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Systematic Review

The Effectiveness of Serious Games for Enhancing Literacy Skills in Children with Learning Disabilities or Difficulties: A Systematic Review

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Abstract: Serious games (SGs) are often used for learning and cognitive improvement. This systematic review aims to verify the effectiveness of SG in enhancing the reading and writing of children with learning difficulties or disorders. The study was conducted according to the PRISMA 2020 Guidelines. The screening processes led to six relevant articles, all of which were randomized trials with a low risk of bias. The number of SGs developed for children with learning disorders with evidence of efficacy is very small, and they focus on enhancing only some aspects of literacy, leaving out the training of some fundamental skills, such as spelling and text comprehension. Serious games are effective in improving reading and metaphonological skills and in ensuring good engagement and enjoyment. However, poor generalization of progress to untreated skills was reported. The importance of investment in this area of research is highlighted.

Keywords: systematic review; serious games; learning disorders; dyslexia; reading; spelling

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1. Introduction

Several studies have demonstrated the positive impact of technological devices for rehabilitation [1], including virtual reality, augmented reality, game-based digital tools, etc. [2]. Among these, in the educational and health field, serious games (SG) are widely used. Their main objective is learning, placing the playful component in the background [3–5]. They are learning games, i.e., playful digital tools, designed for educational and/or therapeutic purposes [6]. The authors of [7] defined SGs as "any game whose main purpose is more than mere entertainment" (p. 6). Serious games use virtual reality in 2D or 3D to achieve objectives other than simple entertainment: they favor the acquisition of psycho-cognitive skills and knowledge by increasing involvement and motivation to learn as these in turn motivate the subject to devote more time to training or rehabilitation. Serious games have proved effective in enhancing cognitive abilities and academic achievements and affect, as well as pleasant mood, in general learning [8]. These tools are within the reach of almost everyone, as many can be used free of charge and easily on technological devices.

A recent review highlighted the potential of these educational tools in different sectors: from surgery to the military, from the learning of decision-making techniques to leadership skills [9]. Their efficacy is demonstrated by their benefits, which are detectable within educational contexts, including experiential learning, research-based learning, self-efficacy, goal setting, and time on task [10]. By integrating neuroscientific and computer engineering models which design graphics, soundtracks, and play activities to achieve specific objectives, SGs have major potential for improving psycho-cognitive symptoms [11,12]. In this regard, studies also demonstrate their efficiency within the context of rehabilitation and/or the improvement of knowledge/skills by subjects with development defined as atypical, such as those with autism spectrum disorder (for a review, see [13,14]), intellectual disability [14], ADHD (for a review, see [15]), and special education needs (for a review, see [16,17]).

Through these innovations, SGs are also designed to improve the skills of reading/writing for students diagnosed with specific learning disabilities, such as dyslexia or dysgraphia, or simply with difficulties in reading and spelling acquisition. Learning disorders are a heterogeneous group, in which the acquisition of reading, spelling and/or mathematical skills is impaired and the deficit is not due to a lack of learning opportunities, cognitive disability, or brain trauma [18,19]. In the last decades, a greater number of mobile applications have been created to assess or intervene in the treatment of dyslexic symptoms [20]. Play SGs ensure high levels of emotion and motivation, which can contribute to improving learning [21].

However, little is known about the real effectiveness of these methodologies in improving the literacy skills of students with learning disorders or difficulties and systematic reviews are lacking. Therefore, this systematic review aims to evaluate, for the first time, the effectiveness of SGs in enhancing the literacy of children with reading and/or spelling disabilities or difficulties.

