Digital Intervention in Children with Developmental Language Disorder: A Systematic Review

Zhaowen Zhou, Cheng Deng, Dongling Yin, Qiaoxue Yang, Zhuoming Chen

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Abstract

Background: Developmental language disorder (DLD) is one of the most common neurodevelopmental disorders. Effective intervention is vital to improving the quality of life for individuals with DLD and preventing negative effects in adulthood. Digital interventions have the potential to complement conventional language intervention, reducing the workload for therapists and increasing accessibility to language training in homes or schools. However, the effectiveness of digital intervention and its influential factors are not yet reported.

Objective: This systematic review aimed to assess the effectiveness of digital interventions on language outcomes of children with DLD and to identify influential factors.

Methods: The study protocol was registered in the International Prospective Register for Systematic Reviews (PROSPERO) and was ascribed to the CRD42023477946 registration code. Literature published to May 2023 was retrieved by searching four databases: "PubMed", "Scopus", "PsycInfo", and "IEEE Xplore", following a method adapted from PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses). Inclusion criteria include studies recruiting patients diagnosed with DLD; Articles that reported digital interventions based on apps, video games, augmented reality, or any other type of software based on language outcomes; and English language articles. Reviews, letters, conference proceedings, abstracts, editorials, and articles not published in English were removed. The titles and abstracts of the identified records were initially screened and selected by two independent and blinded reviewers. Data extraction and quality assessment were performed by three independent reviewers.

Results: Overall, sixteen studies were included; 975 children (61.35% males) with DLD underwent a digital intervention. The mean age ranged from 3.47 to 11.19 years. Eight were randomized control trials (RCT), five were quasi-experimental studies, two were case series, and one was a case report. Targeting domains of digital intervention were phonological skills (n=5), general language function (n=4), vocabulary (n=3), grammar (n=3), and spelling (n=1).

Conclusions: The present systematic review indicates that digital interventions were effective in improving phonological and vocabulary skills in children with DLD. There was less evidence supporting its effectiveness in expressive language skills, which indicates a need to upgrade expressive language digital training programs in the future. Further higher-level evidence, such as RCT studies in this area, is needed to direct the development of digital programs.

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Review

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Conclusions: The present systematic review indicates that digital interventions were effective in improving phonological and vocabulary skills in children with DLD. There was less evidence supporting its effectiveness in expressive language skills, which indicates a need to upgrade expressive language digital training programs in the future. Further higher-level evidence, such as RCT studies in this area, is needed to direct the development of digital programs.

Keywords: Developmental Language Disorder; Digital Intervention; Systematic Review

Introduction

Developmental language disorder (DLD) is one of the most prevalent neurodevelopmental disorders that has profound and lasting effects on individual development [1]. It occurs in around 7.6%~8.5% of preschool children around the world [2, 3]. According to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5), DLD is a neurodevelopmental condition in which there are unexplained and persistent difficulties with language acquisition [4]. The term DLD has been suggested to replace earlier terms, such as specific language impairment (SLI), language impairment, language disorder, and primary spoken language disorder. However, for clarity purposes, in the present review, we will use DLD, although due to its recent introduction, the articles included in the present work used SLI as a diagnostic label.

Language development is a critical domain of children's overall development. Language skills form a core component of communication, which comprises the ability to send and receive information through oral and written language [5]. Language disorders can affect different aspects of language processing, such as the form of language (phonetic, phonological, morphological, morpho-syntactic, and syntactic processing); content (semantic-lexical and phrasal processing); and use (pragmatic and discursive processing) [6]. Individuals with DLD may not only experience difficulties in communication but also face challenges from other different domains.

Due to obstacles in communication, children with DLD are less participated in play and academic learning [7]. DLD may also increase the risk of poor health-related quality of life [8], including mental health problems such as anxiety and depression [9, 10]. Moreover, DLD usually co-occurs with impaired cognitive [11, 12], sensorimotor [11, 13], or behavioral [14] functioning. Developmental disorders related to DLD include learning disorders, delayed milestones, disorders of the acoustic nerve, conduct disorders, attention-deficit/hyperactivity disorder, lack of coordination, and other motor deficits [15]. The impact of DLD may persist to adulthood and have a long-term effect on cognitive function, community function, interpersonal relationships, and employment [16-18]. Therefore, effective intervention in childhood is crucial to improving the quality of life of individuals with DLD and preventing further negative effects in their adulthood.

Convention intervention for DLD is usually delivered in person by speech and language pathologists (SLPs). During treatment sessions, SLPs stimulate children's language skills and teach them language learning strategies, motivating them by using interesting toys and creative activities, and carefully designing interventions that are just right challenging for children. However, that requires SLPs to be well-trained and experienced. Limited by the number of therapists, geographical location, and economic conditions, in-person training is not always available to children with DLD [19].

Digital interventions have the potential to be used as an adjunct to conventional language intervention, which could reduce therapists' workload and increase children's accessibility to language training in settings such as homes or schools, enabling them to practice under the supervision of caretakers or teachers [20]. Digital intervention provides repeated training of particular skills easier; it motivates children by giving automated timely feedback in a game-like format [21]; digital intervention can also be programmed to respond adaptively to the child's level of performance so that training is focused on materials that are just beyond current competence; every response made by the child can be detailly recorded for further analysis. In the economic aspect, digital intervention also has the potential to increase accessibility to care, reduce patients' travel and costs, and develop culturally appropriate services, especially for different language speakers [22].

There is a wide range of digital interventions for children with DLD that are aimed at different language domains. Different studies may employ different digital programs, durations, intensities, and different people and places to deliver intervention. However, how these factors might impact the effectiveness of digital interventions has not been reported yet. The goal of the present review was to systematically analyze the effectiveness of digital interventions on children with DLD and its influential factors from an evidence-based perspective.

Methods

Study identification

This systematic literature review was performed according to the methodology described in the Cochrane Handbook for Systematic Reviews [23] and was reported based on the PRISMA statement for reporting systematic reviews [24]. Additionally, the study protocol was registered in the International Prospective Register for Systematic Reviews (PROSPERO) and was ascribed to the CRD42023477946 registration code.

All literature published to May 2023 was retrieved by searching the databases "PubMed", "Scopus", "PsycInfo", and "IEEE Xplore" using the following search terms: (("developmental language disorder" OR "language delay" OR "speech delay" OR "language impairment*" OR "speech impairment*" OR "language disorder*" OR "speech disorder*" OR "language difficult*" OR "speech difficult*") AND ("Child*" OR "Preschool") AND ("computer-based" OR "computer assisted therapy" OR "computer games" OR "software" OR "websites" OR "computer*" OR "digital*" OR "electronic" OR "gaming" OR "internet*" OR "video game*" OR "online" OR "on-line" OR "web*"))

No limitations in the search strategy were applied to the publication date, study design, or language. References of considered studies were also searched to identify any further relevant data.

