion criteria and meta-analyses that examined cognitive and literacy skills in dyslexia (e.g., Carioti et al., 2021; Collins et al., 2018; Melby-Lervåg et al., 2012; Parrila et al., 2020a; Reis et al., 2020), we further checked their reference lists to identify additional articles for review and possible inclusion. Finally, we contacted researchers who published on the topic but did not provide sufficient information for the calculation of effect sizes to share their data.

Studies were included if they reported quantitative data on reading and/or listening comprehension from children and adolescents with dyslexia up to tertiary education. We also included studies whose participants had a specific learning disorder (SLD) with impairment in reading since this term is used in DSM-V as an alternative to dyslexia. Considering that dyslexia is characterized by low decoding skills (Catts et al., 2005; Cutting et al., 2013), we also included studies in which participants had either a former diagnosis of dyslexia or were selected on the basis of decoding scores at or below the 16^{th} percentile or its equivalent (i.e., a standard score of 85) in word reading assessments.

Studies were excluded (a) if the participants were described as being at risk for reading difficulties (e.g., familial risk), or had a history of reading difficulties without further testing, (b) if the participants were described as slow readers, poor readers, or poor decoders; and (c) if the participants with SLD were identified on the basis of poor reading comprehension. Finally, we excluded studies that lacked a comparison group of typical readers or studies with insufficient data to determine effect sizes. Publications from the same author(s) were also checked to ensure that duplicate datasets were not included in the meta-analysis.

For reading comprehension, our final sample included 76 studies with 91 unique samples of CA controls and 23 unique samples of RL controls. For listening comprehension, our sample included 14 studies with 18 unique samples of CA controls and 4 unique samples of RL controls. Due to the small number of studies in the latter group, we did not perform any moderator analyses with this group.

Coding procedures and recorded variables

Only studies published in English were included in our meta-analysis. The data were recorded into different coding spreadsheets according to the type of comprehension outcome (i.e., reading, listening) and the type of control group (i.e., CA or RL). The second, third, and fourth author (doctoral students in educational psychology with extensive training in meta-analyses) entered the data in the spreadsheets and then compared them for accuracy. The intercoder agreement ranged from 97 to 98%. The discrepancies between the coders were resolved after discussing the studies with the first author or, in the case of two studies, after obtaining more information from the authors.

To enable effect size comparisons, means, standard deviations, and sample sizes were extracted for each measure of reading and listening comprehension in each study. Variables coded from each study included task and group characteristics as noted below (see Appendices 1–3).

Task characteristics

We coded two types of information in regard to the reading comprehension outcomes: information about the response format of the comprehension tasks (i.e., multiple choice, cloze task, picture matching, and open-ended questions) and whether the reading comprehension task was completed following oral reading or silent reading (coded as reading mode).

Sample and group characteristics

First, we coded information on participants' age and grade level. The participants' age ranged from 6 to 17 years. For the moderator analysis, the grade levels were assigned to two groups (the first group comprised G1 to G5 and the second G6 to G12). For the dyslexia/RD groups, the sample selection criteria (i.e., former diagnosis and following screening) was also coded as a moderator. The "former diagnosis" category included studies that identified their sample as individuals with dyslexia based on previous reports (see e.g., Grant et al., 2007; Re et al., 2011; Temple et al., 2001). In turn, studies coded as "following screening" included samples identified through the assessment of their word reading skills.

Next, we assigned the orthographies in which the studies were conducted into two categories (alphabetic and non-alphabetic). The alphabetic category included the European languages and Hebrew (Verhoeven & Perfetti, 2017). The studies in the non-alphabetic category were all conducted in Chinese. Furthermore, based on Seymour et al. (2003), we classified the alphabetic orthographies into three categories: low orthographic consistency: English, French, Danish, and Hebrew; medium orthographic consistency: Dutch, Portuguese, and Swedish; and high orthographic consistency: Greek, Italian, German, Spanish, Norwegian, and Finnish. Finally, the studies in which vocabulary was assessed were assigned into two categories: (1) groups were matched on vocabulary (19 studies) and (2) groups were not matched on vocabulary (22 studies).

Moderators

In each study, we coded seven important moderators that could help us explain some of the anticipated variability in the effect sizes: (a) writing system, (b) grade level, (c) selection criteria, (d) orthographic consistency, (e) reading mode, (f) response format, and (g) vocabulary control. All of the moderators included in our meta-analysis were categorical moderators.

Statistical analysis

The metafor package of the R statistical program (Viechtbauer, 2010) and specifically the *escalc* function was used to calculate each effect size (Hedges' *g*). We chose "SMD" as the option in order to automatically correct the positive bias in the standardized mean difference (Hedges, 1981). Whenever possible, we used the means and standard deviations to calculate Hedges' *g*, or various combinations of information (e.g., *t* statistics, *p* values, sample sizes), when means and standard deviations were not available. For studies including both CA and RL control groups in reading and listening comprehension, a separate effect size was calculated for each of the four comparisons. Robust variance estimation (RVE) meta-analysis models were then employed to obtain summary effect sizes from calculated effect sizes using the robumeta package (Fisher & Tipton, 2015). Whether or not the overall effect size differed from zero was tested with a *t* test. Tau^2 was reported to examine the variation in effect sizes between studies. Tau^2 estimates the variance in the true effect sizes and values are in the same metric as the effect size (Borenstein et al., 2009). I^2 statistics were used to assess heterogeneity and identify their potential sources, which is the proportion of total variation between effect sizes that is caused by real heterogeneity rather than chance.

We also used random effects model to calculate the overall effect sizes by using the *metafor* package in order to simplify our analyses and to present a single effect size for each sample. The results of the random effects model analyses including forest plots and Galbraith plots are included in the Supplementary Material. Similar results are obtained when using random effects models and RVE models (see Footnote #4).

Moderator variables were also explored as potential sources of additional variance in the effect sizes. All moderators in the present study were categorical variables, so dummy coding must be used when using RVE models (Fisher & Tipton, 2015). Considering the similar results of random effects models and smaller statistical power using dummy coding in RVE models, linear models in random effects models were used to predict the study's outcome from the moderator variables. The degree of difference between the subsets of studies was tested with a *Q* test (Hedges and Olkin, 2014). A significant value on this test indicates a reliable variability between the effect sizes.

Publication bias

We conducted the Rank Correlation and Egger's Regressions tests to examine for possible publication bias. In addition, we created funnel plots to assess the asymmetrical distribution of the studies around the mean effect size, which is also an indicator of publication bias (Borenstein et al., 2009). In the funnel plot, the sample size is plotted on the *y* axis and the effect size on the *x* axis. In the presence of bias, the funnel should be asymmetric. Finally, in order to examine the impact of studies that might be missing from the analysis, the "trim and fill" method for random-effects models (Duval & Tweedie, 2000) was used.

Results

Meta-analytic results

The RVE model demonstrated that the overall mean effect size differences between the DYS and CA/RL control groups in reading comprehension were significant (see Table 1). For the CA-DYS comparison, the overall mean effect size across 91 effects was 1.430 ($p < 0.0001$, 95% CI = [1.250, 1.610]), favoring the CA group. The overall mean effect size for the RL-DYS comparison (estimated from 23 effects) was 0.640 ($p = 0.0344$, 95% CI = [0.052, 1.230]) favoring the RL group. The overall mean effect size for the CA-DYS comparison in listening comprehension was also significant ($g = 0.432$, $p = 0.0045$, 95% CI = [0.152, 0.712]; see Table 1) and was favoring the CA group. The overall mean effect size for the RL-DYS comparison in listening comprehension was not significant.[4]

The heterogeneity analysis further showed that the variation between studies was significant for both the CA-DYS ($I^2 = 89.55\%$, $Tau^2 = 0.5810$, $p < 0.0001$) and the RL-DYS ($I^2 = 95.53\%$, $Tau^2 = 1.0879$, $p = 0.0344$) group comparisons in reading comprehension, as well as for the CA-DYS ($I^2 = 86.51\%$, $Tau^2 = 2828$, $p = 0.0045$) group comparison in listening comprehension.