The review is structured as follows. First, we illustrate our research within the scientific literature; the inclusion, exclusion, and eligibility criteria used; and the synthesis of relevant information from the identified and selected studies. We then report the characteristics of SGs for the improvement of reading/writing skills, as well as engagement. We attempt to answer the following research questions: (1) What is the evidence for the efficacy of the use of SGs for children with learning difficulties or disorders? (2) Is progress sustained in long-term follow-ups? (3) Does effective training demonstrate generalization with secondary effects on untreated cognitive functions? (4) Are there cognitive functions for which SGs are not available (for which research is required)? (5) What are the characteristics of the games that have proven to be effective? In particular, (5.a) Which cognitive functions do they rehabilitate and with which exercises? (5.b) Which gamification features do they have? (5.c) How was the training carried out (methods, exercise times, devices, duration, etc.)?

2. Materials and Methods

2.1. Literature Search

This study was conducted according to the guidelines for the preferred reporting items for systematic reviews and meta-analyses (PRISMA). In particular, the research question, search strategy, inclusion and exclusion criteria, and risk-of-bias assessments were performed according to PRISMA guidelines, which require 27 items to be met when reporting a systematic review [22–24].

We identified relevant studies that investigated the efficacy of serious games' treatment of spelling, reading, and reading comprehension skills in primary- and middle-school students diagnosed with dyslexia and/or dysgraphia or with difficulty in reading and/or spelling acquisition.

2.2. Search Strategy and Screening Process

Web of Science, PubMed, EBSCOhost, and Scopus databases were searched on 18 October 2022 using the following search string: ("serious game*" OR edugame* OR "edu game*" OR "digital game*") AND (dyslex* OR dysortograph* OR dysgraph* OR "learning disorder*" OR "learning deficit*" OR "learning disabilit*" OR "reading disorder*" OR "reading disabilit*" OR "reading deficit*" OR "spelling disorder*" OR "spelling disabilit*" OR "spelling deficit*" OR "poor read*" OR "poor spell*"). We limited the identification of the keywords to the topic section (title, abstract, keywords). We also searched the preprint servers PsyArXiv, Open Science Framework, and PROSPERO using the aforementioned keywords.

Once we identified the relevant articles from these studies, we used the backward reference searching method (the works cited in the selected articles) and a posteriori to further studies (the studies that cited the articles we considered).

2.3. Eligibility Criteria

Articles published from 1 January 2007 to 18 October 2022 and written in the English, Italian, French, or Spanish language were eligible.

2.3.1. Inclusion Criteria

Studies were included in the current review if the following criteria were satisfied:

- A specific focus on an SG-based intervention;
- Participants must be primary or secondary school students;
- Participants must be students with a diagnosis of dyslexia and/or dysgraphia or identifiable as "poor readers" and/or "poor spellers".

2.3.2. Exclusion Criteria

Studies that met any of the following criteria were excluded:

- Lack of a control group (i.e., groups that received treatment other than a serious game or no treatment);
- Lack of assessment of pre- and post-intervention outcomes;
- Lack of reading, writing, or comprehension of text as outcome measures;
- Use of technological tools that differ from SGs (e.g., videogames, robots, virtual reality, etc.);
- Where SG not used as an intervention tool, but for other purposes (for example, as an assessment tool);
- Focus on children affected by other disabilities or on children developing typically, without difficulties in reading and/or spelling acquisition;
- Systematic reviews, meta-analyses, non-journal papers, editorials, dissertations, theoretical or qualitative studies, single case studies, letters to authors, comments on published articles, and grey literature in general;
- Full text not available.

2.4. Study Selection and Data Extraction

The screening process was performed using the digital tool, Rayyan [25] and reported in Figure 1. The study's selection process consisted of three phases: eliminating duplicates, screening the titles and abstracts, and reading full texts.

After the removal of duplicates, all identified records were blinded and screened for potential relevance based on title and abstract by three independent researchers (C.V.M., E.T., G.N.). The author independently reviewed studies for eligibility as per the inclusion/exclusion criteria and extracted the data according to the criteria defined in advance. Disagreements were discussed with the team and resolved. After these initial screening steps, full texts were independently reviewed by the first three authors, considering the specific reference to the eligibility criteria. To reach a joint decision, the emerging discrepancies were discussed within the team. An inter-rater reliability analysis was performed using the Fleiss Kappa (κ) test, which measures the agreement between more than two evaluators.

