

Review

A Systematic Review and Meta-Analysis of Reading and Writing Interventions for Students with Disorders of Intellectual Development

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Abstract: Students with disorders of intellectual development (ID) experience challenges in reading and writing, indicating the need for research-based interventions. This systematic review and meta-analysis investigated the effects of reading and writing interventions for students aged 4–19 with disorders of ID using randomized controlled trials (RCTs) and quasi-experimental designs (QEDs). We conducted electronic searches of relevant databases, backward and forward searches, and contacted experts in the field. Based on predefined criteria, nine studies were included in the systematic review, and seven were included in the meta-analysis. The reading interventions included decoding strategies, often combined with sight-word and supplemental instructions appropriate to the participants' adaptive and cognitive skills. None of the studies aimed to increase writing skills. The overall mean effect size from the reading interventions for trained reading was large ($g = 0.95$, 95% CI = [0.51, 1.38]), for transfer reading small-to-moderate ($g = 0.49$, 95% CI = [0.20, 0.78]) and for transfer writing small ($g = 0.04$, 95% CI = [−0.36, 0.44]). Students with disorders of ID can benefit from reading interventions combining decoding strategies and sight word reading. There is a need for RCT and QED studies investigating writing interventions for students with disorders of ID only.

Keywords: decoding; encoding; linguistic comprehension; linguistic production; special needs education



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1. Introduction

Students with disorders of intellectual development (hereafter disorders of ID) are likely to face challenges in reading and writing acquisition because of significant limitations to cognitive functioning ($IQ \leq 69$) and adaptive behaviour [1]. Limitations in speech, language [2], and phonological skills [3,4] are common in students with disorders of ID, as are challenges with oral motor skills [5] and fine motor skills [6]. These are all skills that are commonly found to be associated with reading and writing acquisition [7].

However, low levels of reading and writing skills in students with disorders of ID [8] may also be related to limited access to high-quality phonic reading and writing instructions adapted specifically for these students [9]. Traditionally, expectations of reading and writing development among students with disorders of ID have been low [10], and they have also had access to fewer learning situations in reading and writing compared to other students [2].

Limited empirical studies on reading and writing interventions for students with disorders of ID exist [11], and the studies available are usually small-scale, include students with and without disorders of ID or focused on groups with a specific aetiology (e.g., Down syndrome). Furthermore, the studies seem to be based on how to teach either reading

or writing and not focused on whether or how these skills can be used to support each other [12].

No previous review has investigated the overall mean effect size of group studies including only students with disorders of ID. The present study is guided mainly by a pragmatic paradigm. By combining the qualitative method in the systematic review, and the quantitative method in the meta-analysis, we explore the existing interventions and investigate what may constitute an effective reading and/or writing intervention when compared to no intervention or practice as usual. In addition, we seek a more complete understanding of the gaps in existing research. Therefore, we examined the evidence on reading and/or writing interventions for students with disorders of ID using a randomized controlled trial (RCT) and quasi-experimental design (QED). This knowledge is first and foremost important to give students with disorders of ID access to effective research-based interventions, as this may optimize the student's educational opportunities, self-expression and effective social communication [2], participation in leisure activities, and employment [7]. Second, it is important for prioritizations in future research involving this group of students.

1.1. Barriers to Reading and Writing Development

Reading and writing are basic skills [13] that gradually develop from logographical, via alphabetical, to orthographical skills [14]. The process of accurately and fluently transforming written letters into words (decoding) and transforming spoken words into letters (encoding), respectively, is especially critical [15]. Phonological skills, including phonological awareness [16,17], phonological memory [16,17] and letter-sound correspondence [17], have been found to be associated with the development of these basic skills.

However, students with disorders of ID have serious limitations in phonological skills [4,9]. Limitations in short-term memory [18] may affect their ability to process and store sound-based information for short periods of time [12], which may hinder the development of alphabetical skills, decoding and encoding, even if letter-sound knowledge is acquired [12,19]. Limitations in phonological awareness, including blending, segmenting, and deletion, in students with disorders of ID may be critical in learning to decode unfamiliar words [20] and for spelling acquisition [12].

Linguistic skills are shown to be associated with reading and writing development among students with disorders of ID [2]. The ability to understand written text requires knowing word meanings, understanding passage structure, and making inferences [21]. Producing written text requires complex linguistic production skills such as planning, revising and self-regulation [13]. Therefore, limitations that are often seen in both phonological skills and in linguistic skills in students with disorders of ID [5,22] may make their development of reading and writing skills especially challenging.

1.2. No Existing Reviews on Reading and/or Writing Interventions for Students with Disorders of ID Only

Two meta-analyses on reading interventions, including a mix of participants with and without disorders of ID, exist. Sermier Dessemontet et al. [10] included six group-comparison studies involving 264 participants (IQ = 40–88, ages 6–33). Their results indicated that the overall effect of the intervention on phonics skills was small-to-moderate ($g = 0.41$). Reichow et al. [11] synthesised seven control group studies with 352 students (IQ = 40–88, ages 5.5–18). Their findings on word reading ($g = 0.54$) and decoding ($g = 0.40$) also indicated small-to-moderate effects on reading outcomes [11]. There are also previous review studies that have included a mix of group studies and single-case studies involving students with or without disorders of ID [23,24]. Overall, their results indicated that the participants benefited from systematic phonic-based reading interventions.

No peer-reviewed systematic review and/or meta-analysis of control group studies to date have summarized writing interventions for students with disorders of ID. However, in a dissertation, Rodgers [25] identified three group-design studies including students with and without disorders of ID. Only one of them involved a pretest-posttest control-group

design: Haviland [26] (not included in the present review because it is not possible to separate the data for participants with disorders of ID) studied a total of 22 students with and without ID (IQ = 62–85, ages 12–18) and explored instructions on text writing (sentence combining). The writing outcomes of the participants suggest a positive summary mean effect ($g = 0.41$) of the intervention (calculated by Rodgers [25]).

None of the existing reviews on reading or writing involving students with disorders of ID have reported the maintenance effect [11], which may extend our knowledge of the sustainable effect of reading and writing interventions for this group of students.

1.3. The Present Study

We explored the available reading and/or writing interventions using RCTs or QEDs, including students with identified disorders of ID regardless of aetiology with or without comorbid conditions. Furthermore, we investigate (a) the effect of the included reading and/or writing interventions, (b) whether there is any transfer effect to untrained words, and (c) any maintenance effect on students' reading and writing outcomes several months after completion of the intervention.

2. Materials and Methods

To ensure quality and transparency, the present study was designed and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) [27].