Moderator analyses

Orthographic consistency and vocabulary control significantly explained some of the variability in the effect sizes in the CA-DYS comparisons in reading comprehension (see Table 2). More specifically, the effect size was larger in the low orthographic consistency than in the medium orthographic consistency group ($g = 1.5324$ for low orthographic consistency and $g = 0.8816$ for medium orthographic consistency, $Q = 5.5349$, $p = 0.0437$). In addition, the effect size was larger in studies in which the groups were not matched on vocabulary ($g = 1.5893$ for groups not matched on vocabulary and $g = 1.1284$ for groups matched on vocabulary, $Q = 5.0438$, $p = 0.0247$). None of the moderators explained the variability in the effect sizes in the RL-DYS comparisons in reading comprehension (see Table 3).

Finally, as shown in Table 4, orthographic consistency explained the variability in the effect sizes in the CA-DYS comparisons in listening comprehension. More specifically, the effect size was larger in the low orthographic consistency than in the high orthographic

[4] Notice that similar results are obtained when using random effects models. More specifically, when we reran the analyses using robumeta, in reading comprehension, the overall mean effect for the CA-DYS comparison was 1.4374 ($p < 0.0001$, 95% CI = [1.2572, 1.6175]) and the overall mean effect for the RL-DYS comparison was 0.6509 ($p = 0.0243$, 95% CI = [0.0845, 1.2173]). In listening comprehension, the overall mean effect for the CA-DYS comparison was 0.4558 ($p = 0.0015$, 95% CI = [0.1737, 0.7378]) and the overall mean effect for the RL-DYS comparison was 0.0222 ($p = 0.8753$, 95% CI = [-0.2548, 0.2991]). The results of this analysis can be found in Supplementary Material.

Table 1 Meta-analytic results: overall standardized mean differences for the control group and the dyslexic group

Outcomes	Comparison	*k*	*n*	*g*	*t*	95% CI		*p* value	I^2	Tau^2
Reading	CA-DYS	91	121	1.430	15.400	[1.250, 1.610]		< 0.0001	88.6452	0.5810
Comprehension	RL-DYS	23	26	0.640	2.260	[0.052, 1.230]		0.0344	92.7648	1.0879
Listening	CA-DYS	18	23	0.432	3.230	[0.152, 0.712]	0.0045		84.6528	0.2828
Comprehension	RL-DYS	4	5	0.021	0.242	[−0.261, 0.303]		0.8250	8.7249	0.0078

k number of samples, *n* number of effect sizes, *g* effect size.

Table 2 Results of moderator analyses in reading comprehension for the CA and DYS groups

Moderator variable	Number of effect sizes (*k*)	*g*	*p* value	95% CI	Difference in *d* (highest-lowest category)	Significance test (*Q*)	*p* value
1. Writing system					0.4461	2.5317	0.1116
Alphabetic	80	1.3832	< 0.0001	[1.1926, 1.5738]			
Non-alphabetic	11	1.8293	< 0.0001	[1.3139, 2.3446]			
2. Grade level					0.3126	2.2548	0.1332
G1 to G5	43	1.5161	< 0.0001	[1.2664, 1.7657]			
G6 to G12	26	1.2035	< 0.0001	[0.8807, 1.5262]			
3. Selection criteria					0.0219	0.0125	0.9110
Former diagnosis	40	1.4843	< 0.0001	[1.2026, 1.7660]			
Following screening	45	1.4624	< 0.0001	[1.2002, 1.7245]			
4. Orthographic consistency					0.6508	5.5349	0.0437
Low	56	1.5324	< 0.0001	[1.3069, 1.7578]			
Medium	8	0.8816	0.0036	[0.2874, 1.4758]			
High	17	1.1594	< 0.0001	[0.7450, 1.5737]			
5. Reading mode					0.2720	1.2712	0.2595
Oral	19	1.2104	< 0.0001	[0.8181 1.6028]			
Silent	42	1.4824	< 0.0001	[1.2186 1.7462]			
6. Response format					0.5511	4.0873	0.2522
MC	37	1.3906	< 0.0001	[1.1103, 1.6708]			
Cloze tasks	24	1.7447	< 0.0001	[1.3959, 2.0936]			
Picture matching	11	1.1936	< 0.0001	[0.6870, 1.7003]			
Open-ended	13	1.3457	< 0.0001	[0.8808, 1.8106]			
7. Vocabulary control					0.4609	5.0438	0.0247
Matched on vocabulary	19	1.1284	< 0.0001	[0.8325, 1.4244]			
Not matched on vocabulary	22	1.5893	< 0.0001	[1.3170, 1.8616]			

k number of effect sizes, *g* estimated Hedges' *g* for subsets of studies belonging to different categories of the moderator variable, *Q* significant *Q* test value for categorical variables, *MC* multiple choice.

Table 3 Results of moderator analyses in reading comprehension for the RL and DYS groups

Moderator variable	Number of effect sizes (k)	g	p value	95% CI	Difference in d (highest-lowest category)	Significance test (Q)	p value
1. Writing system					0.1653	0.0604	0.8058
Alphabetic	17	0.6084	0.0773	[−0.0666, 1.2834]			
Non-alphabetic	6	0.7737	0.1803	[−0.3581, 1.9056]			
2. Grade level					0.0077	0.0001	0.9910
G1 to G5	9	0.3302	0.4246	[−0.4803, 1.1407]			
G6 to G12	5	0.3379	0.5375	[−0.7362, 1.4120]			
3. Selection criteria					0.8865	2.4806	0.1153
Former diagnosis	13	1.0362	0.0053	[0.3077, 1.7647]			
Following screening	10	0.1497	0.7231	[−0.6786, 0.9781]			
4. Orthographic consistency					0.6622	0.5785	0.7488
Low	11	0.8293	0.0908	[−0.1319, 1.7906]			
Medium	1	0.4306	0.7901	[−2.7396, 3.6007]			
High	5	0.1671	0.8194	[−1.2675, 1.6016]			
5. Reading mode					1.4503	2.8790	0.0897
Oral	5	−0.0909	0.8963	[−1.4573, 1.2755]			
Silent	10	1.3594	0.0060	[0.3902, 2.3287]			
6. Response format					0.4698	0.3664	0.8326
MC	7	0.6540	0.2063	[−0.3603, 1.6684]			
Cloze tasks	5	0.1842	0.7679	[−1.0392, 1.4076]			
Picture matching	6	0.5831	0.2980	[−0.5149, 1.6811]			
Open-ended	-						
7. Vocabulary control					0.2595	0.1214	0.7275
Matched on vocabulary	10	0.1895	0.6027	[−0.5242, 0.9033]			
Not matched on vocabulary	3	−0.0700	0.9142	[−1.3440, 1.2039]			

k number of effect sizes, g estimated Hedges' g for subsets of studies belonging to different categories of the moderator variable, Q significant Q test value for categorical variables, *MC* multiple choice.

Table 4 Results of moderator analyses in listening comprehension for the CA and DYS groups

Moderator variable	Number of effect sizes (*k*)	*g*	*p* value	95% CI	Difference in *d* (highest-lowest category)	Significance test (*Q*)	*p* value
1. Writing system					No moderator analyses		
Alphabetic	18	0.4558	0.0015	[0.1737, 0.7378]			
Non-alphabetic	0	-	-	-			
2. Grade					0.6659	1.7073	0.1913
G1 to G5	12	0.5057	0.0064	[0.1419, 0.8694]			
G6 to G12	2	−0.1602	0.7357	[−1.0904, 0.7700]			
3. Selection criteria					0.4237	2.2482	0.1338
Former diagnosis	8	0.2103	0.3304	[−0.2132, 0.6338]			
Following screening	10	0.6340	0.0005	[0.2770, 0.9911]			
4. Orthographic consistency					1.0037	6.1311	0.0466
Low	11	0.6689	< 0.0001	[0.3555, 0.9824]			
Medium	5	0.2425	0.3463	[−0.2621, 0.7471]			
High	2	−0.3348	0.4171	[−1.1434, 0.4739]			
5. Response format					0.1265	0.2018	0.9040
MC	3	0.4358	0.1076	[−0.0951, 0.9667]			
Picture matching	5	0.3698	0.0680	[−0.0274, 0.7671]			
Open-ended	5	0.4963	0.0110	[0.1135, 0.8790]			
6. Vocabulary control					0.2084	0.2026	0.6526
Matched on vocabulary	5	0.0934	0.7189	[−0.4151, 0.6018]			
Not matched on vocabulary	2	−0.1150	0.7642	[−0.8668, 0.6367]			

k number of effect sizes, *g* estimated Hedges' *g* for subsets of studies belonging to different categories of the moderator variable, *Q* significant *Q* test value for categorical variables, *MC* multiple choice.