For articles suitable for inclusion in this systematic review, the first three authors extracted data related to study characteristics (i.e., target group, intervention, control group, etc.), assessment of outcome, intervention characteristics (i.e., play frequency and intensity, cognitive skills trained, type of element of gamification), and efficacy. See Tables 1 and 2 for a description of the studies included and their type of training.

To describe the characteristics of each SG included in this systematic review, we used the Quality Criteria for Serious Games developed by [26]. They divide the evaluation into two sections: the serious section, which indicates the specific objectives that differentiate SGs from other types of gamifications; and the game section, which describes the contents necessary to highlight a playful component within these learning tools. We also analyzed the integration between the characterizing learning objective (serious section) within the gameplay (game section) according to the indications provided by [26]. Tables 3 and 4 present a detailed description of each section. The qualitative evaluation for each SG included in this systematic review was performed independently by the second and third researchers, and the percentage of agreement and Cohen's K were computed.

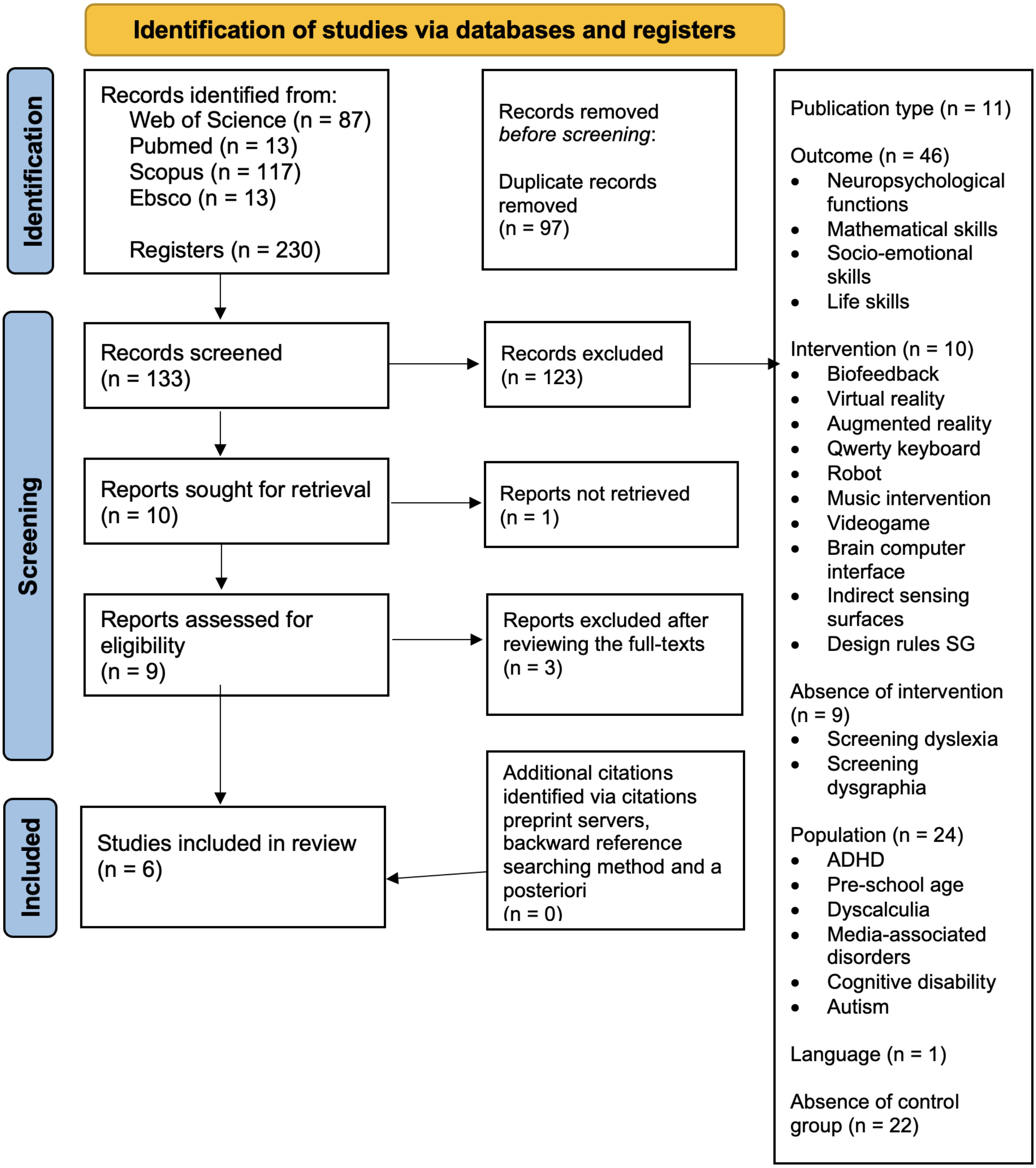

Figure 1. PRISMA flowchart of the literature search and screening process.

2.5. Quality Assessment

We used the revised Cochrane risk-of-bias tool for randomized trials (RoB 2) [27,28] to assess the quality of the evidence and risk of bias in the studies included in the present review. The RoB 2 tool is divided into five categories of bias (domains) that might affect the results of randomized trials, specifically bias arising from the following: randomization process; deviations from intended interventions; missing outcome data; measurement of the outcome; and selection of the reported result [29]. Following the algorithms created for each domain (ibid.), it is possible to establish a judgment as to the risk of bias for each of the aforementioned domains from among the following options: low risk; some concerns; high risk of bias. An independent assessment of the study quality was conducted by two authors of this review and the percentage of agreement and Cohen's K [30] were computed. Any differences were objectively concluded after a discussion among the first three authors.

3. Results

3.1. Data Extraction