2.1. Inclusion and Exclusion Criteria

The primary studies had to meet the following criteria for inclusion in this review:

- Include students with disorders of ID (IQ ≤ 69 identified by standardized tests accounting for standard error) or a diagnosis known to be associated with disorders of ID (e.g., Down syndrome) for mean ages 4–19 years. Studies including students with comorbidities such as autism spectrum disorder (ASD) are also included. When a study includes participants with and without disorders of ID, it must be possible to separate the data for participants with disorders of ID.
- Use either RCT or QED with a pretest-posttest control-group design.
- All intervention contexts were accepted (e.g., individual or group teaching in schools, clinics or at home).
- Include one or more elements of reading (decoding and linguistic comprehension) and/or writing (encoding and linguistic productions) instructions with or without the use of technology. Studies targeting solely emergent reading and writing skills or matching skills were excluded.
- To be included in the meta-analysis, studies also had to report effect sizes on the required dependent reading and writing variables, or it had to be possible to calculate these effect sizes from the reported data. Studies with reported nonsymmetric distributions (e.g., medians) were excluded. In studies examining students with and without disorders of ID, statistics had to be reported separately, or the authors had to provide data on request to be included.

2.2. Search Strategy and Study Selection

First, papers published in Danish, English, Norwegian, and Swedish were identified in electronic searches of the following databases between 13 February 2018 and 17 March 2018: Academic, Amed, Campbell Library, Cochrane, Embase, Eric, Medline, Norart, ProQuest, PsycINFO, Scopus, SweMed+, and Web of Science. We included synonyms for disorders of ID, reading, writing and participants, and no time limit was set. In line with the PRISMA statement, search terms and an example of a full-search strategy are attached in Supplementary Material Search Strategy S1. This first search resulted in 14,726 hits. We also searched electronic databases for grey literature (Base, Nora and OpenGrey), with

70 hits. In addition, an ancestral search of relevant systematic reviews was performed with 41 hits. This resulted in 9338 candidate studies after removing duplicates.

The two-stage screening process utilized the systematic review software DistillerSR [28] for (1) title and abstract screening and (2) screening for full-text eligibility. In stage 1, 142 candidate studies met the screening criteria and were included in stage 2. Multiple publications of the same study sample were full-text screened for complete information [29], favouring data from the first-published study. Three studies involving students with or without disorders of ID and the authors were contacted due to the inclusion criteria. Two of them forwarded the requested raw data associated with participants with identified disorders of ID only [30,31], and one had to be excluded because separate data for participants with disorders of ID were not available [26]. In general, where eligibility was unclear, the co-authors discussed the study in question until agreement was reached. This process resulted in seven included studies [20,30–35].

In addition, backward searches of the included studies and other relevant sources from the process of full-text screening were conducted and resulted in 52 hits. Furthermore, the second author sent six newly published candidate studies to the first author. One of these papers [36] met the inclusion criteria. We also contacted 28 authors in the field with three or more relevant hits (1 October 2019). Of the 13 respondents, one reported a relevant study in progress (now published: [9]). Then, forward citation searches in Google Scholar of the included studies generated 23 hits.

Manual searches were performed through all issues of the journals of seven of the included articles from 2010 to April 2021: *Journal of Child Psychology and Psychiatry*, *Journal of Intellectual Disabilities*, *Psychology in the Schools*, *Reading and Writing, Remedial and Special Education*, *Research in Developmental Disabilities*, and *The Journal of Special Education*, resulting in 2 hits.

The search was updated on 30 March with 2412 hits and for grey literature on 8 April 2021 with 43 hits. In total, the updates resulted in 1650 hits after the duplicates were removed, and these were added to the DistillerSR. Thereafter, the two-stage screening process was repeated with additional references. Eighteen studies went to full-text screening, and one more study met our inclusion criteria [37]. Three studies from the original search and one study from the updated search were impossible to recover (see Supplementary Material Search Strategy S2 for an overview).

The total search yielded 17,138 hits through database searches and 238 through other searches. The final result after removing duplicates was 11,089 candidate studies.

For a full overview of the study selection processes, see Figure 1. (For an overview of a selection of excluded candidate studies, see Supplementary Material Excluded Studies S1).

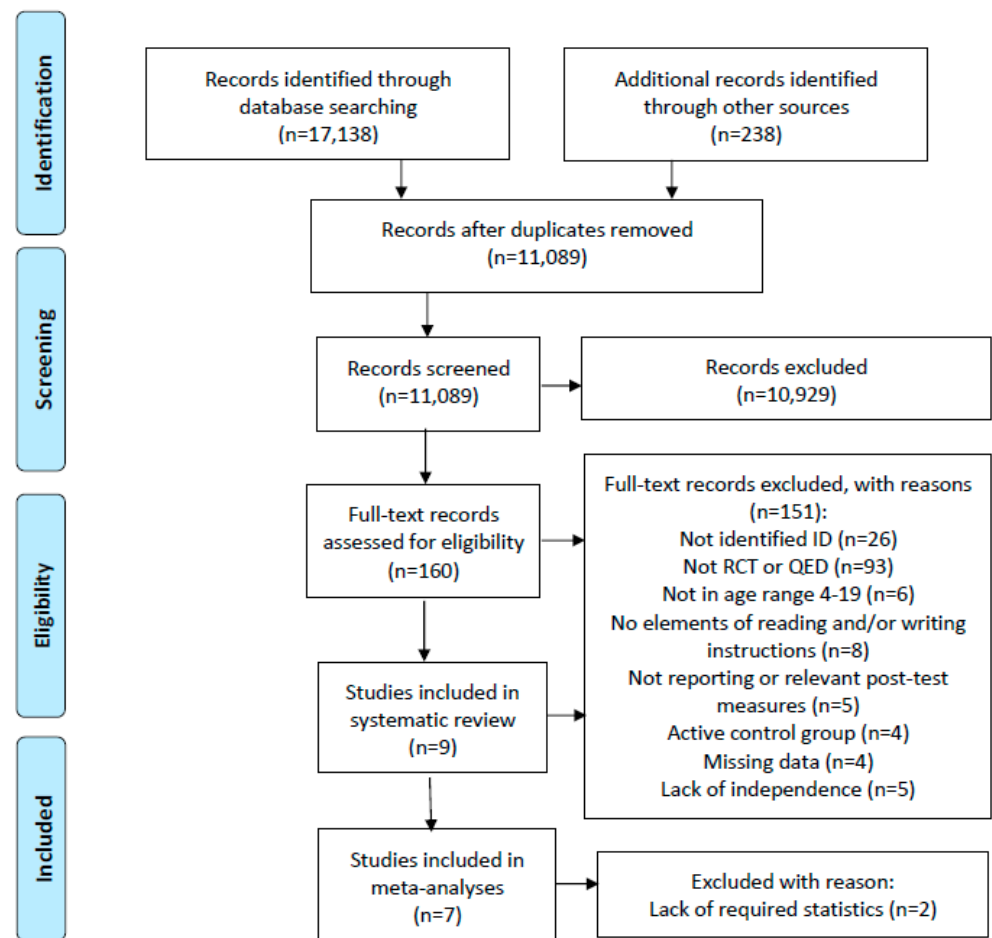


Figure 1. Study flow chart.