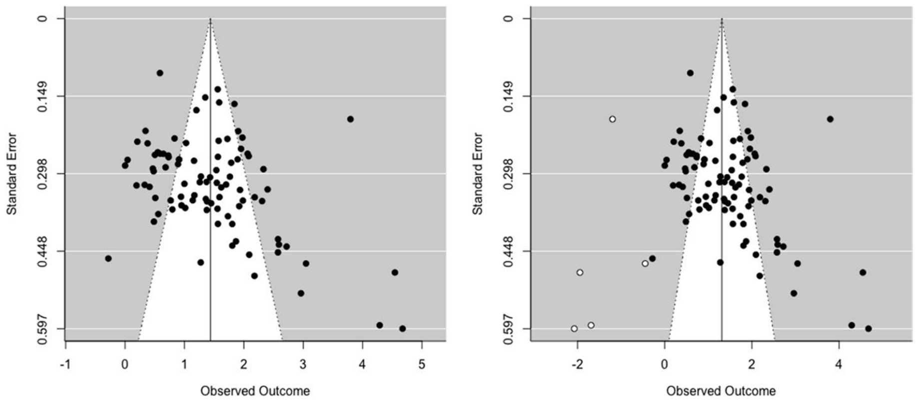

Fig. 2 Funnel plot for CA-DYS (left) and funnel plot with imputed samples for CA-DYS (right) in reading comprehension

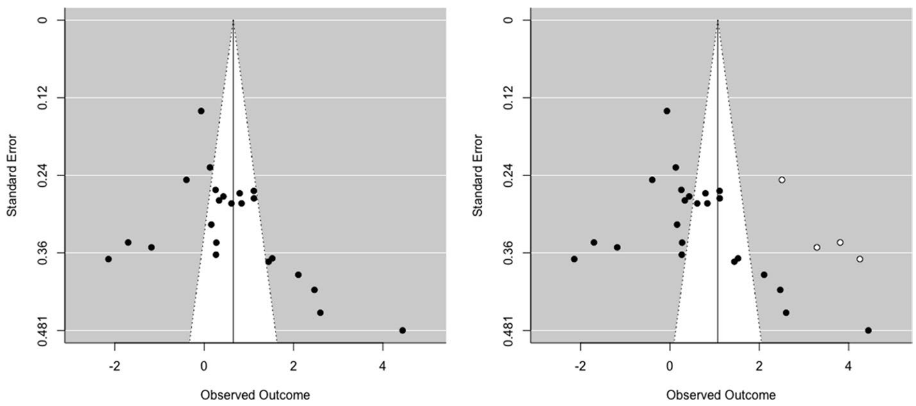

Fig. 3 Funnel plot for RL-DYS (left) and funnel plot with imputed samples for RL-DYS (right) in reading comprehension

consistency group ($g=0.6689$ for the low orthographic consistency group and $g=-0.3348$ for the high orthographic consistency group, $Q=6.1311$, $p=0.0466$).

Publication bias

The results of Egger's Regression Test suggested the presence of publication bias in the model with the CA-DYS comparison ($z=4.3181$, $p<0.0001$) and the RL-DYS comparison ($z=2.5115$, $p=0.0120$) in reading comprehension, and the CA-DYS comparison ($z=-2.7026$, $p=0.0069$) in listening comprehension. As suggested by the Rank Correlation Test, the Kendall's tau for the comparisons in reading comprehension (tau = 0.2083, $p=0.0033$ for the CA-DYS comparison; tau = 0.3518, $p=0.0189$ for the RL-DYS comparison) and the CA-DYS comparison in listening comprehension (tau = -0.4641, $p=0.0067$) were significant. Subsequently, the "trim and fill" analyses were performed for the CA/

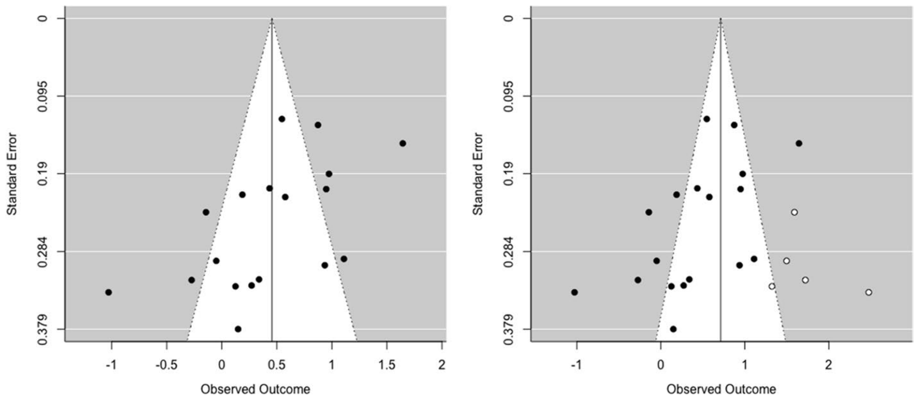

Fig. 4 Funnel plot for CA-DYS (left) and funnel plot with imputed samples for CA-DYS (right) in listening comprehension

Table 5 Publication bias analyses

Outcomes	Comparison	Egger's method		Rank correlation test		Trim and fill procedure	
		z	*p*	Kendall's tau	*p*	Imputed	Corrected effect sizes
Reading comprehension	CA-DYS	4.3181	< 0.0001	0.2083	0.0033	5	1.3105
	RL-DYS	2.5115	0.0120	0.3518	0.0189	4	1.0714
Listening comprehension	CA-DYS	− 2.7026	0.0069	− 0.4641	0.0067	5	0.7119
	RL-DYS	− 0.4070	0.6840	− 0.6667	0.3333	0	0.0222

RL-DYS comparisons in reading comprehension and the CA-DYS comparison in listening comprehension. In reading comprehension, the funnel plot indicated that studies were missing to the left of the mean for the CA-DYS comparison (see Fig. 2) and to the right of the mean for the RL-DYS comparison (see Fig. 3). In listening comprehension, the funnel plot indicated that studies were missing to the right of the mean for the CA-DYS comparison (see Fig. 4). Therefore, the true effect size may be somewhat lower for the CA-DYS comparison in reading comprehension (corrected effect size = 1.3105), but higher for the RL-DYS comparison in reading comprehension (corrected effect size = 1.0714) and the CA-DYS comparison in listening comprehension (corrected effect size = 0.7119) than that reported in the initial analyses (see Tables 5 and 6).

Discussion

The purpose of this meta-analysis was to examine the extent to which individuals with dyslexia experience deficits in reading and listening comprehension. In line with our expectation, individuals with dyslexia were found to experience a deficit in reading comprehension ($g = 1.43$) that, following Cohen (1988), can be characterized as large. The effect size in listening comprehension was also significant, but relatively small ($g = 0.43$). Taken together, these findings suggest that the reading comprehension deficits of individuals with dyslexia are likely a product of underlying deficits in both decoding and oral language skills. Clearly, deficits in broader language skills compromise listening comprehension (see also Adlof & Hogan, 2018; Snowling et al., 2020a), but because they are not combined with deficits in decoding (i.e., decoding is not involved in listening comprehension tasks), the effect size in listening comprehension is significantly smaller than the one in reading comprehension.

Interestingly, the effect size for the CA-DYS comparison in reading comprehension in our meta-analysis ($g=1.43$) is almost double the one reported by Reis et al. (2020; $d=0.72$). This is likely due to the fact that our meta-analysis included dyslexia studies with younger participants. We take this finding to mean that, in adulthood, some of the individuals with dyslexia have likely developed mechanisms to compensate for their poor word reading skills when completing reading comprehension tasks (e.g., Birch & Chase, 2004; Deacon et al., 2012; Parrila et al., 2007; Pedersen et al., 2016).