The process through which the studies were included in the systematic review is described in Figure 1. The initial searches provided 230 papers potentially relevant to the present study. Of these, 117 were identified from Scopus, 87 from Web of Science, 13 from PubMed, and 13 from EBSCOhost. No articles were identified from screening the reference lists of the identified studies.

The duplicates were removed (N = 97) and 133 entries were screened. After screening the titles and abstracts, 123 articles were removed, leaving a total of 10 articles for assessment of the eligibility criteria. As shown in Figure 1, 123 articles were excluded for the following reasons: (1) 11 for the publication type; (2) 46 for the outcomes (neuropsychological functions, mathematical skills, socio-emotional skills, or life skills); (3) 10 for using an intervention based on other technological tools (particularly biofeedback, virtual reality, augmented reality, qwerty keyboards, robots, musical interventions, video games, brain–computer interfaces, indirect sensing surfaces, and SG-design rules); (4) 9 for the use of SGs for screening (for dyslexia and dysgraphia) and not for rehabilitative purposes; (5) 24 for the population examined (ADHD, pre-school age, dyscalculia, media-associated disorders, cognitive disability, or autism); (6) 1 for language; and (7) 22 for the absence of a control group. After reviewing the full texts, a further three articles were excluded due to not meeting the inclusion criterion concerning the presence of a control group. In addition, two articles were excluded because the first and second researchers contacted the authors three times, but never received a response. We obtained a Fleiss K of 0.77 (substantial agreement level), an almost perfect agreement according to the reference values of [31].

This selection procedure supplied six articles suitable for inclusion in this systematic review (see Figure 1 for a synthesis of the studies included).

3.2. Sample Characteristics and Demographic Information

Table 1 summarizes some of the demographic and clinical information about the samples studied. Overall, 249 children participated in the selected studies. The authors of [32] did not refer to the gender percentage of the participants (N = 36). In the five remaining studies (N = 213) 61.5% of the participants were males and 38.5% were females. A total of 135 students with a learning disorder (N = 53) or difficulty (N = 82) were trained with SGs, while 114 children were included in the control groups, in the selected studies. None of the studies characterized the type of reading/spelling deficit or whether the participants suffered from phonological or superficial impairment.