2.3. Data Extraction

The nine studies that met the inclusion criteria were subjected to data extraction. Two documents describing the coding categories (Supplementary Material Coding Documents S1 and S2) were used to guide data extraction to collect the characteristics of the intervention studies included in the systematic review (see Table 1) and the effects of intervention (see Table 2). The first and fourth authors coded the studies together.

Table 1. Characteristics of the intervention studies included in the systematic review.

Authors, Year, Location	Design Target Aspect Control Condition	Sample Size (n)	Age M in Months (SD)	IQ M (SD)	Description of the Sample	Intervention for DID	Content Components Reading	Content Components Writing	Teaching Materials	Dosage Delivered	Organisation	Provider
* Ahlgrim-Delzell et al., 2016, USA	Randomized control trial PAU	^c Treated: 14 ^c Control: 13	^c Treated: 119.92 (38.83) ^c Control: 112.82 (32.59)	UK IQ-tests: ^c Treated: 50.07 (9.52) ^c Control: 50.77 (7.80)	Aetiology of DID: Multifactorial Verbal: Non-verbal/AAC Decoding: No Adaptive:	Partly Supplemental instruction	Decoding: Phonics, sound blending, sound segmentation, word recognition, text reading combined with sight word Linguistic comprehension: Comprehension questions	Encoding: Linguistic production:	Early Reading Skill Builder iPad/app: GoTalk Now- text-to-speech and letters, words, pictures	^c Approximately 46.67 h in 32 W	Individually	Teachers from the school staff
							¹ Emergent skills: Phonological awareness, letter knowledge Others:					
Allor et al., 2010, USA	Quasi-experimental design PAU	Treated: 34 Control: 25	Treated: 95.28 (17.52) Control: 92.64 (17.88)	UK IQ-tests: ^c Treated: 56.35 (8.38) ^c Control: 58.36 (8.46)	Aetiology of DID: Multifactorial Verbal: Verbal Decoding: Varied Adaptive:	No Supplemental instruction	Reading: Decoding: Phonics, word recognition, sound blending, fluency, text reading Linguistic comprehension: Comprehension strategies	Encoding: Linguistic production:	Early Intervention in Reading and Foundation Level Graded books	^c Approximately 298 h in 79.54 W	Individually/groups on 2–4 students	Teachers with special education from the research staff
							¹ Emergent skills: Phonological awareness, letter knowledge, concepts of print ¹ Others: Oral language, vocabulary					
Browder et al., 2012, USA	Randomized control trial PAU	Treated: 47 Control: 46	Grade K-5	Unknown IQ-tests: Treated: 41.50 (12.60) Control: 43.50 (13.30)	Aetiology of DID: Multifactorial Verbal: Varied Decoding: No Adaptive:	Yes Supplemental instruction	Decoding: Phonics combined with sight word Linguistic comprehension: Comprehension strategies	Encoding: Linguistic production:	Early Literacy Skills Builder Teaching Script Picture books	^c Approximately 153.60 h in 24 W	Individually/groups on 2–4 students	Teachers with special education from the school staff
							¹ Emergent skills: Phonological awareness, letter knowledge, concepts of print Others: Vocabulary					
Burgoyne et al., 2012, UK	Randomized control trial PAU WL	Treated: 28 Control: 26	Treated: 80.48 (14.74) Control: 77.82 (15.88)	WPPSI-III *** ^c Treated: 11.82 (6.23) ^c Control: 10.19 (6.84)	Aetiology of DID: Down syndrome Verbal: Varied Decoding: Varied Adaptive: Behavioural challenge	Yes Supplemental instruction	Decoding: Phonics, text reading combined with sight word Linguistic comprehension: Comprehension strategies	Encoding: phonetic spelling Linguistic production:	Teacher manual Games with targeted words Pictures Graded books Phonics items Letter and Sounds DfES	^c 66.70 h in 20 W	Individually	Teaching assistants from the school staff
							¹ Emergent skills: Phonological awareness, letter knowledge ¹ Others: Vocabulary					
Connors et al., 2006, Canada	Quasi-experimental design PAU	Treated: 20 Control: 20	Treated: 113.40 (16.80) Control: 117.84 (13.08)	WISC-III: Treated: 53.85 (8.80) Control: 52.09 (11.37)	Aetiology of DID: Multifactorial Verbal: Varied Decoding: no Adaptive:	Partly Supplemental instruction	Decoding: Phonics, sound blending Linguistic comprehension:	Encoding: Linguistic production:	Letters, words, pictures presented on cards and computer	^c 7.30 h in 9.5 W	Individually	research assistants from the research staff
							¹ Emergent skills: Phonological awareness, letter knowledge Others:					

Table 1. Cont.

Authors, Year, Location	Design Target Aspect Control Condition	Sample Size (n)	Age M in Months (SD)	IQ M (SD)	Description of the Sample	Intervention for DID	Content Components Reading	Content Components Writing	Teaching Materials	Dosage Delivered	Organisation	Provider
* Finnegan, 2011, USA	Randomized control trial PAU	** c Treated: 23 c Control: 6	c Treated: 108.35 (33.59) c Control: 105.00 (39.45)	Unknown IQ-test: c Treated: 55.75 (10.29) c Control: 47.75 (7.80)	Aetiology of DID: Multifactorial Verbal: Varied Decoding: Varied Adaptive:	Partly Supplemental instruction	Decoding: Phonics, sound blending, sound segmentation, single-word reading Linguistic comprehension: Comprehension strategies ¹ Emergent skills: Phonological awareness, letter knowledge Others:	Encoding: Linguistic production:	Stories and songs from Dr. Maggie’s Phonic Series/Resource Guide Cards with letters, words, pictures	c 5.80 h in 6 W	Individually	Researcher
Goetz et al., 2008, UK	Quasi-experimental design PAU WL	Treated: 8 Control: 7	c Treated: 111.63 (12.30) c Control: 128.57 (24.33)	Unknown IQ-test: c Treated: 55.75 (10.29) c Control: 47.75 (7.80)	Aetiology of DID: Down syndrome Verbal: Decoding: Emerging Adaptive:	Partly	Decoding: Phonics, sound blending, sound segmentation, word recognition, text reading combined with sight word Linguistic comprehension: ¹ Emergent skills: Phonological awareness, letter knowledge Others:	Encoding: Letter formation Linguistic production:	Jolly Phonics and Reading Intervention Books for the targeted sound. Word-lists Graded books	c 26.70 h in 8 W	Individually	Teaching assistants from the school staff
von Ment-zer et al., 2020, Swe-den	Randomized control trial PAU WL Quasi-experimental design PAU WL	Treated: 10 Control: 7	c Treated /c Control: 120 (33.6)	Mild, moderate, severe	Aetiology of DID: Down syndrome Verbal: Varied AAC Decoding: Emerging Adaptive:	Partly Supplemental instruction	Decoding: Computer-based phonics, sound blending, sound segmentation, word recognition Linguistic comprehension: Comprehension strategies ¹ Emergent skills: Phonological awareness, letter knowledge Others:	Encoding: Spelling Linguistic production:	Computer software: Grapho-Game	c 3.33 h in 4 W	Individually	Teachers from the school staff
Robles-Bello et al., 2020, Spain		Treated: 20 Control: 18	c Treated: 60.00 (14.40) c Control: 52.80 (22.80)	WPPSI-III Treated: 54.00 Control: 54.00	Aetiology of DID: Down syndrome Verbal: Varied Decoding: No Adaptive:	Yes	Decoding: Phonics, text reading combined with sight word Linguistic comprehension: Comprehension strategies ¹ Emergent skills: Phonological awareness ¹ Others: Vocabulary	Encoding: Letter formation Linguistic production:	Troncoso and del Cerro’s reading method	hours in 36 W	Individually	Teaching psychologists **** Parents Teachers from the school staff