However, we also found that individuals with dyslexia were performing significantly worse than their RL-matched controls ($g=0.64$; a moderate effect size). This is interesting because the reading-level matched design (Bradley & Bryant, 1978; Bryant & Goswami, 1986) lies on the assumption that the dyslexia group and a group of younger children have a similar reading level. If younger children are matched to older dyslexic individuals on their reading ability, we would expect them to be matched on all reading tasks (including reading comprehension) and not just on one or two reading tasks. A similar issue was recently reported by Parrila et al. (2020a) in a meta-analysis with studies from consistent orthographies. This finding suggests that when researchers say they matched their samples on one reading task, we cannot assume that they matched them on all reading outcomes. Clearly, this meta-analysis did not set to resolve the issues around the use of RL-matched controls (see e.g., Zoccolotti, 2020, for a detailed discussion on this topic), but our finding adds one more piece of evidence to further question the value of using an RL-matched design in dyslexia research.

Our moderator analyses revealed a significant effect of orthographic consistency (differences being larger in languages with low orthographic consistency) and a significant effect of vocabulary matching (differences being larger in studies in which the groups were not matched on vocabulary knowledge). In regard to the former, a possible explanation might be that reading comprehension is a more demanding task in languages with low orthographic consistency (e.g., English, French) because decoding (one of the building blocks of reading comprehension according to the "simple view of reading") is more challenging for children with dyslexia in languages with low orthographic consistency (see Carioti et al., 2021; see also McClung & Pearson, 2019). In regard to the latter, our finding confirms the additive negative effects of vocabulary deficits on reading comprehension. We already know that children with dyslexia differ from their controls on word reading skills and that many children with dyslexia experience difficulties in oral language skills (e.g., Adlof & Hogan, 2018; Snowling et al., 2020a). In the presence of significant group differences in word reading skills, if researchers match their CA and DYS groups on vocabulary, in essence, they take away the possible negative effects of vocabulary on reading comprehension. The fact that we did not observe a similar finding in listening comprehension likely has to do with the small sample of studies used in the moderator analysis.

In contrast to our expectation, writing system did not moderate the effect sizes. There might be two possible explanations for this finding. First, it is possible that the differences between writing systems in the severity of the decoding deficits of individuals with dyslexia are not as large to elicit significant effects of writing system. Even though McClung and Pearson (2019) provided some preliminary evidence that orthographic depth may moderate the severity of reading comprehension deficits (comprehension deficits being more severe in more inconsistent orthographies), to our knowledge, no study has examined differences in reading comprehension between writing systems. Second, our sample of studies in the non-alphabetic category was relatively small ($k = 11$) compared to the one in the alphabetic category ($k = 80$) and this may have prevented us from detecting a significant effect.

The effects of "response format" and "reading mode" were also non-significant. In regard to "response format," our finding is in contrast to the finding of Collins et al. (2018). Because our meta-analysis included a more homogeneous group of studies (i.e., we selected our studies to include individuals with dyslexia or significant word reading difficulties and not just struggling/slow readers), it is possible that the effect of "response format" in these groups is not strong enough to moderate the effect sizes. In other words, among children with dyslexia or very low word reading skills, reading comprehension is impacted irrespective of how these children are asked to respond to comprehension questions. However, it is also possible that "response format" interacts with participants' age (e.g., performance in picture matching tasks being more impacted in younger children with dyslexia) and because we did not perform multiple meta-regression moderator analysis and we could not detect it. In regard to "reading mode," our finding was rather surprising given that oral reading adds another layer of complexity to the task demands (i.e., motor programming) and because of the feedback to the system oral reading creates. Again, it is possible that the decoding deficits of individuals with dyslexia have such a profound impact on their reading comprehension that reading mode does not have any additive effects.

Some limitations of our meta-analysis are worth noting. First, researchers have been using different approaches and cut-off scores to identify their participants with dyslexia. At the same time, because in some studies on learning disability their participants were selected on the basis of poor word reading, we felt we should also include them in this meta-analysis. It is possible that the different ways of selecting individuals with dyslexia along with our decision to include children with learning disabilities specific to reading may have influenced our results. Second, we did not conduct a multiple meta-regression moderator analysis that controls for the effects of other potential moderators. Because some of the moderators may covary (e.g., the type of comprehension task may vary as a function of participants' age), the results may be confounded. Unfortunately, the sample of effect sizes in some categories was too small to allow us to examine the effects of interactions. Third, the extent to which our findings on listening comprehesnion generalize (and even hold) may be tempered by the small sample size. Fourth, all the studies in the "non-alphabetic" orthographies category came from Chinese. As such, our findings may not generalize to other non-alphabetic orthographies. Finally, as the focus of this special issue is on secondary consequences of dyslexia, we focused only on comprehension and we did not calculate the effect sizes in word reading skills.

To conclude, we found that individuals with dyslexia experience large difficulties in reading comprehension. The estimated effect size ($g = 1.43$) is not as large as that reported for word reading skills in previous meta-analyses on dyslexia (e.g., Melby-Lervåg et al., 2012; Parrila et al., 2020a) and this reinforces the notion of considering reading comprehenesion a secondary symptom of dyslexia. At the same time, we found a small effect on listening comprehension, which reinforces the finding of previous studies that children with dyslexia may experience deficits in broader language skills. Taken together, our findings suggest that the reading comprehension deficits in individuals with dyslexia are likely the product of deficits in both decoding and oral language skills Tables 7 and 8.

Appendix 1

Table 6 Studies with chronological age-matched controls

Study	Language	Subgroup		Individuals with dyslexia			Age-matched		RC task		
			Grade level	Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	Vocabulary match
Abu-Rabia (2007)	Alphabetic (Arabic)	Grade 3	G1–5		44.33, (18.13) $N=30$	Previous diagnosis		63.66, (23.55) $N=30$	Multiple choice	Silent	
Abu-Rabia (2007)	Alphabetic (Arabic)	Grade 6	G6–12		47.33, (13.62) $N=30$	Previous diagnosis		60.66, (21.48) $N=30$	Multiple choice	Silent	
Abu-Rabia (2007)	Alphabetic (Arabic)	Grade 9	G6–12		54.66, (13.32) $N=30$	Previous diagnosis		65.33, (26.48) $N=30$	Multiple choice	Silent	
Abu-Rabia (2007)	Alphabetic (Arabic)	Grade 12	G6–12		54.33, (10.4) $N=30$	Previous diagnosis		66.33, (15.19) $N=30$	Multiplechoice	Silent	
Angelelli et al. (2017)	Alphabetic (Italian)		G1–5	8.8	−0.34, (0.77) $N=16$	Standardized test	8.57	0.22, (0.59) $N=16$			
Angelelli et al. (2010)	Alphabetic (Italian)		G1–5	9.4	−0.57, (0.67) $N=28$	Standardized test	9.48	−0.02, (0.54) $N=28$	Multiple choice		Matched
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	16.21, (2.04) $N=29$	Standardized test	11.48	16.71, (2.26) $N=34$	Multiple choice	Silent	
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	15.46, (3.19) $N=29$	Standardized test	11.48	18.24, (2.13) $N=34$	Multiple choice	Silent	

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Reading mode	
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	16.97, (2.77) $N=29$	Standardized test	11.48	18.24, (1.99 $N=34$	Multiple choice	Silent	
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	15.62, (3.57) $N=29$	Standardized test	11.48	18.26, (2.42) $N=34$	Multiple choice	Silent	
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	16.03, (3.44) $N=29$	Standardized test	11.48	18.03, (2.18) $N=34$	Multiple choice	Silent	
Bar-Kochva and Hasselhorn (2015)	Alphabetic (German)		G1–5	11.61	13.46, (3.51) $N=29$	Standardized test	11.48	15.26, (3.3) $N=34$	Multiple choice	Silent	
Bazen et al. (2020)	Alphabetic (Dutch)	Early dx (before G7)	G6–12	16.5	12.85, (4.21) $N=41$	Previous diagnosis	16.5	14.61, (5.06) $N=31$	Multiple choice		Matched
Bazen et al. (2020)	Alphabetic (Dutch)	Late dx (after G7)	G6–12	16.7	14.39, (5.59) $N=24$	Previous diagnosis	16.5	14.61, (5.06) $N=31$	Multiple choice		Matched
Bishop et al. (2009)	Alphabetic (English)				84.6, (11.31) $N=73$	Standardized test		100.2, (11.61) $N=176$		Not silent	Not matched
Bonifacci et al. (2017)	Alphabetic (Italian)		G1–5	10.39	−0.86, (1.01) $N=19$	Previous diagnosis	10.24	−0.31, (0.9) $N=76$	Multiple choice		
Bowey (2008)	Alphabetic (English)	Phonological	G1–5	9.6	83.75, (7.61) $N=16$	Standardized test	9.3	94.38, (7.52) $N=21$			Not matched