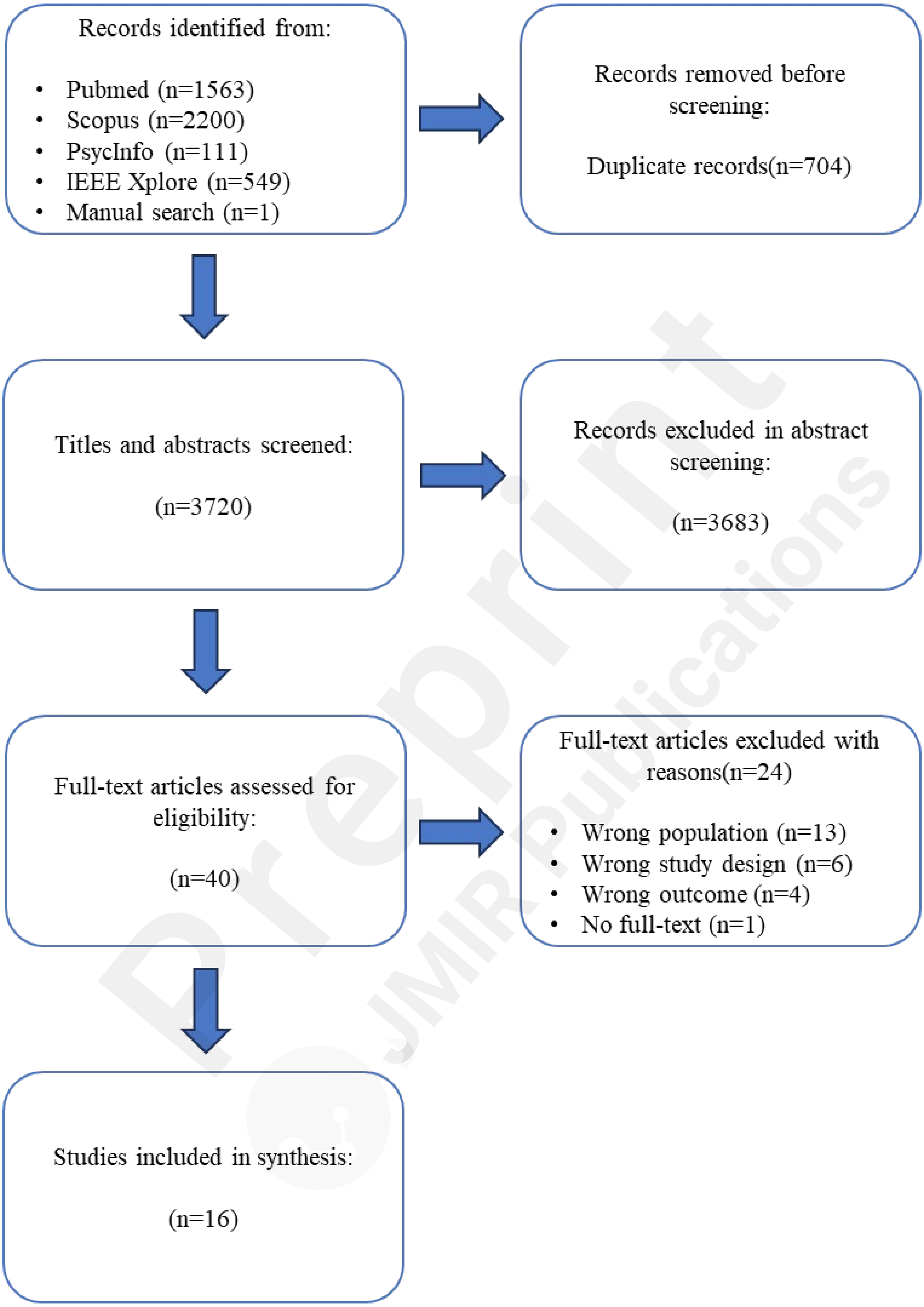
The records identified by the search were uploaded on "Rayyan" [25] to organize the study selection more efficiently. The titles and abstracts of the identified records were initially screened and selected by two independent and blinded reviewers (Z.Z. + C.D.) based on their pertinence to the review topic. Conflicts and disagreements were resolved by consensus.

The following set of pre-defined inclusion criteria were then individually applied to the selected articles in their full-text version: (i) Studies recruiting patients diagnosed with DLD; (ii) Articles that reported digital interventions based on apps, video games, augmented reality, or any other type of software based on language outcomes; (iii) English language articles. Reviews, letters, conference proceedings, abstracts, and editorials were excluded. Articles not published in English were removed. Articles with targeted populations of children with cognitive delay, deafness, autism spectrum disorders, genetic syndromes (Down syndrome, Klinefelter syndrome), neurological deficits, pervasive developmental disorders, traumatic brain injuries, primary disorders (sensory, neurological, psychiatric), children with dysphonia, dysarthria, dysrhythmias or stuttering, dyslalias or specific speech articulation disorder, bilingualism.

Data extraction and quality assessment

Data extraction and quality assessment were performed by three independent reviewers (Z.Z., C.D., and D.Y.). The extracted data and results of the quality assessment are reported in Table 1. The quality of retrieved articles was assessed by the JBI checklist. JBI's critical appraisal tools can be used to evaluate the quality of a wide range of published articles, such as randomized controlled trials (RCTs), and extend to case series and studies reporting prevalence data [26]. The purpose of this appraisal is to assess the methodological quality of studies and to determine the extent to which a study has addressed the possibility of bias in its design, implementation, and analysis. Studies with percentage scores of < 49% were classified as weak, studies between 50% and 79% were moderate, and studies ≥ 80% were classified as high in quality with reduced bias. This classification has been used in prior systematic reviews [27].

Figure 1. PRISMA Flow Chart Describing the Inclusion Process of the Articles



Results

The following records were identified via electronic databases: PubMed (n = 1563); Scopus (n = 2200), PsycINFO (n = 111), and IEEE Xplore (n = 549), which yielded 4497 unique records. One additional record was identified via manual searching. The flow diagram in Figure 1 shows the records remaining at each stage and the reasons for exclusion of articles reviewed at the full-text stage. One full-text article could not be sourced for review and was excluded at the full-text stage; all were published between 1932 and 2023. A total of sixteen articles met the inclusion criteria for this study.

Of the 16 studies that met the inclusion criteria, 8 were randomized control trials [21, 28-34], 5 were quasi-experimental studies [35-39], 2 were case series [40, 41], and one was case reports [42]. According to the quality assessment, six studies were of high quality, eight were of moderate quality, and one was of weak quality out of 16 studies. The oldest study was conducted in 2001, and the most recent study was conducted in 2022.

Overall, 975 children diagnosed with DLD were included, 61.35% were male and 38.65% were female (gender proportion not reported in four studies). Mean age ranges from 3.47 to 11.19 years old.

The digital intervention programs employed included: *Fast Forword (FFW)* [43] (n=9), *DynaVox V-Max* (n=1), *Reading Doctor* [44] (n=1), □□ *TipOn* [45] (n=1), *My Sentence Builder* [46](n=1), *Jingyun Rehab Platform [35]* (n=1), *My PlayHome* [47] (n=1), *Dr. Neuronowski*[48] (n=1), and a program developed by Heikkilä et al. [37] and was run with Presentation software (Neurobehavioral systems; n=1). Among the nine programs mentioned above, seven of them are software for computers, tablets, or mobile phones, *Jingyun Rehab Platform* is a website for computers, tablets, and mobile phones, and *DynaVox V-Max* is an augmentative and alternative communication (AAC) device. Five of the programs were developed in English, two of them were developed in Chinese (□□ *TipOn* and *Jingyun Rehab Platform*), one was in Finnish, and one was in Polish.