Note: AAC = alternative augmentative communication, ABAS-II = Adaptive Behavior Assessment System-second edition, AT = alternative treatment, Control = Control group, CFT1-R = Culture Fair Intelligence Test-scale 1 revised, DID= disorders of intellectual development, M = mean, MA = mental age, n = number, PAU = practice as usual, SB-4 = Stanford-Binet Intelligence Scale-fourth edition, SD = standard deviation, Treated = treated group, WISC-III = Wechsler Intelligence Scale for Children-third edition, WL = waiting list, WPPSI-III = Wechsler Preschool and Primary Scale of Intelligence-Third Edition, W = weeks, * = of the original sample, 73% in Ahlgrim-Delzell et al., 2016, and 56% in Finnegan, 2011, had DID and is included, based on data from the authors, ** = collapsed two treated groups, *** = non-verbal IQ in raw score collapsed by the substests’ block design and object assembly, **** = based on information from the author, c = calculated by reviewer, ¹ = excluded in the synthesis regarding the simple view models, Blanc cells and parts = lacking information.

Table 2. Effects of interventions on dependent variables in reading and writing.

Authors	Measurements for the Dependent Variables	Effect on Trained Reading	Effect on Transfer Reading	Collapsed Transfer Reading Effect for MA (M)	Effect on Trained Writing	Effect on Transfer Writing
* Ahlgrim-Delzell et al., 2016	^c NST: Decoding for picture-word matching	^c d = 1.21				
Allor et al., 2010	ST/WLPB-R4: Listening comprehension ST/WLPB-R4: Non-word reading ST/TOWRE: Phonemic decoding efficiency ST/WLPB-R4: Letter-word identification ST/WLPB-R4: Passage comprehension		d = 0.34 d = 0.58 d = 0.49 ¹ d = 0.51 d = 0.04	^c d = 0.39		
Burgoyne et al., 2012	ST/YARC: Single-word reading NST: Non-word reading NST: Phonetic spelling		d = 0.23 ^{1,2} d = 0.25 ^{1,2}	^c d = 0.24		d = 0.07 ^{1,2}
^x Connors et al., 2006	NST: Sounding out	^c d = 0.85 ¹				
* Finnegan, 2011	^c ** ST/WJ-IIIDRB: Letter-word identification ^c ** ST/WJ-IIIDRB: Non-word reading ^c ** NST: Transfer word ^c ** NST: Training word	^c d = 0.93 ¹	^c d = 0.29 ^c d = 1.07 ¹ ^c d = 0.50 ¹	^c d = 0.62		
Goetz et al., 2008	ST/EWR: Early Word recognition ST/BAS: Word reading NST: Non-word reading		d = 1.03 d = 0.80 d = 0.40 ¹	^c d = 0.74		
Robles-Bello et al., 2020	*** ST/CUMANIN: Reading *** ST/CUMANIN: Writing		^c d = 0.92			^c d = 0.00 ^{1,2}

Note: AAC = Academic Achievement Tests-french translation, ST = standardised test, MA = meta-analysis, NST = non-standardised test, WLPB-R4 = Woodcock Language Proficiency Battery-Revised, TOWRE = Test of Word Reading Efficiency, YARC = York Assessment of Reading, BAS = British Ability Scales, EWR = Early Word Recognition Test, * = of the original sample, 73% in Ahlgrim-Delzell et al. (2016) and 56% in Finnegan (2011) had disorders of intellectual development and is included, based on data from the authors, ** = collapsed two intervention groups, *** = based on information from the author, ^c = calculated by reviewer, ¹ = floor effect pre-test, ² = floor effect post-test, ^x = recalculation from F-value, Blanc cells and parts = lacking information

To identify the requested data [29], subcalculations (i.e., age, IQ, duration, sample size) were performed by the first author in Excel (Version 1908) and by the fourth author in IBM SPSS Statistics (Version 26), returning consistent results. Within each study, Cohen's *d* was used as the comparable standardized mean difference/effect size metric [38]. For one effect size [35], we converted the reported *F*-value to Cohen's *d*. For the subgroups of participants with identified disorders of ID, we used sample size, means, and pooled standard deviations (SD) for pretest and posttest scores using Comprehensive Meta-Analysis (Version 3 [CMA-V3]) [39].

2.4. Data Analysis

2.4.1. Narrative Synthesis of the Systematic Review

For the narrative synthesis, we used the data in Table 1 to describe patterns of characteristics within and across the included studies. The aim was to identify characteristics that might influence and explain any similarities and differences across interventions using the following procedures: frequency distributions of different variables; concept mapping (identifying relationships between results); thematic analysis (identifying the most important themes); content analysis (compressing text into fewer content categories); and examining similarities and differences between variables to integrate them into a new cross-study interpretation [40].

2.4.2. Meta-Analysis

Seven studies were included in the meta-analyses. Browder et al. [33] and von Mentzer [37] were excluded due to a lack of appropriate statistics.

The data in Table 2 formed the basis for the meta-analyses using CMA-V3 [39]. We calculated the effect sizes for each group comparison using Hedges' *g*, as this measure is corrected for sample size with no tendency to an upward bias in small samples [41]. According to Cohen [42], benchmark values may be inconsistent, and overall effect sizes were interpreted and discussed regarding different influencing variables [43].