Table 6 (continued)

Study	Language	Subgroup		Individuals with dyslexia			Age-matched		RC task		
			Grade level	Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Reading mode	Vocabulary match
Bowey (2008)	Alphabetic (English)	Surface	G1–5	9.6	76.23, (12.27) *N* = 12	Standardized test	9.3	94.38, (7.52) *N* = 21			Not matched
Breznitz (2002)	Alphabetic (Hebrew)		G1–5	10.3	8.5, (2.7) *N* = 20	Standardized test	10.3	10.7, (1.3) *N* = 20	Multiple choice	Silent	
Breznitz (2002)	Alphabetic (Hebrew)		G1–5	10.3	7.6, (1.4) *N* = 20	Standardized test	10.3	10.2, (1) *N* = 20	Multiple choice	Silent	
Caravolas et al. (2005)	Alphabetic (Czech)	Czech	G1–5	10.6	14.48, (3.82) *N* = 40	Previous diagnosis	10.5	28.95, (7.81) *N* = 40	Cloze	Silent	
Caravolas et al. (2005)	Alphabetic (English)	English	G1–5	10.5	13.77, (4.53) *N* = 27	Previous diagnosis	10.4	25.56, (6.01) *N* = 27	Cloze	Silent	
Casalis et al. (2012)	Alphabetic (French)			10.6	78, (9.56) *N* = 27	Previous diagnosis	10.3	94, (5.27) *N* = 22	Picture Matching		Not matched
Chik et al. (2012)	Non-alphabetic (Cantonese)		G1–5	9.77	12.54, (5.72) *N* = 101	Standardized tested	9.74	20.93, (4.33) *N* = 101			Not matched
Chik et al. (2012)	Non-alphabetic (Cantonese)		G1–5	9.77	11.76, (4.74) *N* = 101	Standardized tested	9.74	17.61, (2.62) *N* = 101	Multiple choice		Not matched
Chung et al. (2010)	Non-alphabetic (Chinese)		G6–12	13.65		Previous Diagnosis	13.66	13.48, (2.06) *N* = 27	Multiple choice		Matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	Vocabulary match
Chung et al. (2020)	Non-alphabetic (Chinese)		G6–12	12.7	5.18, (1.89) $N=57$	Previous diagnosis	12.7	9.51, (2.01) $N=57$		Not matched	
Chung et al. (2020)	Alphabetic (English)		G6–12	12.7	6.16, (1.99) $N=57$	Previous diagnosis	12.7	9.58, (1.9) $N=57$		Not matched	
Chung et al. (2018)	Non-alphabetic (Chinese)		G6–12	13.2	5.96, (3.38) $N=25$	Standardized test	13	10.28, (2.79) $N=25$	Silent		
Chung et al. (2011)	Non-alphabetic (Chinese)		G6–12	13.64	8.43, (3.55) $N=30$	Previous diagnosis	13.66	13.57, (1.98) $N=30$		Matched	
Chung et al. (2013)	Non-alphabetic (Chinese)		G6–12	13.8	3.92, (1.74) $N=26$	Previous diagnosis	14	6.58, (1.65) $N=26$		Not matched	
Compton et al. (2012)	Alphabetic (English)	LD in RC	G1–5		79.67, (4.41) $N=58$	Standardized test		103.69, (6.57) $N=356$	Silent		
Compton et al. (2012)	Alphabetic (English)	LD in WR	G1–5		86.71, (9.53) $N=71$	Standardized test		99.93, (8.29) $N=463$	Silent		
Constantinidou and Stainthorp (2009)	Alphabetic (Greek)				87.38, (4.02) $N=20$	Previous diagnosis		96.42, (2.25) $N=20$			

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Cutting et al. (2009)	Alphabetic (English)		G6–12	11.65	86.78, (5.76) N = 18	Standardized test	11.67	111.67, (9.5) N = 21	Cloze	Silent	
Cutting et al. (2009)	Alphabetic (English)		G6–12	11.65	8.67, (1.85) N = 18	Standardized test	11.67	13.1, (1.51) N = 21	Multiple choice	Not silent	
Cutting et al. (2013)	Alphabetic (English)		G6–12	12.3	87.58, N = 20	Standardized test	12.2	112.5, N = 19			Not matched
Cutting et al. (2013)	Alphabetic (English)		G6–12	12.3	84.63, N = 20	Standardized test	12.2	115.95, N = 19			Not matched
Cutting et al. (2013)	Alphabetic (English)		G6–12	12.3	83.95, N = 20	Standardized test	12.2	105, N = 19			Not matched
Cutting et al. (2013)	Alphabetic (English)		G6–12	12.3	92.63, N = 20	Standardized test	12.2	114.21, N = 19		Not silent	Not matched
de Carvalho et al. (2014)	Alphabetic (Portuguese)				−1.07, (0.69) N = 17	Previous diagnosis		−0.07, (0.88) N = 98	Open-ended	Not silent	Not matched
de Jong and Van der Leij (2003)	Alphabetic (Dutch)		G1–5		7.9, (2.83) N = 19			16.21, (6.01) N = 19	Multiple choice		Not matched
de Jong and Van der Leij (2003)	Alphabetic (Dutch)		G6–12		5.69, (3.12) N = 19			12.46, (7.61) N = 19	Multiple choice		Not matched
de Luca et al. (2002)	Alphabetic (Italian)		G6–12	13.1	−0.68, (0.7) N = 12	Previous diagnosis	12.4	0.19, (0.6) N = 10	Multiple choice	Not silent	Matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
de Oliveira et al. (2014)	Alphabetic (Portuguese)		G6–12	10.78	35.47, (5.65) $N=18$	Previous diagnosis	10.59	37.19, (4.65) $N=22$	Picture matching		Matched
Di Filippo et al. (2008)	Alphabetic (Italian)		G6–12	11.7	−0.11, (0.99) $N=24$	Standardized test	11.8	0.46, (0.62) $N=42$	Multiple choice	Not silent	
Edwards et al., (2004)	Alphabetic (English)			11.17	88.9, (17.12) $N=21$	Previous diagnosis	11.62	118, (12.6) $N=24$			Not matched
López-Escribano (2007)	Alphabetic (Spanish)	Double deficit		9.1	69.6, (30.02) $N=10$	Standardized test	10.4	60.89, (28.91) $N=9$	Open-ended	Silent	
Finn et al. (2014)	Alphabetic (English)			9.13	8.31, (3.27) $N=32$	Standardized test	8.69	13.33, (3.11) $N=43$	Open-ended	Not silent	Not matched
Fletcher et al. (2006)	Alphabetic (English)		G1–5	9.66	1921.7, (132.3) $N=47$	Standardized test	9.27	2166.7, (116) $N=47$	Multiple choice		
Fletcher et al. (1994)	Alphabetic (English)	Discrepancy-based	G1–5		107.97, (16.76) $N=29$	Standardized test		109.72, (17.36) $N=47$	Cloze tasks	Silent	Not matched
Fletcher et al. (1994)	Alphabetic (English)	Discrepancy-based	G1–5		84.69, (17.13) $N=29$	Standardized test		89.89, (16.1) $N=47$	Open-ended	Silent	Matched
Fletcher et al. (1994)	Alphabetic (English)	Regression-based	G1–5		78.44, (9.93) $N=16$	Standardized test		109.72, (17.36) $N=47$	Cloze	Silent	