Phonological skills were the most frequently targeted skill in digital intervention for DLD (5 out of 16). General language function was reported in four studies. Vocabulary and grammar are each reported in three studies. Only one study examined the effect of digital intervention targeting spelling of children with DLD.

Phonological Skills (n=5)

The effectiveness of digital intervention in phonological skills for children with DLD was reported in six studies. Among these studies, four were targeted on receptive phonological skills, including phoneme awareness, letter-sound aptitude, and early decoding ability. Only one study assessed the effectiveness of digital interventions in expressive phonological skills.

The programs employed to conduct receptive phonological skills training in four studies were varied, including the *Reading Doctor* iPad application, □□ *TipOn* (mobile application), *FFW,* and *Dr. Neuronowski.* The duration of the digital intervention was 6 to 9 weeks. The main design of the game to train receptive phonological skills was to discriminate the sounds, tones, syllables, and words presented and match sounds with pictures or words. Significant improvement in receptive phonological skills was found in all the studies included compared with the control group.

The study conducted by Heikkilä, Lonka [37] was the only one that targeted expressive phonological skills. The audiovisual group received the training with the program utilizing audiovisual speech. The auditory group received the same training but with auditory speech only. The training period lasted six weeks, 5 days a week, 10–15 minutes per day. Results showed that audiovisual speech might be more effective than auditory speech in training phonological skills in children.

General (n=4)

There were four studies [30, 31, 40, 41] that examined interventions targeting more than one domain. The same digital program and intervention procedures were applied to all four studies.

Children participated in the *FFW* program for 1 hour and 40 minutes (100 minutes: five games of 20 minutes each) each weekday for 6 weeks (30 days). The intervention ended when they reached the dismissal criterion established by Scientific Learning Corporation of 90% completion on 5 of 7 exercises or until they exhibited plateaus in performance for 10 days before the 6-week end date. Case series performed by Deppeler, Taranto [40] and Friel-Patti, DesBarres [41] showed that *FFW* was only beneficial to half of the participants with DLD in standardized language tests and auditory processing. RCTs conducted by Cohen, Hodson [30] and Gillam, Loeb [31] revealed that though participants gained improvement from *FFW*, there was no additional effect for computer-intervention compared to conventional intervention.

Vocabulary (n=3)

Among sixteen studies included, three studies targeted vocabulary learning. Yi, Chen [35] and Zwitserlood, Harmsel [21] focus on the receptive vocabulary of children with DLD, using pictures of online platforms or software games. Alant, Champion [42] used AAC with pictures and pronunciation to improve receptive and expressive vocabulary skills. The intervention periods of intervention for vocabulary skills were 2~3 months. All three studies showed that digital interventions were beneficial for children's vocabulary skills.

Grammar (n=3)

Three studies included grammar as the primary focus of digital intervention for DLD, of which two examined the effectiveness of *FFW*, and one investigated *My Sentence*. Both Hsu and Bishop [33], and Bishop, Adams [39] employed *FFW* to implement receptive training of grammatical skills. Children heard a spoken sentence and then moved or activated objects on the computer screen to match the spoken sentence. Children in these two studies both showed greater accuracy in the training program but showed no significant improvement on standardized tests of receptive grammar. Washington, Warr-Leeper [32] used *My Sentence* to address expressive grammar deficits in DLD. Results showed that computer-based training significantly outperformed conventional intervention, but no significant differences in treatment gains were found between computer-based training and non-computer-based training.

Spelling (n=1)

Bishop, Adams [38] conducted a study on the efficacy of *FFW* in enhancing spelling skills in children aged 8 to 13 with DLD. The training sessions required participants to type words corresponding to visually presented items while simultaneously hearing their spoken names. In case of errors or requests for assistance, the program provided phonological and orthographic prompts to facilitate accurate spelling. Each trained child completed a varying number of training sessions (ranging from 6 to 29 sessions) lasting 15 minutes each, at a frequency of 3 to 5 sessions per week. On average, participants engaged in over 1000 trials and successfully acquired an average of 1.4 novel spellings per session. However, trained groups did not differ from the untrained control group in terms of gains made on standardized tests of spelling or word and nonword reading.

Table 1. Description And Main Outcomes of Digital Intervention Studies for Children With DLD

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
Alant et al. 2013	N=1. Intervention (N=1); No control group.	M, 100%, age NR	*DynaVox V-Max,* twice a week at the University Speech and Hearing Clinic for 45 min, once a week at her elementary school for 30 min, 3 months. Setting: University Speech and Hearing Clinic, elementary school Provider: two speech and language pathologists and the parent	Vocabulary-receptive and expressive	Positive changes in performance on the receptive and expressive vocabulary testing and scores on communication functions used based on video analyses before and after intervention.	3/8 (weak)	Case report
Bishop et al. (2005)	N=36.Modified speech (M, N=14), ordinary speech (S, N=13), and untrained control (U, N=9).	Group M: mean age 10.78±1.86; Group S: mean age 11.19±1.12; Group U: mean age 10.28±0.88. Gender of each group was not reported.	Modified speech (M): *FFW*, 5 sessions per week, each 15 minutes, 4 weeks Ordinary speech (S): usual special educational input Untrained control (U): no intervention. Setting: school Provider: school staff	Spelling	Children presented with FFW do less well than those trained with ordinary speech. Trained groups did not differ from the untrained group in terms of gains made on standardized tests of spelling or word and nonword reading.	9/9 (high)	Quasi-experimental
Bishop et al. (2006)	N=36.Modified speech (M, N=13), ordinary speech (S, N=15) and untrained control (U, N=9).	Group M: mean age 11.08±1.13; Group S: mean age 10.85±1.79; Group U: mean age	Modified speech (M): *FFW*, 5 sessions per week, each 15 minutes, 4 weeks Slow speech (S): trainings with a 1.2-	Grammar-receptive	Responses speeded up, and most children performed well above chance, accuracy typically remained	9/9 (high)	Quasi-experimental

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
		10.28±0.88. Gender of each group was not reported.	second delay between the end of one sentence segment and the start of the next Untrained group (U): continued to receive their regular educational input Setting: school Provider: school staff		below 95% correct. Trained groups did not differ from untrained children on language or auditory outcomes. Acoustically modified speech input did not enhance comprehension.		
Carson (2020)	N=24. Intervention (N=14); Control (N=10)	M 13(54.17%), mean age 4.75. Age and gender of each group were not reported.	Intervention: Reading Doctor (RD) iPad applications, twice a week, each 20–25min, 8-week Control: teacher-delivered small-group activities related to letters and sounds Setting: preschool. Provider: teachers, SLP students and initial teacher education (ITE) students.	Phonological skills-receptive	Children in the intervention group performed significantly better than children in the control condition in phoneme blending, phoneme segmentation, letter-sound recognition, accuracy of phoneme–grapheme conversions.	7/13 (moderate)	RCT
Chen & Lin. (2022)	N=49. Intervention (N=34); Control (N=15).	Intervention: mean age 5.85±0.53; Control: mean age 5.65±0.53. Gender of each group was not reported.	Intervention: □□ *TipOn*, 1 session per week, each 1 hour, 9 weeks Control: delayed intervention Setting: home Provider: parents	Phonological skills-receptive	Children in the experimental group exhibited significantly greater pre-post gains in word definition tasks and lexical tone than the control	8/13 (moderate)	RCT