In each analysis, the overall effect size was estimated by calculating a weighted mean based on a random-effects model because variations in effect sizes across studies may be systematic (e.g., differences in the measures used) rather than attributable only to random error [38]. When Hedges' *g* is expressed in positive terms, treated group performance on the test is better than the control group (i.e., higher group mean). A 95% confidence interval (CI) was calculated for each effect size to determine whether it was greater than zero; if the confidence interval did not cross zero, the effect was statistically significant.

The *Q*-test for heterogeneity was used to examine variation in effect sizes between studies. Defined as a weighted sum of squares that can be partitioned into their component parts, *Q* reflects the total dispersion of studies around the grand mean [29]. As *Q* is a standardized measure, the expected value does not depend on the metric for effect size; in this test, a significant value indicates significant variability between effect sizes in the sample of studies. I^2 was used to determine the proportion of the variance in the observed effect due to the variance in true effects rather than sampling error [38].

2.5. Assessment of Risk of Bias

Risk of bias (RoB) within studies was assessed using the revised Cochrane RoB2 [27] online tool for randomized trials, which is divided into five domains: randomization process, deviations from intended interventions, lack of outcome data, measurement of outcome, and selection of reported results [44]. Based on answers to the series of questions in RoB2, a proposed judgement is generated by an algorithm, rating each domain as low, some concerns or high risk of bias [29].

2.6. Inter-Rater Agreement

Twenty-two percent of the included studies were double-coded by an independent expert (PhD) on students with disorders of ID and systematic review.

Concerning the risk-of-bias judgement, interrater agreement was 100% for every domain except the randomization process, where it was 67% due to differing applications of the coding categories, probably no and no information. Overall, interrater agreement regarding the risk of bias was 94%.

Regarding study characteristics, the overall interrater agreement rate was 93%, including 100% agreement for authors/year/location, design, control condition and target aspect, sample size, age in months, IQ, writing-related aspects trained, organization, and providers. For other characteristics, interrater agreement was as follows: dosage delivered: 97% for hours and 99% for weeks; reading-related aspects trained: 84%; description of the sample: 89%; teaching materials: 75%; and interventions developed or adapted for disorders of ID: 50%. The last rate reflects differing application of the coding categories partly and no; additionally, one of the coders overlooked information on the supplementary instruction in one table.

Interrater agreement for the effect sizes was calculated as the standardized correlation coefficient Pearson's r , which is suitable for quantitative variables and indicates covariation and its strength [38]. Pearson's r varies between -1 and $+1$, where 1 indicates a positive correlation. The effect on trained reading was $r = 1$, and the effect on transfer reading was $r = 0.60$ because one coder included the effect size from one test (CTOPP, measuring phonological skills only). When these effect sizes were removed, interrater agreement was $r = 0.84$. Any disagreement was resolved by consulting the primary paper and discussion between coders.

3. Results

3.1. Study Characteristics

The studies were published from 2006 to 2020 and conducted in Canada (1), Spain (1), Sweden (1), the UK (2), and the USA (4).

3.1.1. Design

The selected studies included five RCTs [30,31,33,34,37] and four QEDs [20,32,35,36]. Two RCTs [34,37] and two of the QEDs [20,36] used a waiting-list control (data from only the first two time points are included in this review). The level of reported detail of the control conditions varied across studies. Broadly, eight of the included studies reported that the control group received practice-as-usual (i.e., phonics-based, sight-word recognition or emergent skills instructions). One study reported that the intervention was applied only in the treated group [36].

3.1.2. Participants

The total sample included 372 participants, ranging from 15 to 93 (M sample size = 41.0, SD = 24.0): 204 were in the treated group, ranging in age from 5.0–10.0 years (M = 8.2, SD = 1.8); 168 were in the control group, ranging in age from 4.5–10.6 years (M = 8.2, SD = 2.2). In the treated group, IQ ranged from 41.5–56.4 (M = 52.0, SD = 5.6); in the control group, IQ ranged from 43.5–58.4 (M = 51.0, SD = 5.1). All participants had IQs identified as falling within the disorders of ID range. Values from von Mentzer's [37] sample were not included in the above reporting of age and IQ since they had collapsed age for the treated and control groups together (M = 10.0 years, SD = 2.8), and no IQ values were given in the paper. Since all participants in their sample had Down syndrome, they still fulfilled the inclusion criteria for this review.

Overall, the sample exhibited multifactorial disorders of ID; in four studies, all participants had Down syndrome [20,34,36,37]. Participants' verbal skills varied; in Ahlgrim-Delzell et al. [30], all students were nonverbal and used augmentative and alternative communication (AAC) only. Participants exhibited varying decoding skills at pretest, except for Goetz et al. [20], in which emerging decoding skills were required to participate.

3.2. Narrative Description of the Interventions

3.2.1. Reading and Writing Instruction Components

Reading intervention programmes: Six studies used a low-tech reading programme. Browder et al. [33] developed the Early Literacy Skills Builder, adapted for AAC users. Robles-Bello et al. [36] used Troncoso and del Cerro's reading developed for children with disorders of ID. Burgoyne et al. [34] developed the reading intervention for students with disorders of ID using research-based reading instructions tested in previous studies. Allor et al. [32], Goetz et al. [20] and Finnegan [31] adapted Early Intervention in Reading, Jolly Phonics Reading Intervention and Dr. Maggie's Phonic Series for students with disorders of ID.

Technology-based interventions: Three studies used technology. Ahlgrim-Delzell et al. [30] developed the Early Reading Skills Builder using iPad and the app GoTalk-Now. von Mentzer et al. [37] used a computer with the software GraphoGame designed initially for children with dyslexia. Conners et al. [35] delivered a phonological reading intervention on both computers and paper cards.

Decoding: All interventions were phonics-based. The targeted decoding skills were sound blending and segmentation (e.g., practising segmenting and blending words starting/ending with the sound of the day); word recognition (e.g., recognizing high-frequency phonetically irregular words and decoding words ranging from phonetically regular to more complex); text reading (e.g., reading an instructional level book with 90–94% accuracy); fluency (e.g., repeated reading of continuous text); and single word reading (e.g., converting letters into sounds and blending those sounds into spoken words). Five studies combined decoding with sight-word instructions [20,30,33,34,36].

Linguistic comprehension: Except for Conners et al. [35] and Goetz et al. [20], all the studies included instructions on linguistic comprehension (e.g., questions about the text, making predictions and inferences).

Writing: Three studies involved simple encoding instruction in phonetic spelling [34] and letter formation [20,36], but only two studies measured writing outcomes. However, all three studies including writing aspects, specified that the interventions' main foci were reading outcomes.