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Reading mode	
Fletcher et al. (1994)	Alphabetic (English)	Regression-based	G1–5		70.93, (7.64) $N=16$	Standardized test		89.89, (16.1) $N=47$	Open-ended	Silent	
Fletcher et al. (1994)	Alphabetic (English)	Both	G1–5		81.06, (15.37) $N=48$	Standardized test		109.72, (17.36) $N=47$	Cloze	Silent	
Fletcher et al. (1994)	Alphabetic (English)	Both	G1–5		71.75, (8.16) $N=48$	Standardized test		89.89, (16.1) $N=47$	Open-ended	Silent	
Fletcher et al. (1994)	Alphabetic (English)	Low achievement	G1–5		83.96, (10.08) $N=56$	Standardized test		109.72, (17.36) $N=47$	Cloze	Silent	
Fletcher et al. (1994)	Alphabetic (English)	Low achievement	G1–5		71.13, (5.54) $N=56$	Standardized test		89.89, (16.1) $N=47$	Open-ended	Silent	
Georgiou et al. (2010)	Alphabetic (Greek)		G6–12	12.5	8.7, (2.3) $N=26$	Previous diagnosis	12.5	11.3, (3.3) $N=86$	Open-ended	Not silent	
Ghelani et al. (2004)	Alphabetic (English)		G6–12	15.6	8.2, (2.5) $N=20$	Standardized test	15	10.8, (2.6) $N=25$	Multiple choice	Not silent	
Ghelani et al. (2004)	Alphabetic (English)		G6–12	15.6	91.3, (16.7) $N=20$	Standardized test	15	115, (12.8 $N=25$	Multiple choice	Silent	
Gibson et al. (2006)	Alphabetic (English)			9.1	94.6, (17.1) $N=44$	Standardized test	9.9	127.9, (14.5) $N=44$	Open-ended	Silent	Not matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Goswami et al. (2013)	Alphabetic (English)			11.6	86.6, (12.8) $N=38$	Previous diagnosis	11.5	106.7, (13.1) $N=25$	Multiple choice	Silent	Not matched
Goulandris et al. (2000)	Alphabetic (English)			15.79	28.8, (3.85) $N=20$	Standardized test	15.68	29.58, (4.09) $N=19$			
Ho (2009)	Alphabetic (English)			14.16	86.39, (9.85) $N=21$	Standardized test	10.9	116.65, (7.09) $N=17$		Silent	
Ho (2009)	Alphabetic (English)			14.16	7.76, (2.72) $N=21$	Standardized test	10.9	12.35, (2.34) $N=17$	Multiple choice	Not silent	
Hsu (2013)	Non-alpha-betic (Chinese)		G1–5	10.8	5.45, (2.78) $N=17$	Previous diagnosis	10.2	16.71, (2.39) $N=21$		Silent	
Jiménez et al. (2008)	Alphabetic (Spanish)	Double deficit	G1–5	9.21	0.54, (0.16) $N=19$	Standardized test	9.95	0.81, (0.11) $N=100$			
Jiménez et al. (2008)	Alphabetic (Spanish)	Double deficit	G1–5	9.21	0.54, (0.23) $N=19$	Standardized test	9.95	0.78, (0.17) $N=100$	Picture matching		
Kida et al. (2016)	Alphabetic (Portuguese)		G1–5	10.58	0.63, (0.50) $N=19$	Previous diagnosis	10.25	1, (0.58) $N=19$		Silent	
Kida et al. (2016)	Alphabetic (Portuguese)		G1–5	10.58	0.26, (0.45) $N=19$	Previous diagnosis	10.25	0.90, (0.81) $N=19$		Silent	

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Kida et al. (2016)	Alphabetic (Portuguese)		G1–5	10.58	0.26, (0.45) $N=19$	Previous diagnosis	10.25	0.90, (0.57) $N=19$		Silent	
Krafnick et al. (2014)	Alphabetic (English)			9.8	78.3, (11) $N=15$	Previous diagnosis	9.9	110.3, (10) $N=15$	Cloze	Silent	
Layes et al. (2015)	Alphabetic (Arabic)		G1–5	10.9	10.48, (2) $N=36$	Standardized test	10.5	13, (1.84) $N=20$	Picture matching	Silent	
Layes et al. (2017)	Alphabetic (Arabic)		G6–12	11.1	9.85, (3.6) $N=20$	Previous diagnosis	10.9	13.64, (1.24) $N=20$	Picture matching	Silent	
Leach (2003)	Alphabetic (English)		G1–5	10.5	103.1, (8.3) $N=28$	Standardized test	10.5	107.2, (12.7) $N=95$	Picture matching	Silent	
Leikin and Bouskila (2004)	Alphabetic (English)		G1–5	10.5	5.5, (1.9) $N=20$	Previous diagnosis	10.6	7.7, (0.9) $N=20$	Multiple choice	Not silent	
Locascio et al (2010)	Alphabetic (English)			11.85	2.88, (1.4) $N=44$	Previous diagnosis	11.82	7, (1.31) $N=24$			Matched
Locascio et al (2010)	Alphabetic (English)			11.85	2.37, (1.79) $N=44$	Previous diagnosis	11.82	7.08, (1.5) $N=24$	Open-ended	Silent	
Locascio et al (2010)	Alphabetic (English)			11.85	6.52, (2.6) $N=44$	Previous diagnosis	11.82	11.04, (1.49) $N=24$			

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia Age	Individuals with dyslexia Mean, (SD) N	Individuals with dyslexia Dyslexia selection criteria	Age-matched Age	Age-matched Mean, (SD) N	RC task Response type	RC task Reading mode	Vocabulary match
Locascio et al (2010)	Alphabetic (English)			11.85	8.23, (2.33) $N=44$	Previous diagnosis	11.82	12.46, (1.96) $N=24$	Multiple choice	Not silent	
Locascio et al (2010)	Alphabetic (English)			11.85	85.32, (11.09) $N=44$	Previous diagnosis	11.82	109.46, (6.97), $N=24$	Cloze	Silent	
Loizidou-Ieridou (2012)	Alphabetic (Greek)		G1–5	9.6	75, (3.7) $N=36$	Previous diagnosis	9.4	86, (5.5) $N=12$	Multiple choice		
Mahfoudhi et al. (2010)	Alphabetic (Arabic)	Grade 3	G1–5		8, (5) $N=9$	Previous diagnosis		14.57, (12.55) $N=37$	Cloze	Silent	
Mahfoudhi et al. (2010)	Alphabetic (Arabic)	Grade 4	G1–5		10.3, (5.42) $N=10$	Previous diagnosis		21.21, (12.15) $N=47$	Cloze	Silent	Matched
Mahfoudhi et al. (2010)	Alphabetic (Arabic)	Grade 5	G1–5		14.19, (6.82) $N=16$	Previous diagnosis		28.49, (12.42) $N=43$	Cloze	Silent	
Mahfoudhi et al. (2010)	Alphabetic (Arabic)	Grade 6	G6–12		26.36, (8.41) $N=11$	Previous diagnosis		32.1, (11.72) $N=39$	Cloze	Silent	
Masoura et al. (2020)	Alphabetic (Greek)			8.7	0.74, (0.2) $N=13$	Previous diagnosis	9.8	0.82, (0.11) $N=14$	Open-ended	Not silent	
Meng et al., (2011a, 2011b)	Non-alphabetic (Chinese)		G1–5	10.4	36, (12) $N=27$	Standardized test	10.3	59, (7) $N=27$	Picture matching		