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
					group. Positive relationship between the total number of phonetic games played and the pre-post gain in the word definition production task.		
Cohen et al. (2005)	N=77, FFW (N=23); Computer software (N=27); Control (N=27).	FFW: M 16 (69.57%), mean age 7.34±1.29; Computer software: M 22 (81.48%), mean age 7.43±1.21; Control: M 17 (62.96%), mean age 7.41±1.17.	Group A: *FFW*, 5 days a week, each 90 min, 6 weeks Group B: Computer software, educational software packages, 5 days a week, each 90 min, 6 weeks Group C: Control. No intervention. Setting: home Provider: parents	General-expressive and receptive	Each group made significant gains in language scores, but there was no additional effect for either computer intervention.	9/13 (moderate)	RCT
Dacewicz et al. (2018)	N=36. Experiment group (N=18); Control group (N=18).	Experiment group: M 13 (72.22%), mean age 6.3±1.0; Control group: M 13(72.22%), mean age 6.0±0.8.	Experiment: *Dr. Neuronowski*, four sessions per week, each 1 hour, 6 weeks. Control: other computer games for identification and discrimination of syllables and words, four sessions per week, each 1 hour, 6 weeks. Setting: a separate	Phonological skills-receptive	In the experimental group, MMN amplitude enhancement was observed in both ISI conditions. In both experimental and control groups, P3a amplitude was enhanced in both ISIs.	9/13 (moderate)	RCT

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
			room at the Nencki Institute or the Early Intervention Centre. Provider: a trained consultant				
Deppeler et al. (2004)	N=8, FFWD (N=8); No control group.	M 5(62.5%), mean age 8.00.	*FFW*, 5 days a week, each 100 min, 6 weeks Setting: computer laboratory at the Krongold Centre, Monash University Provider: two researchers	General-expressive and receptive	All participants showed at least one area of improvement on auditory discrimination and short-term auditory memory. Over half of the auditory processing gains remained evident after 4 weeks. One third of these gains were evident after 12 months.	5/10 (moderate)	Case series
Friel-Patti et al. (2001)	N=5. Intervention (N=5); No control group.	M 3 (60.00%), age range 5.83 ~ 9.17.	*FFW*, 5 days a week, each 100 min, 6 weeks Setting: Callier Center for Communication Disorders, The University of Texas at Dallas Provider: graduate student	General-expressive and receptive	Modest changes in standardized measures of language after intervention for 3 of the 5 children. There were no clinically significant changes in language sample measures.	7/9 (moderate)	Case series
Gillam et al. (2008)	N=216. CALI (N=54), FFW (N=54), ILI (N=54), AE	CALI: M 34 (62.96%), mean age 7.42; *FFW*: M	CALI (computer-assisted language intervention): software for	General-expressive and receptive	FFW was not more effective at improving general language	12/13 (high)	RCT

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
	(N=54).	29 (53.70%), mean age7.50; ILI: M 38 (70.37%), mean age7.67; AE: M 35 (64.81%), mean age 7.58.	phonological skills, 5 days a week, each 100 min, 6 weeks *FFW*: *FFW*, 5 days a week, each 100 min, 6 weeks ILI (individualized language intervention): literature-based, 5 days a week, each 100 min, 6 weeks AE (academic enrichment): computer software not for language development, 5 days a week, each 100 min, 6 weeks Setting: a quite area Provider: SLP		skills or temporal processing skills than a nonspecific comparison treatment (AE) or specific language intervention comparison treatments (CALI and ILI) that did not contain modified speech stimuli.		
Heikkilä et al. (2018)	N=20. Audiovisual training group (N=10); Auditory training group (N=10).	Audiovisual training group: M 6 (60.00%), mean age 8.75; Auditory training group: M 7 (70.00%), mean age 9.08.	Audiovisual: program developed by authors and run with Presentation software, 5 days a week, each 10–15 minutes, 6 weeks Auditory: same program with the screen blocked. 5 days a week, each 10–15 minutes, 6 weeks Setting: Valteri Onerva School Provider: SLP	Phonological skills-Expressive	Training with audiovisual speech can improve the phonological skills of children with DLD in the repetition of nonsense words. Audiovisual speech might be more effective than auditory speech in training phonological skills in children.	9/9 (high)	Quasi-experimental

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
Hsu & Bishop. (2014)	N=96. DLD-trained (N=28); TD-Grammar-matched (N=28); TD-age-matched (N=20); DLD-untrained (N=20)	DLD-trained: mean age 8.6±1.32; TD-Grammar-matched: mean age 9.1±1.32; TD-age-matched: mean age 5.8±0.86; DLD-untrained: mean age 8.9±0.77. Gender of each group was not reported.	DLD-trained: *FFW*, 5-7 min per day, 4 sessions in 4–6 days TD-Grammar-matched: *FFW*, 5-7 min per day, 4 sessions in 4–6 days TD-age-matched: *FFW*, 5-7 min per day, 4 sessions in 4–6 days DLD-untrained: no intervention Setting: not mentioned Provider: not mentioned	Grammar-receptive	Children with DLD showed greater accuracy with repeated sentences compared with unique sentences. Training did not improve children's performance on a standardized test of receptive grammar.	7/13 (moderate)	RCT
Loeb et al. (2009)	N=103. FFW (N=24), CALI (N=29), ILI (N=25), AC (N=25).	FFW: M 14 (58.33%), mean age 7.42±9.97; CALI: M 17 (58.62%), mean age 7.33±11.35; ILI: M 17 (68.00%), mean age 7.58±8.72; AC: M 18 (72.00%), mean age 7.33±10.48.	FFW: *FFW*, 5 days a week, each 100 min, 6 weeks CALI: other software targeted phonological skills, 5 days a week, each 100 min, 6 weeks ILI: literature-based intervention, 5 days a week, each 100 min, 6 weeks AE: software not for language development, 5 days a week, each 100 min, 6 weeks. Setting: School Provider: SLP	Phonological skills-receptive	Children in the FFW, CALI, and ILI conditions showed significant improvement in blending sounds compared to the AC group immediately after the test. After 6 months, long-term gains were moderate for blending sounds, but not significant. None of the interventions resulted in significant changes in reading skills.	8/9 (high)	Quasi-experimental