All the children attended the first years of primary school (from first to third grade, mean age = 8.1; SD = 0.32) and no students attended secondary schools. The pupils learned a very consistent (Finnish or German) or mostly consistent (Kazakh or Arabic) orthography [33].

Table 1. Descriptive synthesis of studies included. EG: experimental group. CG: control group. ♂= Male. ♀= Female.

ID	Authors	N	Gender			Age		Grade	Disorder/Difficulty	Language	Inclusion Criteria	Sample Size			
												Pre-Test		Post-Test	
			TOT	CG	EG	Mean	SD					CG	EG	CG	EG
1	Salah et al. (2016) [32]	36	N/A	N/A	N/A	N/A	N/A	Primary (grade not specified)	Learning disorder	Arabic	Specific learning disorder with minimal knowledge of the Arabic alphabet	18	18	18	18
2	Görgen et al. (2020) [34]	50	♂= 28 ♀= 22	♂= 13 ♀= 12	♂= 15 ♀= 10	EG = 8.50; CG = 8.55	EG = 0.67; CG = 0.66	Second and third	Reading disorder	German	Mild reading deficit in German mother tongue	25	25	25	25
3	Ronimus et al. (2019) [35]	37	♂= 23 ♀= 14	♂= 11 ♀= 9	♂= 12 ♀= 5	8.23	0.34	Second	Poor readers	Finnish	Poor readers (moderate and severe reading difficulties), without a severe cognitive deficit	20	17	20	17
4	Ronimus et al. (2020) [36]	70	♂= 48 ♀= 22	N/A	N/A	7,64	0.37	First	Poor readers and poor spellers	Finnish	Native Finnish speakers with reading and spelling difficulties	23	23 (with GL Reading SG) 24 (with GL Spelling SG)	22	23 (with GL Reading SG) 24 (with GL Spelling SG)
5	Kashani-Vahid et al. (2019) [37]	20	♂= 20 ♀= 0	♂= 10 ♀= 0	♂= 10 ♀= 0	8.10	N/A	Primary (grade not specified)	Learning disorder	Arabic	Reading deficit	10	10	10	10
6	Salgarayeva et al. (2021) [38]	36	♂= 21 ♀= 15	♂= 10 ♀= 8	♂= 11 ♀= 7	8.17	0.38	Second	Poor readers and poor spellers	Kazakh	Reading and spelling difficulties in Kazakh mother tongue	18	18	18	19

3.3. Type of Training

As shown in Table 2, all the studies were randomized control trials, with children randomly assigned to the experimental group or control group, except for one study [34], in which there was a pseudo-randomized assignment based on the level of severity of the reading disorder and school grade. The control groups received traditional teaching support in all the studies, except in [34], where non-specific digital training on logic and attentional skills was provided.

The experimental groups received training with SGs. Note that in two studies [35,36], the same SG was used; additionally, in [36], the participants received not only the original SG version (i.e., GraphoLearn reading) of [35] but also the version with metaphonological training (i.e., GraphoLearn spelling) integrated.

The SGs primarily focused on enhancing reading and metaphonological awareness skills, except for [37], which focused on memory and attention training. Note that all the studies included in the review used exercise to improve sublexical grapheme-to-phoneme (and vice versa) mapping. In fact, the studies included tasks such as target letter identification, matching a word (or letter) with the corresponding image, matching a sound to its written equivalent (letter, syllable, or word), grapheme–phoneme correspondence and word reading, metaphonological tasks, letter recognition, the reading of syllables, fluid syllabic reading, and reading stimuli with difficult pronunciations. There were no SGs to improve lexical difficulties (with exercises including, for example, irregular words, and homophones rather than homographs), as well as training for the comprehension of the written text. Writing was trained only in [31], but just in a letter painting task, and not with real exercises on the spelling of words. Neuropsychological skills were trained in two of the studies. In particular, in [32], there were exercises on mnemonic recovery (card matching), the identification of moving target stimuli (selective attention), overcoming obstacles as a result of acoustic stimulation (auditory attention), and puzzles (visual–spatial skills and executive skills), as well as exercises on literacy, such as target letter identification, letter painting, and matching words (or letters) with images. The SGs used in [37] featured exercises on memory, selective attention, and divided attention.