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Reading mode	
Miller-Shaul (2005a, 2005b)	Alphabetic (Hebrew)		G1–5		0, (1.37) $N=25$	Previous diagnosis		0, (0.58) $N=25$	Multiple choice		
O'Connor (2018)	Alphabetic (English)	Grade 2	G1–5		92.63, (8.3) $N=182$	Standardized test		106.9, (8.83) $N=72$	Cloze	Silent	Not matched
O'Connor (2018)	Alphabetic (English)	Grade 2	G1–5		76.33, (10.4) $N=182$	Standardized test		98.76, (16.63) $N=72$	Open-ended	Not silent	
O'Connor (2018)	Alphabetic (English)	Grade 4	G1–5		84.45, (9.45) $N=182$	Standardized test		97.63, (7.47) $N=78$	Cloze	Silent	
O'Connor (2018)	Alphabetic (English)	Grade 4	G1–5		72.63, (8.71) $N=145$	Standardized test		97.21, (12.54) $N=78$	Open-ended	Not silent	
Paizi et al. (2013)	Alphabetic (Italian)			11.7	−0.7, (1.2) $N=17$	Standardized test	11.6	0.4, (0.9) $N=17$	Multiple choice	Silent	
Parrila et al. (2020c)	Alphabetic (Greek)	Grade 4	G1–5	9.6	32.58, (5.05) $N=22$	Standardized test	9.7	35.82, (7.94) $N=28$	Cloze	Not silent	
Parrila et al. (2020c)	Alphabetic (Greek)	Grade 6	G6–12	11.8	37.59, (5.27) $N=22$	Standardized test	11.9	40.62, (6.89) $N=26$	Cloze	Not silent	
Pennington et al. (2001)	Alphabetic (English)		G1–5	9.91	0.44, (0.12) $N=35$	Previous diagnosis	9.86	0.62, (0.07) $N=21$	Picture matching	Silent	Matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Pennington et al. (2001)	Alphabetic (English)		G6–12	14.92	0.69, (0.14) $N=36$	Previous diagnosis	14.65	0.78, (0.11) $N=20$	Picture matching	Silent	Matched
Peters et al. (2020)	Alphabetic (English)		G1–5	7.71	77.55, (11.71) $N=18$	Previous diagnosis	7.65	101, (13.63) $N=18$	Multiple choice	Silent	Not matched
Primor et al. (2011)	Alphabetic (Hebrew)		G1–5		−2.5, (0.6) $N=190$	Standardized test		−2.18, (0.6) $N=190$	Picture matching	Silent	Not matched
Primor et al. (2011)	Alphabetic (Hebrew)		G1–5		−2.82, (0.53) $N=190$	Standardized test		−2.48, (0.53) $N=190$	Picture matching	Silent	
Schiff et al. (2011)	Alphabetic (Hebrew)		G6–12		66.41, (10.25) $N=39$	Previous diagnosis		76.15, (8.47) $N=40$	Multiple choice		
Shu et al. (2006)	Non-alphabetic (Mandarin)			11.11	10, (4.85) $N=75$	Standardized test	11.6	15, (3.31) $N=77$	Cloze	Silent	
Snowling et al., (2020a, 2020b)	Alphabetic (English)			8	56.45, (9.85) $N=21$	Previous diagnosis	8	60.98, (8.48) $N=64$		Not silent	
Snowling et al., (2020a, 2020b)	Alphabetic (English)			9	63.18, (6.7) $N=20$	Previous diagnosis	9	67.38, (7.13) $N=64$		Not silent	Not matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Solan et al. (2007)	Alphabetic (English)		G6–12	11.9	27.43, (8.19) 23	Previous diagnosis	11.5	74.68, (11.69) $N=19$	Multiple choice		Matched
Swanson and Alexander (1997)	Alphabetic (English)		G1–5		3.7, (3.91) $N=40$	Standardized test		13.3, (5.94) $N=39$	Open-ended	Silent	Matched
Swanson and Ashbaker (2000)	Alphabetic (English)			15.1	84.7, (6.4) $N=30$	Standardized test	14.8	110.67, (4.76) $N=30$	Cloze	Silent	
Swanson and Jerman (2007)	Alphabetic (English)				81, (14.2) $N=18$	Standardized test		100.47, (17.85) $N=23$	Cloze		Not matched
Swanson et al. (2006)	Alphabetic (English)			13.17	78.28, (13.33) $N=19$	Standardized test	12.39	104.6, (15.27) $N=15$			
Swanson et al. (2006)	Alphabetic (English)			13.17	7.39, (2.52) $N=19$	Standardized test	12.39	11.2, (3.17) $N=15$		Not silent	Matched
Talli et al. (2016)	Alphabetic (Greek)		G1–5	9.2	−29.73, (10.91) $N=15$	Previous diagnosis	9.2	−18.03, (6.97) $N=30$		Silent	Not matched
Temple et al. (2001)	Alphabetic (English)		G1–5	10.7	83.3, (16.4) $N=13$	Standardized test	10.5	111.2, (6.2) $N=13$	Cloze		Not matched
Tiu et al. (2003)	Alphabetic (English)		G1–5	10.19	90, (11.62) $N=61$	Previous diagnosis	11.5	112.41, (11.75) $N=63$			Not matched

Table 6 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia			Age-matched		RC task		Vocabulary match
				Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	23.89, (12.1) $N=28$	Previous diagnosis	9.77	37.84, (1.49) $N=26$	Picture matching		Matched
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	−29,335.99, (17,934.6) $N=28$	Previous diagnosis	9.77	−12,094.67, (3036.01) $N=26$	Picture matching		
Vukovic et al. (2010)	Alphabetic (English)		G1–5		544.61, (51.03) $N=18$	Standardized test		630.43, (40.72) $N=247$	Multiple choice		
Wong et al. (2017)	Non-alphabetic (Chinese)		G1–5	8.1	12.12, (5.69) $N=8$	Previous diagnosis	8.1	23.03, (4.99) $N=34$	Multiple choice		
Xiao-Yun and Ho (2014)	Non-alphabetic (Chinese)			10	14.4, (3.29) $N=21$	Standardized test	10.1	16.83, (2.79) $N=15$	Cloze	Silent	
Zoccolotti et al. (2005)	Alphabetic (Italian)		G1–5	8.4	−0.7, (0.92) $N=9$	Standardized test	8.7	0.63, (0.65) $N=28$	Multiple choice	Not silent	Matched
											Matched
											Matched

Appendix 2

Table 7 Studies with reading level-matched controls in reading comprehension

Study	Language	Subgroup		Individuals with dyslexia			Reading-matched		RC task		
			Grade level	Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Reading mode	Vocabulary match
Casalis et al. (2012)	Alphabetic (French)			10.6	78, (9.56) $N=27$	Former diagnosis	7.8	85, (12.94) $N=25$	Picture matching		Matched
Casalis et al. (2004)	Alphabetic (French)		G1–6	10.1	-9.18, (3.49) $N=33$	Following assessment	7.5	-5.61, (2.82) $N=33$	Picture matching	Oral	
Chik et al. (2012)	Non-alphabetic (Chinese)		G1–6	9.77	12.54, (5.72) $N=101$	Following assessment	7.73	11.89, (5.74) $N=101$			Not matched
Chik et al. (2012)	Non-alphabetic (Chinese)		G1–6	9.77	11.76, (4.74) $N=101$	Following assessment	7.73	11.89, (5.74) $N=101$	Multiple Choice		Not matched
Chung et al. (2009)	Non-alphabetic (Chinese)		G6–G12	13.65	7.96, (3.4) $N=27$	Former diagnosis	11.81	10.89, (3.5) $N=27$	Multiple Choice		Matched
Chung et al. (2011)	Non-alphabetic (Chinese)		G6–G12	13.64	8.43, (3.55) $N=30$	Former diagnosis	13.66	11.3, (3.57) $N=30$	Multiple Choice		Matched
Chung et al. (2013)	Non-alphabetic (Chinese)		G6–G12	13.8	3.92, (1.74) $N=26$	Former diagnosis	13.9	4.5, (1.68) $N=26$	Multiple Choice		Matched
Constantinidou and Stainthorp (2009)	Alphabetic (Greek)				87.38, (4.02) $N=20$	Former diagnosis		94.99, (2.98) $N=20$		Oral	

Table 7 (continued)