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
Washington et al. (2011)	N=34. CAT (N=11); nCAT (N=11); No treatment (N=12).	CAT: M 8 (72.73%), age range 3.92~4.50; nCAT: M 8 (72.73%), age range 4.17~4.83; No treatment: M 11(91.67%), age range 3.50~4.92.	CAT (computer-assisted treatment): *My sentence builder*, once a week, each 20 min, 10 weeks nCAT (non-computer-assisted treatment): "table-top" procedures, once a week, each 20 min, 10 weeks No treatment: children awaiting treatment Setting: not mentioned Provider: SLP	Grammar-expressive	C-AT and nC-AT participants significantly outperformed controls pre-to-post to 3 months post-treatment in both assessment contexts. No significant differences in treatment gains were found between C-AT and nC-AT.	8/13 (moderate)	RCT
Yi et al. (2022)	N=162. Intervention (N=84); Control (N=78).	Intervention: M 44 (52.38%), mean age 4.88±0.79; Control: M 42 (53.85%), mean age 4.69±0.85.	Intervention: *Jingyun Rehab Platform*, daily task, 3 months Control: conventional home-based rehabilitation recommendations, 3 months Setting: home Provider: parents	Vocabulary-receptive	Children with DLD in the cloud-based rehabilitation group performed significantly better in language abilities than the control group. The frequency of training sessions was proportional to their performance on language, memory, and cognition tasks.	9/9 (high)	Quasi-experimental
Zwitserlood et al. (2022)	N=72. Intervention (N=36); Control (N=36).	Intervention: M 26(72.22%), mean age 3.47±0.17;	Intervention: *My PlayHome*, 12 sessions in an 8–9-week period, each 10-min Control:	Vocabulary-receptive	Children in both groups learned significantly more target	8/13 (moderate)	RCT

Authors (year)	No. of Participants (Cases and Controls)	Gender (M, %) and mean age	Intervention	Speech and language abilities trained	Results (Summary of Findings)	JBI Score (quality)	Study design
		Control: M 25(69.44 %), mean age 3.53±0.21.	intervention based on real objects, 12 sessions in an 8–9-week period, each 10-min Setting: daycare center Provider: SLP		words than control words. No significant differences in gains between the two intervention conditions were found.		

Discussion

The main aim of the present review was to assess the impact of digital interventions on the language outcomes of children with DLD and to identify its influential factors. Because most of the studies aimed to verify the effectiveness of interventions for specific language skills, the analysis of the literature was organized according to the target language area.

Phonological skills were the most researched skills among all included studies, especially receptive phonological skills. Studies showed that digital intervention is helpful in improving phonological skills. Digital intervention programs have the advantage of providing grading acoustically modified speech signals and image or video resources [36]. Hierarchically auditory and visual cueing is crucial in phonological training [49]. Digital interventions are designed to adapt the level of difficulty and cues of the training according to the success of the child on multiple trials, which might be the reason digital intervention is effective.

In the studies targeting phonological skills, researchers also aimed to improve participants' other abilities including word learning [29], reading [28, 36], and working memory [34] through phonemic awareness training. That might be because phonological skills are also related to other language skills [50] and cognitive function [34, 51], which are of great importance to children's development. However, phonological training only proved to be beneficial to word learning and working memory, but not reading skills. It is suggested that children with language impairment and poor reading skills need a more comprehensive approach to improve their reading skills that extends beyond an emphasis on phonemic awareness [36].

General language and speech function was the second most concerned topic in digital interventions. Domains assessed in the studies included receptive and expressive language such as word, phrase, sentence, and auditory processing. Results showed that only half of the children with DLD gained progress after training. Digital interventions were not more effective than conventional treatment. Cohen, Hodson [30]indicated that children with DLD already received intensive specialist therapy and educational support, while digital interventions were not sufficient in and of themselves to confer additional therapeutic benefit. The varied results between individuals combined with the generally inconsistent patterns of performance on certain games create uncertainty as to which elements of *FFW* are producing improvements [40]. Meta-analyses also indicated that there was no significant effect of *FFW* on any outcome measure in comparison to active or untreated control groups [52]. Therefore, further studies are needed to evaluate the effectiveness of specific training games or formats of digital interventions.

In studies targeting vocabulary skills, digital intervention was of promising effectiveness. children with DLD showed significant improvement after 2~3 months of intervention. Vocabulary training might involve cognitive functions and enhance more global skills [53, 54]. Yi, Chen [35] suggested that children's language development can promote growth hormone secretion in children, stimulate brain development, promote children's intellectual development, and have a positive role in improving children's language communication skills. Therefore, it is recommended that children with DLD receive vocabulary training.

Studies targeting grammar deficits in DLD showed greater accuracy after intervention but no significant improvement on standardized tests of receptive grammar, or no significant differences in treatment gains between computer-based training and non-computer-based training. These studies indicated that the effectiveness of grammar training through digital training was doubtful. The possible reasons might be, in grammar training games, accuracy could be improved by simply rote learning the meaning of the whole sentence, or by memorizing the correct answers [33]. Therefore, even if children with DLD have difficulties in analyzing the sentence structure, they can still behave well in the training. For this reason, when targeting higher language functions such as grammar, more diverse materials, and learning patterns are needed to promote the generalization of functions.

Spelling was the least concerning ability in children with DLD in the included articles. The possible reason is that spelling disorders in DLD children manifest at school age, and only then do they receive attention from teachers and parents. Phonological representations, morphological awareness, and reading skills are three elements closely related to the spelling abilities of children with DLD [55]. Therefore, a spelling task can be used not only to train spelling accuracy but also to train the component skill of converting from sounds to letters. However, Bishop, Adams [38] found that the groups that received training did not exhibit significant differences compared to the control group in terms of improvements in standardized assessments of spelling, word reading, and nonword reading. The reason might be this study was conducted in school, and time spent on computerized training may reduce the amount of time spent on regular literacy instruction. As computers become more widespread in society, it is possible that in future this problem could be overcome by having children do such training at home.

Although digital interventions for DLD were proven effective in several studies, there was evidence showing that DLD did not additionally benefit from digital intervention. Several factors might need to be considered when delivering digital treatment for DLD:

The first factor to be considered is the targeting domain of intervention. In the domains discussed above, digital interventions are demonstrated to be practical and effective in improving basic language and speech skills such as phonological skills and vocabulary skills. Training of these skills requires lots of repetition and hierarchical audiovisual input, which can be easily achieved by digital techniques [36]. Phonological skills and vocabulary skills are also the prerequisites for learning higher language skills such as grammar and reading [56, 57]. However, digital interventions targeting higher language functions such as grammar and spelling, which might involve more cognitive functions [58], were required to be more diversified and more interesting.

Expressive language tended to receive less attention in digital interventions compared to receptive language. Only two studies included in this review focused on expressive language, and five considered both expressive and receptive language. Law, Garrett [59] reported that in-person speech and language therapy interventions were effective for expressive phonological and expressive vocabulary difficulties. However, in computer-based training for expressive language skills, in-time feedback is not provided automatically, which might lower children's motivation to participate. With the development of computerized language analysis techniques, in-time feedback from the digital program might make expressive language evaluation and training more effective [60, 61].