Table 2. Sample groups. EG: experimental group. CG: control group. Asterisk (*) indicates an estimate of value based on information available.

ID	Authors	CG		EG										Efficacy Results	Engagement
										Duration of Training					
		Type of Pairing	Treatment	SG Name	Trained Skills	Tasks	Supervisor	Place of Intervention	Intervention Device	Duration in Weeks	Total Duration (in Hours)	No. of Sessions Per Week	Duration of Sessions (in Minutes)		
1	Salah et al. (2016) [32]	Randomized assignment	Traditional teaching support (presentation slides)	Super Alpha	Metaphonological awareness, reading, and neuropsychological skills	- Mnemonic recovery (card matching) - Identification of moving target stimulus (selective attention) - Overcoming obstacles as a result of acoustic stimulation (auditory attention) - Puzzles (visual–spatial skills and executive skills) - Target letter identification - Letter painting - Matching words (or letters) and images	A tester (at the back of the class) for eventual technical details; a teacher to help them in case	School	Touchpad 7 (7 9.7-inch iPad Pro)	N/A	N/A	N/A	N/A	D > C in learning to read words of the Arabic alphabet	Good engagement
2	Görgen et al. (2020) [34]	Pseudo-randomized assignment based on the level of severity of the reading disorder and school grade	Non-specific digital training on logic and attentional skills	Meister Cody-Namagi	Metaphonological awareness and reading	Word/image matching	They told all parents that the children had to carry out the training on their own. However, they cannot exclude that there was parental support during the training.	Home	Tablet	8.8 (SD = 0.76; range: 8–11)	N/A	3.3 (SD = 0.38, range = 2–4)	29.28 (SD = 1.31, range = 25–30)	D > C: reading complex and long words, identifying phonemes D = C: G–P mapping, comprehension of text, reading non-words, and simple and short words, syllable counting, and vowel length.	Children enjoyed the training

Table 2. *Cont.*

ID	Authors	CG		EG										Efficacy Results	Engagement
										Duration of Training					
		Type of Pairing	Treatment	SG Name	Trained Skills	Tasks	Supervisor	Place of Intervention	Intervention Device	Duration in Weeks	Total Duration (in Hours)	No. of Sessions Per Week	Duration of Sessions (in Minutes)		
3	Ronimus et al. (2019) [35]	Randomized assignment	Traditional teaching support	GraphoLearn (GL) Reading	Reading skills	- Matchingsounds to their written equivalents (letters, syllables, or words)	Teachers and parents	School and/or home	Tablet+	6	5.41 *	5	10	D > C: in word reading; D = C: in (untrained) writing, text comprehension, sentence reading speed	Good engagement and motivation to learn
4	Ronimus et al. (2020) [36]	Randomized assignment	Traditional teaching support	GraphoLearn (GL) GLReading and GL spelling	Metaphonological awareness and reading skill	- GL reading: grapheme–phoneme correspondence and word reading - GL spelling: metaphonological tasks	Only a few caregivers reported sometimes helping children with training (10.8% of teachers and 26.9% of parents).	School and/or home	Computer	6	5.44	2–3 sections for a day; the number of sections for the week is N/A	20 * (range: 10–30)	D > C: reading only for those who use GL reading or with a high self-efficacy D = C: for those who use GL spelling or with low frequency	Self-efficacy was associated with reading gain and marginally with spelling gain.
5	Kashani-Vahid et al. (2019) [37]	Randomized assignment	Traditional teaching support (presentation slides)	Maghzineh	Memory and attention	- Simon memory task - Selective attention - Divided attention - Memory of visual patterns	N/A	N/A	Tablet or smartphone	4	20	7 *	43 *	D > C: reading, reading comprehension, language, and metaphonological awareness	
6	Salgarayeva et al. (2021) [38]	Randomized assignment	Traditional teaching support	Qazaqsha logoped	Metaphonological awareness and reading skills	- Letter recognition - Reading syllables - Fluid syllabic reading - Reading sounds with difficult pronunciations aloud - Reading full words and word groups	Teachers and parents	School and/or home	N/A	8	N/A	7 *	Range: 8–10	D > C: reading accuracy D = C: writing, text comprehension, reading speed	