Study	Language	Subgroup	Grade level	Individuals with dyslexia Age	Mean, (SD) N	Dyslexia selection criteria	Reading-matched Age	Mean, (SD) N	RC task Response type	Reading mode	Vocabulary match
Goswami et al. (2013)	Alphabetic (English)			11.6	86.6, (12.8) N=38	Following assessment	9.6	100, (10.3) N=25	Multiple Choice	Silent	
Goulandris et al. (2000)	Alphabetic (English)			15.79	28.8, (3.85) N=20	Following assessment	10.39	23.67, (4.67) N=18			
Hsu (2013)	Non-alphabetic (Chinese)			10.8	5.45, (2.78) N=17	Former diagnosis	8.9	12.58, (2.59) N=19		Silent	
Katzir et al. (2006)	Alphabetic (English)			8.3	13.12, (8.24) N=17	Former diagnosis	7.05	15.88, (11.31) N=17	Cloze		Matched
Layes et al. (2017)	Alphabetic (Arabic)		G1–G5	11.13	9.85, (3.6) N=20	Former diagnosis	9.73	14.16, (1.32) N=18	Picture Matching	Silent	
Loizidou-Ieridou (2012)	Alphabetic (Greek)		G1–G5	9.6	75, (3.7) N=36	Former diagnosis	8.52	84, (3.2) N=12		Silent	Matched
Parrila et al. (2020)	Alphabetic (Greek)	Grade 4	G1–G5	9.6	32.58, (5.05) N=22	Following assessment	6.8	23.5, (5.42) N=30	Cloze	Oral	Matched
Parrila et al. (2020)	Alphabetic (Greek)	Grade 6	G1–G5	11.8	37.59, (5.27) N=22	Following assessment	8.9	23.11, (7.69) N=24	Cloze	Oral	Matched
Pennington et al. (2001)	Alphabetic (English)		G1–G5	9.91	0.44, (0.12) N=35	Following assessment	9.04	0.47, (0.11) N=25	Picture Matching	Silent	Not matched

Table 7 (continued)

Study	Language	Subgroup		Individuals with dyslexia			Reading-matched		RC task		
			Grade level	Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Reading mode	Vocabulary match
Pennington et al. (2001)	Alphabetic (English)		G6–G12	14.92	0.69, (0.14) N = 36	Following assessment	11.31	0.63, (0.16) N = 31	Picture Matching	Silent	Not matched
Peters et al. (2020)	Alphabetic (English)		G1–G5	7.71	77.55, (11.71) N = 18	Former diagnosis	5.91	94.89, (11.81) N = 18	Multiple Choice	Oral	
Schiff et al. (2011)	Alphabetic (Hebrew)		G6–G12		66.41, (10.25) N = 39	Former diagnosis		67.76, (10.25) N = 38	Multiple Choice		
Swanson and Ashbaker (2000)	Alphabetic (English)			15.1	84.7, (6.4) N = 30	Following assessment	9.16	110.1, (4.79) N = 30	Cloze	Silent	
Talli et al. (2016)	Alphabetic (Greek)		G1-G5	9.23	-29.7, (10.91) N = 15	Former diagnosis	7.28	-28, (10.14) N = 30		Silent	Matched
Talli et al. (2016)	Alphabetic (Greek)		G1-G5	9.23	-23.2, (10.51) N = 15	Former diagnosis	7.28	-21.6, (9.16) N = 30		Oral	Matched
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	23.89, (12.1) N = 28	Former diagnosis	7.82	24.14, (12.1) N = 28	Picture Matching		
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	-29,335.99, (17,934.61) N = 28	Former diagnosis	7.82	-17,301.72, (8758.06) N = 28	Picture Matching		
Xiao-Yun and Ho (2013)	Non-alphabetic (Chinese)			10	14.4, (3.29) N = 21	Following assessment	9.1	15.27, (3.05) N = *12*	Cloze	Silent	Matched

Appendix 3

Table 8 Studies with chronological age-matched controls in listening comprehension

Study	Language	Subgroup		Individuals with dyslexia			Age-matched		LC task	
			Grade level	Age	Mean, (SD) N	Dyslexia selection criteria	Age	Mean, (SD) N	Response type	Vocabulary match
Compton et al. (2012)	Alphabetic (English)	Learning disability in reading comprehension	G1–6		40.91, (7.83) $N=58$	Following assessment		54.75, (8.49) $N=356$		
Compton et al. (2012)	Alphabetic (English)	Learning disability in word reading	G1–6		44.33, (8.42) $N=71$	Following assessment		52.33, (9.25) $N=463$		
Constantinidou and Stainthorp (2009)	Alphabetic (Greek)				97.49, (1.63) $N=20$	Former diagnosis		98.09, (1.84) $N=20$		
De Jong and Van der Leij (2003)	Alphabetic (Dutch)	Kindergarten			18.16, (3.32) $N=19$	Former diagnosis		19.11, (3.54) $N=19$	Multiple choice	Matched
De Jong and Van der Leij (2003)	Alphabetic (Dutch)	Grade 1	G1–6		20.05, (2.93) $N=19$	Former diagnosis		19.42, (3.02) $N=19$	Multiple choice	Matched
De Jong and Van der Leij (2003)	Alphabetic (Dutch)	Grade 1	G1–6		12.53, (2.59) $N=19$	Former diagnosis		13.78, (2.77) $N=19$	Multiple choice	Matched
de Oliveira et al. (2014)	Alphabetic (Portuguese)		G6–G12	10.78	38.29, (1.72) $N=18$	Former diagnosis	10.59	37.69, (2.44) $N=22$	Picture matching	Matched

Table 8 (continued)

Study	Language	Subgroup	Individuals with dyslexia				Age-matched		LC task	
			Grade level	Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Vocabulary match
Fletcher et al. (1994)	Alphabetic (English)	Discrepancy	G1–6		95.46, (14.64) $N=29$	Following assessment		93.38, (14.18) $N=47$	Open-ended	
Fletcher et al. (1994)	Alphabetic (English)	Regression-based	G1–6		81.3, (6.63) $N=16$	Following assessment		93.38, (14.18) $N=47$	Open-ended	
Fletcher et al. (1994)	Alphabetic (English)	Both discrepancy and regression-based	G1–6		87.92, (10.56) $N=48$	Following assessment		93.38, (14.18) $N=47$	Open-ended	
Fletcher et al. (1994)	Alphabetic (English)	Low achievement	G1–6		82.91, (7.21) $N=56$	Following assessment		93.38, (14.18) $N=47$	Open-ended	
Gibson et al. (2006)	Alphabetic (English)			9.1	100.2, (11) $N=44$	Following assessment	9.9	104.5, (13) $N=44$	Open-ended	
Gibson et al. (2006)	Alphabetic (English)			9.1	93.3, (17.3) $N=44$	Following assessment	9.9	105.5, (12.6) $N=44$	Multiple choice	
Leach et al. (2003)	Alphabetic (English)		G1–6	10.5	110.2, (14.5) $N=28$	Following assessment	10.5	112.7, (12.9) $N=95$	Picture matching	Matched
Robertson and Joanisse (2010)	Alphabetic (English)	Working memory load 1	G1–6	10.6	92.86, (7.2) $N=14$	Following assessment	9.8	95.54, (6) $N=14$	Picture matching	Matched
Robertson and Joanisse (2010)	Alphabetic (English)	Working memory load 2	G1–6	10.6	83.93, (9.92) $N=14$	Following assessment	9.8	83.63, (9.59) $N=14$	Picture matching	Matched

Table 8 (continued)

Study	Language	Subgroup		Individuals with dyslexia			Age-matched		LC task	
			Grade level	Age	Mean, (SD) *N*	Dyslexia selection criteria	Age	Mean, (SD) *N*	Response type	Vocabulary match
Robertson and Joanisse (2010)	Alphabetic (English)	Working memory load 3	G1–6	10.6	83.04, (11) $N=14$	Following assess-ment	9.8	83.97, (11) $N=14$	Picture matching	Matched
Talli et al. (2016)	Alphabetic (Greek)		G1–6	9.23	-23.2, (-10.51) $N=15$	Former diagnosis	9.25	-14.2, (-7.5) $N=30$		Not matched
Tiu et al. (2003)	Alphabetic (English)		G1–6	10.19	97.16, (13) $N=61$	Former diagnosis	11.5	112.08, (17.11) $N=63$		
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	35.79, (3.01) $N=28$	Former diagnosis	9.77	38.87, (0.88) $N=26$	Picture matching	
Toledo et al. (2014)	Alphabetic (Portuguese)			9.82	-8275.74, (2144.58) $N=28$	Former diagnosis	9.77	-6683.25, (1330.02) $N=26$	Picture matching	
Valdois et al. (2021)	Alphabetic (French)		G1–6	12.08	16.9, (1.8) $N=162$	Following assess-ment	11.74	17.8, (1.4) $N=119$	Picture Matching	Not matched
van Daal et al. (2013)	Alphabetic (Dutch)		G6-G12	13.9	26, (13.6) $N=16$	Former diagnosis	13.74	25.3, (13.81) $N=40$		

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Declarations

Competing interests The authors declare no competing interests.

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