The second factor that might affect the effectiveness of digital interventions is the people and place to deliver the intervention. In the included studies, digital interventions were delivered in clinical settings, schools, or at home, and people who carried out digital interventions were speech therapists, schoolteachers, parents, or a combination of two or all three. Digital language training facilitated by trained therapists in clinical settings was shown to be more effective. The reason might be that in home environments, children used to play the game on their own and tend to ignore the instruction during intervention [21]. Also, interventions delivered in school might take away time from their regular classes, which to some extent could be detrimental to their language development [38]. Yi, Chen [35] applied the intervention pattern with therapists deciding on the training topics and sending them to the patient's account, and parents led the training at home. This kind of cooperation proved to be beneficial for children during COVID-19 or children living in remote areas.

The third factor is duration and intensity. The duration of the included studies ranges from 6～12 weeks, and intensity ranges from 15～100 minutes per day. The literature regarding dosage was unclear in optimal intensity, frequency, and duration to maximize efficacy. It seems that interventions carried out for 6 weeks or longer are more effective than those less than 6 weeks. Further investigation of the optimal dosage is necessary. [35]. suggested that the number of training sessions was directly proportional to the performance of children with DLD in language training tasks.

However, the optimal duration and intensity of digital intervention that can meet both treatment needs and avoid the negative effects caused by excessive screen time remain to be resolved. The amount of screen time was cumulatively and negatively linked to the children's lexical and general language abilities [62, 63]. Also, the early onset of screen exposure had negative effects on language development [64]. It is suggested that no more than 2 hours of screen time per day has minimal negative effects on development [65]. Better-quality screen use such as educational programs and co-viewing was associated with stronger child language skills [63].

Limitation

This study had some limitations. Firstly, more studies focused on receptive language skills of DLD, therefore, the results showed receptive language skill training was more effective than expressive language skill training, which might be due to a lack of timely feedback during expression training. Further research is needed on acceptance barriers to draw clearer conclusions on this point. Besides, this review included research on various research designs. The inclusion of studies with different research designs increases the number of studies included, thereby broadening the perspective on this issue. However, at the same time, the risk of bias is also increasing. Also, the quality of the included studies was varied, and more rigorous studies were needed in the future.

Conclusion

The present systematic review indicates that digital interventions are effective in improving phonological skills and vocabulary skills in children with DLD. There is less evidence supporting digital interventions are effective for expressive language skills, which indicates a need to develop expressive language digital training programs in the future. Further higher-level evidence such as RCT studies in this area is also needed to direct future updates the digital programs.

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Conflicts of Interest

The authors declare no conflict of interest.

Abbreviations

DLD: developmental language disorder

References

1. Conti-Ramsden G, Durkin K, Toseeb U, Botting N, Pickles A. Education and employment outcomes of young adults with a history of developmental language disorder. International Journal of Language and Communication Disorders. 2018 Mar;53(2):237-55. PMID: 29139196. doi: 10.1111/1460-6984.12338.
2. Norbury CF, Gooch D, Wray C, Baird G, Charman T, Simonoff E, et al. The impact of nonverbal ability on prevalence and clinical presentation of language disorder: evidence from a population study. Journal of Child Psychology and Psychiatry. 2016 Nov;57(11):1247-57. PMID: 27184709. doi: 10.1111/jcpp.12573.
3. Wu S, Zhao J, de Villiers J, Liu XL, Rolfhus E, Sun X, et al. Prevalence, co-occurring difficulties, and risk factors of developmental language disorder: first evidence for Mandarin-speaking children in a population-based study. Lancet Regional Health-western Pacific. 2023 May;34:100713. PMID: 37283967. doi: 10.1016/j.lanwpc.2023.100713.
4. Association AP. Diagnostic and statistical manual of mental disorder: DSM-5. Washington, DC: American psychiatric association; 2013.
5. Zupan B, Hutchings SM, Everitt LE, Gupta C. Language disorder and internalizing mental health problems in youth offenders: A systematic review. International Journal of Language and Communication Disorders. 2022 Nov;57(6):1207-28. PMID: 35841339. doi: 10.1111/1460-6984.12759.
6. Rinaldi S, Caselli MC, Cofelice V, D'Amico S, De Cagno AG, Della Corte G, et al. Efficacy of the Treatment of Developmental Language Disorder: A Systematic Review. Brain sciences. 2021 Mar 23;11(3). PMID: 33806938. doi: 10.3390/brainsci11030407.
7. Nicola K, Watter P. The comparison of perceived health-related quality of life between Australian children with severe specific language impairment to age and gender-matched peers. BMC pediatrics. 2018 Feb 14;18(1):62. PMID: 29444654. doi: 10.1186/s12887-018-1058-2.
8. Le HND, Mensah F, Eadie P, McKean C, Sciberras E, Bavin EL, et al. Health-related quality of life of children with low language from early childhood to adolescence: results from an Australian longitudinal population-based study. Journal of Child

Psychology and Psychiatry. 2021 Mar;62(3):349-56. PMID: 32488955. doi: 10.1111/jcpp.13277.
9. Lee YC, Chen VC, Yang YH, Kuo TY, Hung TH, Cheng YF, et al. Association Between Emotional Disorders and Speech and Language Impairments: A National Population-Based Study. Child psychiatry and human development. 2020 Jun;51(3):355-65. PMID: 31802296. doi: 10.1007/s10578-019-00947-9.
10. Toseeb U, Oginni OA, Dale PS. Developmental Language Disorder and Psychopathology: Disentangling Shared Genetic and Environmental Influences. Journal of learning disabilities. 2022 May-Jun;55(3):185-99. PMID: 34112015. doi: 10.1177/00222194211019961.
11. Ottosson S, U. SL, Kadesjö B, Gillberg C, Miniscalco C. Neurodevelopmental problems and quality of life in 6-year-olds with a history of developmental language disorder. Acta Paediatrica. 2022 Jan;111(1):115-22. PMID: 34516681. doi: 10.1111/apa.16104.
12. Norbury C, Griffiths S, Goh SKY, Boyes M, Hill E, Viding E. Developmental language disorder: a hidden condition. Lancet Child and Adolescent Health. 2024 Feb 5. PMID: 38330984. doi: 10.1016/s2352-4642(24)00016-6.
13. Tseng YT, Hsu HJ. Not only motor skill performance but also haptic function is impaired in children with developmental language disorder. Research in developmental disabilities. 2023 Mar;134:104412. PMID: 36638673. doi: 10.1016/j.ridd.2022.104412.
14. Goh SKY, Griffiths S, Norbury CF. Sources of variability in the prospective relation of language to social, emotional, and behavior problem symptoms: Implications for developmental language disorder. Journal of abnormal psychology. 2021 Aug;130(6):676-89. PMID: 34553962. doi: 10.1037/abn0000691.
15. Nitin R, Shaw DM, Rocha DB, Walters CEJ, Chabris CF, Camarata SM, et al. Association of Developmental Language Disorder With Comorbid Developmental Conditions Using Algorithmic Phenotyping. JAMA network open. 2022 Dec 1;5(12):e2248060. PMID: 36580336. doi: 10.1001/jamanetworkopen.2022.48060.
16. McGregor KK, Ohlmann N, Eden N, Arbisi-Kelm T, Young A. Abilities and Disabilities Among Children With Developmental Language Disorder. Language Speech And Hearing Services in Schools. 2023 Jul 5;54(3):927-51. PMID: 37159846. doi: 10.1044/2023_lshss-22-00070.
17. Chilosi AM, Brovedani P, Cipriani P, Casalini C. Sex differences in early language delay and in developmental language disorder. Journal of neuroscience research. 2023 May;101(5):654-67. PMID: 34822733. doi: 10.1002/jnr.24976.
18. Clegg J, Hollis C, Mawhood L, Rutter M. Developmental language disorders--a follow-up in later adult life. Cognitive, language and psychosocial outcomes. Journal of Child Psychology and Psychiatry. 2005 Feb;46(2):128-49. PMID: 15679523. doi: 10.1111/j.1469-7610.2004.00342.x.
19. Tohidast SA, Mansuri B, Bagheri R, Azimi H. Provision of speech-language pathology services for the treatment of speech and language disorders in children during the COVID-19 pandemic: Problems, concerns, and solutions. International journal of pediatric otorhinolaryngology. 2020 Nov;138:110262. PMID: 32705994. doi: 10.1016/j.ijporl.2020.110262.
20. Saeedi S, Bouraghi H, Seifpanahi MS, Ghazisaeedi M. Application of Digital Games for Speech Therapy in Children: A Systematic Review of Features and Challenges. Journal of healthcare engineering. 2022;2022:4814945. PMID: 35509705. doi: 10.1155/2022/4814945.
21. Zwitserlood R, Harmsel MT, Schulting J, Wiefferink K, Gerrits E. To Game or Not to Game? Efficacy of Using Tablet Games in Vocabulary Intervention for Children with