Materials: In addition to the reported technology, the studies used materials that visualized the targeted aspects in pictures, letters, and words; only Finnegan [31] reported font and font size. Studies involving continuous text used graded reading books with illustrations [20,32–34].

Supplemental instructions: Almost all studies (except [20,36]) used strategies to address students' adaptive and cognitive challenges, including explicit instruction (e.g., systematic prompting), direct instruction (i.e., structured and led by the teacher); time delays with model prompts and physical guidance; reinforcement responses; arranging materials; repeated opportunities to practise each reading skill; short sessions and breaks as needed; and management of behaviours incompatible with learning.

3.2.2. Intensity, Length, Provider, and Organization

Intensity and length: The duration of interventions ranged from 4 to 80 weeks ($M = 24.4$, $SD = 23.9$) and from 3.3 to 303 h ($Mdn = 36.9$, $M = 76.6$, $SD = 104.1$); sessions per week ranged from 2 to 5, with 10 to 45 min per session. Robles-Bello et al. [36] did not specify the length of each session in the publication; in response to an email request, the author replied that the intervention was delivered daily.

Provider: The interventions were delivered by teachers in three studies and by teaching assistants in two others. One study also involved parents and a teaching psychologist [36]. In the other studies, the interventions were delivered by research staff.

Organization: All studies delivered interventions individually; two studies also organized groups of up to four participants [32,33].

3.3. Effects of Interventions on Reading and Writing

We performed three meta-analyses with 19 effect sizes related to trained reading (Figure 2), transfer reading (Figure 3), and transfer writing (Figure 4). In these figures, the squares show estimated effect sizes, and the horizontal bar for each square predicts the 95% CI. The size of the square indicates the weight of each effect size, and the diamond indicates the overall mean effect size.

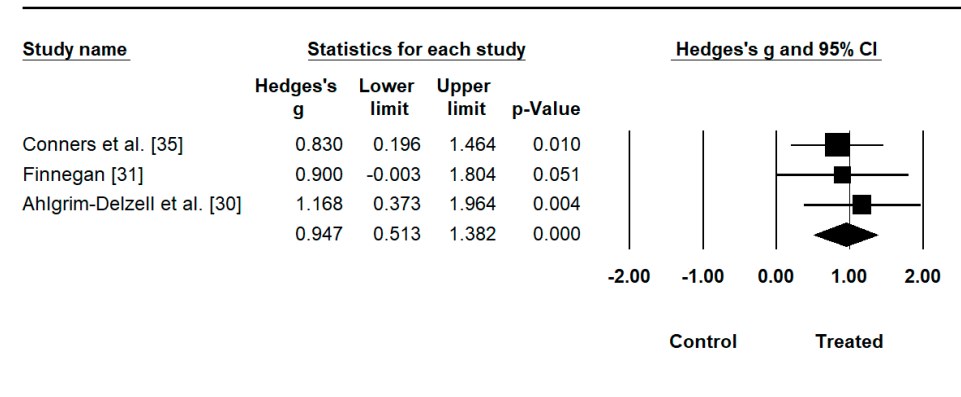


Figure 2. Effect on trained reading [30,31,35].

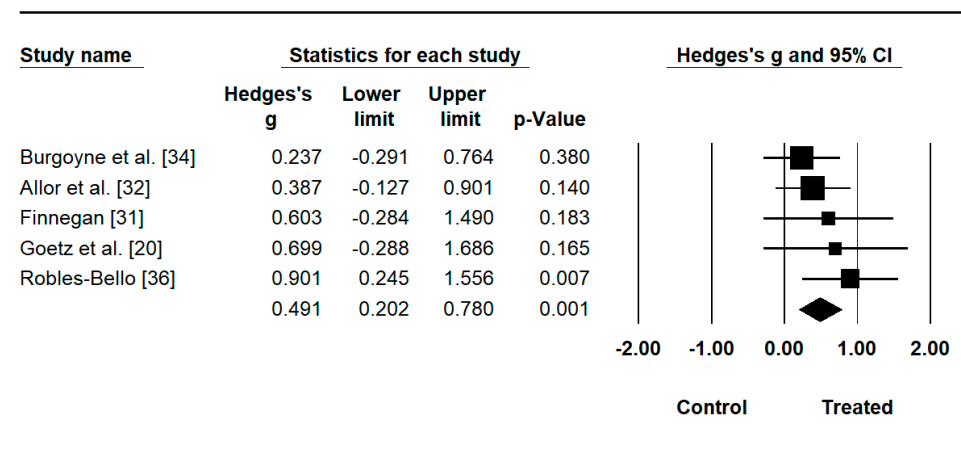


Figure 3. Effect on transfer reading [20,31,32,34,36].

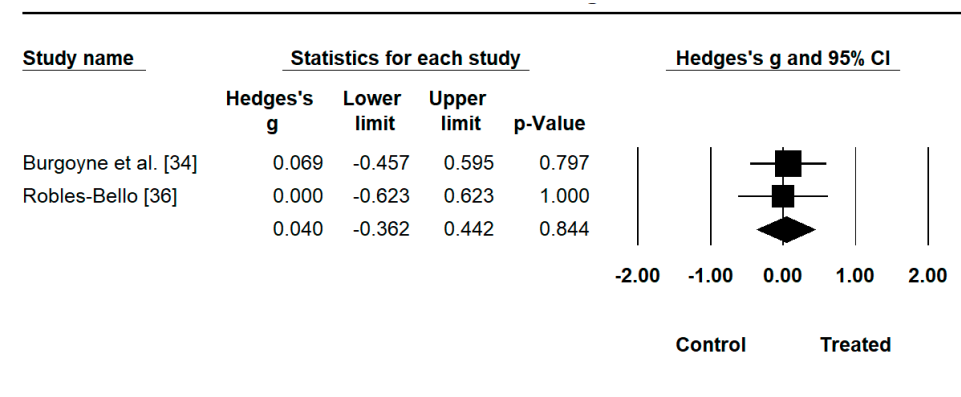


Figure 4. Effect on transfer writing [34,36].

3.3.1. Effect on Trained Reading

The meta-analysis of trained reading included 96 participants: 57 in the treated group and 39 in the control group. The overall mean chronological age at pretest was 9.4 years (SD = 0.5); the treated group ranged in age from 9.0–10.0 (M = 9.5, SD = 0.5), and the control group ranged from 8.8–9.8 (M = 9.3, SD = 0.5). The overall mean IQ was 51.7 (SD = 2.8), ranging from 50.1–55.9 (M = 53.2, SD = 2.9) in the treated group and from 47.8–52.1 (M = 50.2, SD = 2.2) in the control group.