DLD. Applied Sciences. 2022 2022 %J Applied Sciences (Switzerland);12(3). PMID: rayyan-995715172. doi: doi:10.3390/app12031643.

22. Snoswell CL, Taylor ML, Comans TA, Smith AC, Gray LC, Caffery LJ. Determining if Telehealth Can Reduce Health System Costs: Scoping Review. Journal of medical Internet research. 2020 Oct 19;22(10):e17298. PMID: 33074157. doi: 10.2196/17298.
23. Higgins PTJ, Thomas J, Chandler J, Cumpston M, Li T, Matthew J. Page M, et al. Cochrane Handbook for Systematic Reviews of Interventions. 1st ed. Hoboken, NJ, USA: Wiley; 2019.
24. Liberati A, Altman DG, Tetzlaff J, Mulrow C, Gøtzsche PC, Ioannidis JP, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. Journal of clinical epidemiology. 2009 Oct;62(10):e1-34. PMID: 19631507. doi: 10.1016/j.jclinepi.2009.06.006.
25. Tifratene K, Robert P, Metelkina A, Pradier C, Dartigues JF. Progression of mild cognitive impairment to dementia due to AD in clinical settings. Neurology. 2015 Jul 28;85(4):331-8. PMID: 26136516. doi: 10.1212/wnl.0000000000001788.
26. Barker TH, Stone JC, Sears K, Klugar M, Leonardi-Bee J, Tufanaru C, et al. Revising the JBI quantitative critical appraisal tools to improve their applicability: an overview of methods and the development process. JBI evidence synthesis. 2023 Mar 1;21(3):478-93. PMID: 36121230. doi: 10.11124/jbies-22-00125.
27. Roberts F, Cooper K. Effectiveness of high fidelity simulation versus low fidelity simulation on practical/clinical skill development in pre-registration physiotherapy students: a systematic review. JBI database of systematic reviews and implementation reports. 2019 Jun;17(6):1229-55. PMID: 30964770. doi: 10.11124/jbisrir-2017-003931.
28. Carson KL. Can an app a day keep illiteracy away? Piloting the efficacy of Reading Doctor apps for preschoolers with developmental language disorder. International Journal of Speech-Language Pathology. 2020;22(4):454-65.
29. Chen Y, Lin WJ. Efficacy of an integrated intervention with vocabulary and phonetic training for Mandarin-speaking children with developmental language disorders. Child Language Teaching and Therapy. 2022 2022 %J Child Language Teaching and Therapy;38(3):288-302. PMID: rayyan-995711935. doi: doi:10.1177/02656590221101180.
30. Cohen W, Hodson A, O'Hare A, Boyle J, Durrani T, McCartney E, et al. Effects of computer-based intervention through acoustically modified speech (Fast ForWord) in severe mixed receptive-expressive language impairment: outcomes from a randomized controlled trial. Journal of Speech, Language, and Hearing Research. 2005 2005-6 %J J Speech Lang Hear Res;48(3):715-29. PMID: rayyan-995712014. doi: doi:10.1044/1092-4388(2005/049).
31. Gillam RB, Loeb DF, Hoffman LM, Bohman T, Champlin CA, Thibodeau L, et al. The efficacy of Fast ForWord Language intervention in school-age children with language impairment: a randomized controlled trial. Journal of Speech, Language, and Hearing Research. 2008 2008-2 %J J Speech Lang Hear Res;51(1):97-119. PMID: rayyan-995712520. doi: doi:10.1044/1092-4388(2008/007).
32. Washington KN, Warr-Leeper G, Thomas-Stonell N. Exploring the outcomes of a novel computer-assisted treatment program targeting expressive-grammar deficits in preschoolers with SLI. Journal of Communication Disorders. 2011;44(3):315-30.
33. Hsu HJ, Bishop DV. Training understanding of reversible sentences: a study comparing language-impaired children with age-matched and grammar-matched controls. PeerJ. 2014;2:e656. PMID: 25392757. doi: 10.7717/peerj.656.