The overall mean effect size was computed from the three effect sizes for trained reading nested in three studies. Figure 2 shows that the overall mean effect size of differences between the treated and control groups on trained reading measures was $g = 0.95$ (95% CI = [0.51, 1.38], $p < 0.001$), which clearly suggests that the interventions improved students' ability to read taught words.

Between-study heterogeneity was not significant ($Q(2) = 0.44$, $p = 0.803$), indicating small heterogeneity in effect sizes across studies. The I^2 value of 0% indicates that most of the variance in the forest plot is due to sampling error.

3.3.2. Effect on Transfer Reading

The meta-analysis of transfer reading included 195 participants: 111 in the treated group and 84 in the control group. The overall mean chronological age at pretreatment was 7.6 years (SD = 2.0), ranging from 5.0–9.3 (M = 7.6, SD = 1.8) in the treated group and from 4.3–10.4 (M = 7.6, SD = 2.4) in the control group. The overall mean IQ was 54.4 (SD = 3.6), ranging from 54.0–56.4 (M = 55.4, SD = 1.2) in the treated group and from 47.8–58.4 (M = 53.4, SD = 5.3) in the control group.

The overall mean effect size was computed from 14 available effect sizes for transfer reading, nested in five studies. Effect sizes for transfer reading in three studies were collapsed within each study, and the mean effect size for transfer reading was used in the meta-analysis. Figure 3 shows that the overall mean effect on transfer reading between the treated and control groups was $g = 0.49$ (95% CI = [0.20, 0.78], $p < 0.001$). This suggests that the interventions resulted in transfer reading skills among students with disorders of ID, with a small-to-moderate effect. Between-study heterogeneity was not significant ($Q(4) = 2.78$, $p = 0.560$), indicating moderate heterogeneity in effect sizes across studies. The I^2 value of 0% indicates that most of the variance in the forest plot is due to sampling error.

3.3.3. Effect on Transfer Writing

The meta-analysis of transfer writing included 92 participants: 46 in the treated group and 46 in the control group. The overall mean chronological age pretreatment was 5.7 years (SD = 1.1), ranging from 5.0–6.8 (M = 5.9, SD = 1.2) in the treated group and 4.5–6.6 (M = 5.4, SD = 1.5) in the control group. Only one of the included studies reported IQ (M = 54.0, SD = 0.0) [36].

The random-effects mean effect size was computed from the available effect sizes for transfer writing, nested in two studies. Figure 4 shows that the mean effect on transfer writing for the treated and control groups was $g = 0.04$ (95% CI = [−0.36, 0.44], $p < 0.844$), which may indicate that the instructions had no effect on the transfer writing skills of students with disorders of ID. This result may also be caused by the low number of studies. Between-study heterogeneity ($Q(1) = 0.03$, $p = 0.868$) indicated a small heterogeneity of effect size across studies. The I^2 value of 0% indicates that most of the variance in the forest plot is due to sampling error.

3.4. Results of Risk of Bias within Studies

The randomization process: only Finnegan [31] provided detailed information about the randomization process. The other studies that referred to allocation procedures as randomized lacked information about allocation concealment [30,33,34,37]. Four of the studies were considered to be at high risk of bias [20,35–37].

Deviation from the intended intervention: Four studies provoked some concerns [20,32,35,36] because of the providers' awareness of participants' assignment or missing information about deviation.


Missing outcome data: One study [32] was considered to be at high risk of bias because several participants dropped out, and one study reported missing data at both time points [37].

Measurement of the outcome: All studies (except for [35]) were at high risk of bias because of the insufficient description of measurement procedures, floor effects for pretest and posttest without statistical adjustment, outliers, and repetition of measurement items.


Selection of reported results: All studies provoked some concerns in the absence of any description of a prespecified plan for the analysis.

In summary, none of the studies met all the quality indicators. It is worth mentioning that six of the nine included studies reported limitations in the discussion of their results; measurement validity was frequently considered a limitation and potential threat to the validity and reliability of the findings by the authors themselves [30–33,37]. In particular, they considered the appropriateness of the selected tests for students with disorders of ID, the sensitivity of the tests to detect the students' progress, and the students' functioning within the test situations. This risk of bias evaluation indicates a need to improve the quality of future RCTs and QEDs according to the assessed risk of bias domains. The risk of bias summary for each study is shown in Figure 5.


	Randomization process	Deviations from intended interventions	Lack of outcome data	Measurement of outcome	Selection of reported result	Overall
Goetz et al. [20]	–	?	+	–	?	–
Ahlgrim-Delzell et al. [30]	?	+	+	–	?	–
Finnegan [31]	+	+	+	–	?	–
Allor et al. [32]	?	?	–	–	?	–
Browder et al. [33]	?	+	+	–	?	–
Burgoyne et al. [34]	?	+	+	–	?	–
Conners et al. [35]	–	?	+	+	?	–
Robles-Bello [36]	–	?	+	–	?	–
von Mentzer et al. [37]	–	+	–	–	?	–



Low risk



Some concerns



High risk

Figure 5. Risk of bias within studies [20,30–37].

4. Discussion

Our results show that students with ID disorders can improve their reading skills by participating in predesigned interventions tested out by RCTs or QEDs. Improved reading skills transferred to reading tasks that were not directly trained during the interventions but did not transfer to writing tasks. The results offer slight insight into the effects of the intervention on reading comprehension and writing or maintenance effects.

4.1. Students with Disorders of ID Can Benefit from Reading Interventions

The large positive overall mean effect on reading confirms that students with disorders of ID can benefit from reading interventions. Notably, the effect sizes for trained reading are measured using nonstandardized tests, which may yield higher effect sizes than standardized tests [43]. Two of the three effect sizes in the primary studies indicated an observed floor effect on the pretest, which may result in an overall higher effect size [45]. However, the effect size without floor effects tended in the same direction, indicating that participants were able to learn to read the words they were taught in the interventions. The focus in the included studies on students with mild-to-moderate disorders of ID (IQ range 41.5–58.4) may have yielded a higher effect size than if students with a severe disorder of ID had also been included [7]. The participants profited from interventions adapted from programmes for typically developing children or for children with reading and writing difficulties and from the interventions exclusively developed for students with disorders of ID. Most of the interventions incorporated supplemental instructions that were found to be appropriate for addressing challenges with adaptive and cognitive skills, such as limitations in phonological memory, which may be a key factor from the systematic review in explaining why these approaches worked [10].

All the studies included in this review focused on phonic-based instructions, decoding strategies and emergent skills, and mainly all interventions also focused on linguistic comprehension instructions. These elements align with the finding that the best approach to reading instruction for typically developing students incorporates explicit teaching of phonemic awareness, systematic phonics instruction and methods to improve fluency and comprehension [46]. Most of the interventions combined phonic-based instructions with sight-word training. Sight-word strategies without decoding and comprehension instructions do not promote reading skills in students with disorders of ID [33] or in typically developing students [46].

4.2. Transfer Effects from Reading Interventions to Untrained Words

In line with Sermier Dessemontet et al.'s [10] meta-analysis, we found small-to-moderate effects for standardized tests of transfer reading skills, which may yield a more robust effect size than nonstandardized tests [43]. Finnegan [31] noted that the 'transfer' words in her study were unfamiliar terms that had phonetic structures similar to the trained words but were not taught or practised during the study period. In the other studies, no information was provided as to whether the skills transferred to the same phoneme and syllable combinations in new words or to new phoneme and syllable combinations. Future research should address this issue to determine (1) whether reading interventions can contribute to learning effects on reading words in general based on increased phonological alphabetical decoding or (2) whether generalization effects are confined to words with trained phonemes and syllables.

For the trained reading effects described above, the observed floor effects on pretest and some posttest may contribute to higher overall effect size [45]. However, there were no discrepancies between effect sizes in studies with and without observed floor effects, indicating that participants were able to generalize trained skills from the intervention when reading novel words.

4.3. *The Long-Term Effects of Reading Interventions*

The included studies reported no long-term effects on reading. Goetz et al. [20] included long-term follow-up, but the waiting-list control design precluded the possibility of including the results from the controls. In light of the hypothesized challenges faced by students with disorders of ID in maintaining learned skills [7], it was surprising that the reviewed studies did not include long-term postintervention effect measures. While long-term measurement is costly and time-consuming, it seems important to establish whether such interventions have sustainable effects. Future reading intervention studies for students with disorders of ID should therefore include at least a one-year follow-up in light of existing evidence of a fade-out effect within the first year or two following interventions [47].

4.4. *The Effect of Interventions on Trained and Transfer Writing*

The total absence of RCTs or QEDs meeting our inclusion criteria focused on writing as the primary outcome for students with disorders of ID is a critical finding.

Two studies reported transfer writing scores. The meta-analysis of transfer writing may seem like an inconsequential synthesis, but in our opinion, the low overall effect size in transfer writing may be due to the lack of focus on writing instructions in the interventions. Sermier Dessemontet et al. [9] showed that students improved spelling skills with a medium effect size. Writing skills are an important learning and communication strategy for students with disorders of ID [2] and are widely believed to help typically developing students learn to read [15]. There is therefore a pressing need to develop and investigate the potential effects of writing interventions using RCTs or QEDs for students with disorders of ID.

4.5. *Limitations of the Review Process Used in This Review*

There were several limitations in our review. First, our inclusion criteria can be considered rigorous. The decision to include participants with disorders of ID identified by standardized tests highlights a gap in previous research. However, it should be noted that IQ is still reported, and none of the studies reported the participants' level of adaptive skills, which, along with reduced cognitive capacity, constitutes a diagnostic criterion for ID. Therefore, we cannot be sure that the students in the studies in question actually met the criteria for both reduced cognitive capacity and adaptive skills, as greater emphasis has historically been placed on the cognitive aspect of disorders of ID [48]. This means that our results may be somewhat overestimated if some students in the sample had typical adaptive skills [43].

Another limitation is the number of studies that fulfilled the inclusion criteria of being an RCT or a QED. However, these are relevant quality criteria for effect studies involving other groups of students [15], and when two or more studies are available, a meta-analysis could be used to aggregate the results [29,49]. The limited number of studies precluded the planned meta-analyses of trained writing outcomes, long-term effects, and meta-regression of potential interaction effects in terms of moderators, sensitivity analysis, and subgroup analysis. Nevertheless, the lack of research studies represents an important finding for what to consider in future studies.

Another limitation is that variation in the control conditions across studies may have biased our results. As students with disorders of ID commonly receive special education, practice-as-usual may follow a modified curriculum. Therefore, the practice of the control group should be clearly described [50].

The RoB analysis indicates a high risk of overall bias, and a meta-analysis is only as good as the included primary studies. We observed floor effects in six of the seven studies. The floor effect is a well-known challenge in educational research and must be adjusted for statistically [51]. None of the primary studies with observed floor effects described statistical methods for handling the impact of this effect. Where there is a floor effect, the

mean of the observed data is likely to be larger than the true mean [51], which may have influenced our results.

4.6. Implications for Practice

Even though our results should be interpreted with some caution, they align with earlier reviews that employed different designs and involved participants both with and without disorders of ID, confirming that students with disorders of ID can improve their reading skills when participating in interventions. With a view to the increasingly automated and technological society locally and globally (the Fourth Industrial Revolution), reading and writing skills will in the future probably be more important than ever as a tool to actively participate in society [52]. Our results indicated that students with disorders of ID should be afforded access to research-based reading and writing interventions. The content of effective reading intervention adapted to students with disorders of ID seems to have similarities with those designed for typically developing children. Linguistic comprehension, phonic-based reading and emergent skills are usually targeted. However, it is important to note that we tested the effects of multifaceted interventions rather than individual content components.

Although there are no RCTs or QEDs investigating the effects of writing interventions for students with disorders of ID that meet our inclusion criteria, teachers must learn this group of student writing strategies. Until RCT or QED studies are available, there may be a few options to follow. First, it may be useful to adapt writing instruction for these students to effective interventions for typically developing students and/or students with dyslexia and/or dysgraphia. Second, the experimental case-study results and comparison of different writing interventions for students with disorders of ID are indicative of what might work and suggest a point of departure.

5. Conclusions

Students with disorders of ID benefited from interventions focusing on decoding strategies, often combined with sight-word and supplemental instructions appropriate to the participants' adaptive and cognitive skills. We identified several gaps in the existing RCTs and QEDs research base, particularly concerning writing interventions for students with disorders of ID. Future studies should employ RCT or QED designs to investigate trained and transfer effects of writing interventions and combined reading-and-writing interventions and their interplay, as well as long-term effects. Digital ventures and collaborations across researchers will make such research possible. Background data on students with disorders of ID should include both cognitive and adaptive skills, as a diagnosis of disorders of ID depends on significant deviation in both. Although there is still a way to go, addressing these research gaps will help to guide effective future reading and writing interventions for students with disorders of ID.

Supplementary Materials: The following are available online at <https://www.mdpi.com/article/10.3390/educsci11100638/s1>, Coding Document S1: Characteristic of Studies Included in the Systematic Review, Coding Document S2: Effects of Interventions on Dependent Variables on Reading and Writing, Search Strategy S1: Search terms and the search in MEDLINE, Search Strategy S2: Overview of studies that were impossible to recover, Excluded Studies S1: An overview of a selection of excluded studies.

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