34. Dacewicz A, Szymaszek A, Nowak K, Szelag E. Training-Induced Changes in Rapid Auditory Processing in Children With Specific Language Impairment: Electrophysiological Indicators. Frontiers in human neuroscience. 2018;12:310. PMID: 30131683. doi: 10.3389/fnhum.2018.00310.
35. Yi A, Chen Z, Ling W, Yin X, Li Y, Yan J, et al. Effectiveness of cloud-based rehabilitation in children with developmental language disorder during the COVID-19 pandemic: A prospective cohort study. Medicine. 2022;101(33):e30056.
36. Loeb DF, Gillam RB, Hoffman L, Brandel J, Marquis J. The effects of Fast ForWord Language on the phonemic awareness and reading skills of school-age children with language impairments and poor reading skills. American Journal of Speech-Language Pathology. 2009.
37. Heikkilä J, Lonka E, Meronen A, Tuovinen S, Eronen R, Leppänen PH, et al. The effect of audiovisual speech training on the phonological skills of children with specific language impairment (SLI). Child Language Teaching and Therapy. 2018;34(3):269-87. doi: 10.1177/0265659018793697.
38. Bishop D, Adams CV, Lehtonen A, Rosen S. Effectiveness of computerised spelling training in children with language impairments: a comparison of modified and unmodified speech input. International Journal of Language Communication Disorders. 2005;28(2):144-57.
39. Bishop D, Adams CV, Rosen S. Resistance of grammatical impairment to computerized comprehension training in children with specific and non-specific language impairments. International Journal of Language Communication Disorders. 2006;41(1):19-40.
40. Deppeler JM, Taranto AM, Bench J. Language and auditory processing changes following Fast ForWord. The Australian and New Zealand Journal of Audiology. 2004;26(2):94-109.
41. Friel-Patti S, DesBarres K, Thibodeau L. Case studies of children using Fast ForWord. American Journal of Speech-Language Pathology. 2001.
42. Alant E, Champion A, Peabody EC. Exploring interagency collaboration in AAC intervention. Communication Disorders Quarterly. 2013;34(3):172-83.
43. Guo A, Yang W, Yang X, Lin J, Li Z, Ren Y, et al. Audiovisual n-Back Training Alters the Neural Processes of Working Memory and Audiovisual Integration: Evidence of Changes in ERPs. Brain sciences. 2023 Jun 24;13(7). PMID: 37508924. doi: 10.3390/brainsci13070992.
44. de la Fuente J, Moreno-Agostino D, de la Torre-Luque A, Prina AM, Haro JM, Caballero FF, et al. Development of a Combined Sensory-Cognitive Measure Based on the Common Cause Hypothesis: Heterogeneous Trajectories and Associated Risk Factors. The Gerontologist. 2020 Jul 15;60(5):e357-e66. PMID: 31115438. doi: 10.1093/geront/gnz066.
45. Hong J. □□ TipOn (Version 1.0.24) [Mobile application software]. 2018 [cited 2020 2 March]; Retrieved from https://play.google.com/store/apps/details?id=com.TipOn&hl=en_US&gl=US].
46. Washington KN. Using the ICF within speech-language pathology: Application to developmental language impairment. Advances in Speech Language Pathology. 2007 2007/01/01;9(3):242-55. doi: 10.1080/14417040701261525.
47. Shimon Y. My PlayHome, version 3.5.1. [cited 2023 10 September]; Retrieved from: http://www.myplayhomeapp.com/].
48. Dr. Neuronowski. [cited 2023, from https://neuronowski.com/ 10 September].

49. Gijbels L, Yeatman JD, Lalonde K, Lee AKC. Audiovisual Speech Processing in Relationship to Phonological and Vocabulary Skills in First Graders. Journal of Speech, Language, and Hearing Research. 2021 Dec 13;64(12):5022-40. PMID: 34735292. doi: 10.1044/2021_jslhr-21-00196.
50. Snowling MJ, Hayiou-Thomas ME, Nash HM, Hulme C. Dyslexia and Developmental Language Disorder: comorbid disorders with distinct effects on reading comprehension. Journal of Child Psychology and Psychiatry. 2020 Jun;61(6):672-80. PMID: 31631348. doi: 10.1111/jcpp.13140.
51. Jesus LC, Alves LM, Martins-Reis VO. Which cognitive and linguistc factors influence phonological processing in adolescents? CoDAS. 2021;34(1):e20200158. PMID: 34669763. doi: 10.1590/2317-1782/20212020158.
52. Strong GK, Torgerson CJ, Torgerson D, Hulme C. A systematic meta-analytic review of evidence for the effectiveness of the 'Fast ForWord' language intervention program. Journal of Child Psychology and Psychiatry. 2011 Mar;52(3):224-35. PMID: 20950285. doi: 10.1111/j.1469-7610.2010.02329.x.
53. Michaud M, Roy-Charland A, Richard J, Nazair A, Perron M. The Role of Vocabulary Skills in a Storybook-Based Intervention to Stimulate Emotion Comprehension in Preschoolers. Journal of Genetic Psychology. 2021 Nov-Dec;182(6):471-87. PMID: 34455920. doi: 10.1080/00221325.2021.1969884.
54. Griffiths S, Kievit RA, Norbury C. Mutualistic coupling of vocabulary and non-verbal reasoning in children with and without language disorder. Developmental science. 2022 May;25(3):e13208. PMID: 34862694. doi: 10.1111/desc.13208.
55. Broc L, Joye N, Dockrell JE, Olive T. Capturing the Nature of the Spelling Errors in Developmental Language Disorder: A Scoping Review. Language Speech And Hearing Services in Schools. 2021 Oct 18;52(4):1127-40. PMID: 34436934. doi: 10.1044/2021_lshss-20-00086.
56. McCarthy KM, Skoruppa K. Language-specific phonological skills and the relationship with reading accuracy in Sylheti-English sequential bilinguals. Child development. 2023 Mar;94(2):e85-e102. PMID: 36515489. doi: 10.1111/cdev.13880.
57. Kehoe M, Poulin-Dubois D, Friend M. Within- and Cross-Language Relations Between Phonological Memory, Vocabulary, and Grammar in Bilingual Children. Journal of Speech, Language, and Hearing Research. 2021 Dec 13;64(12):4918-48. PMID: 34731575. doi: 10.1044/2021_jslhr-21-00176.
58. Gervain J. Typical language development. Handbook of clinical neurology. 2020;173:171-83. PMID: 32958172. doi: 10.1016/b978-0-444-64150-2.00016-2.
59. Law J, Garrett Z, Nye C. Speech and language therapy interventions for children with primary speech and language delay or disorder. The Cochrane database of systematic reviews. 2003;2003(3):Cd004110. PMID: 12918003. doi: 10.1002/14651858.Cd004110.
60. Finestack LH, Rohwer B, Hilliard L, Abbeduto L. Using Computerized Language Analysis to Evaluate Grammatical Skills. Language Speech And Hearing Services in Schools. 2020 Apr 7;51(2):184-204. PMID: 32255745. doi: 10.1044/2019_lshss-19-00032.
61. Pezold MJ, Imgrund CM, Storkel HL. Using Computer Programs for Language Sample Analysis. Language Speech And Hearing Services in Schools. 2020 Jan 8;51(1):103-14. PMID: 31697609. doi: 10.1044/2019_lshss-18-0148.
62. Mustonen R, Torppa R, Stolt S. Screen Time of Preschool-Aged Children and Their Mothers, and Children's Language Development. Children (Basel, Switzerland). 2022 Oct 18;9(10). PMID: 36291513. doi: 10.3390/children9101577.

63. Madigan S, McArthur BA, Anhorn C, Eirich R, Christakis DA. Associations Between Screen Use and Child Language Skills: A Systematic Review and Meta-analysis. JAMA pediatrics. 2020 Jul 1;174(7):665-75. PMID: 32202633. doi: 10.1001/jamapediatrics.2020.0327.
64. Karani NF, Sher J, Mophosho M. The influence of screen time on children's language development: A scoping review. South African Journal of Communication Disorders. 2022 Feb 9;69(1):e1-e7. PMID: 35144436. doi: 10.4102/sajcd.v69i1.825.
65. Dy ABC, Dy ABC, Santos SK. Measuring effects of screen time on the development of children in the Philippines: a cross-sectional study. BMC public health. 2023 Jun 28;23(1):1261. PMID: 37380949. doi: 10.1186/s12889-023-16188-4.

Supplementary Files

Figures

PRISMA Flow Chart Describing the Inclusion Process of the Articles.