3.4. Quality Criteria for SGs

The qualitative characteristics of the SGs were evaluated according to the criteria in [26], with a percentage of agreement of P(A) = 91% and a Cohen's K of 0.77 (substantial agreement) [30]. The results are reported in Tables 3 and 4.

All the SGs presented several elements that made them "serious" learning tools (see the top part of Table 3): a clear focus on learning, informative and continuous feedback, and the use of appropriate technical language. For the same section, no external acknowledgments from experts or other players were identified (including cases in which the authors were experts in learning sciences). The reading of the studies did not reveal any information regarding the effect of caregivers' support on the use of the game—except for [38]—and the neutrality of the game content.

On the other hand, concerning the game section (see the bottom of Table 3), all the SGs shared the features of adaptation and the progression of the difficulty level, as well as a visual interface appropriate to the purpose of the game and the target group. There was no evidence of playful contexts of collaborative participation and no information about the repetition of the game after a mistake (e.g., "try again!").

As expected, all the included studies reported elements typical of SGs (Table 4), including synergy between learning and play, the appropriate use of the technological tool, the presence of tutorials, the intuitive use of the game commands, the ease of use of the technological tool in reaching the objective, and the low risk of stress and mental and physical complications. We found no elements with which to deduce the presence of a team working on the game design. Furthermore, there was a lack of information in the papers on the adherence to reality, the possibility of cheating, and the absence of technical bugs.

In conclusion, all the SGs evaluated met the quality criteria in [26], presenting at least one (and, often, more than one) characteristic for each quality aspect. The unique exception was the possibility of interacting with other children in multiplayer play or of receiving recognition for the quality of play, because this characteristic is absent from all SGs.

Table 3. Qualitative criteria for each SG. ✓ = criteria identified; ✗ = not identified; N/A = not available.

	Quality Criteria	Quality Aspects	Description	Code	Salah et al. (2016) [32]	Görgen et al. (2020) [34]	Ronimus et al. (2019) [35]	Ronimus et al. (2020) [36]	Kashani-Vahid et al. (2019) [37]	Salgarayeva et al. (2021) [38]
SERIOUS SECTION	Characterizing goal	Focus on the characterizing goal	Constant focus on the learning objective	1.1.a	✓	✓	✓	✓	✓	✓
			Support players in learning	1.1.b	N/A	N/A	N/A	N/A	N/A	✓
			Playful components must not hinder learning	1.1.c	✓	✓	✓	✓	✓	✓
		Clear goals	Appropriate methods for learning area and age of players	1.2.a	✓	✓	✓	✓	✓	✓
			Clarity of objectives	1.2.b	✓	✓	✓	✓	✓	✓
		The indispensability of the characterizing goal	The obligation of the serious section	1.3.a	✓	✓	✓	✓	✓	✓
			The necessity of achieving the goal	1.3.b	✓	✓	✓	✓	✓	✓
			Feasibility of task execution	1.3.c	✓	✓	✓	✓	✓	✓

Table 3. *Cont.*

	Quality Criteria	Quality Aspects	Description	Code	Salah et al. (2016) [32]	Görgen et al. (2020) [34]	Ronimus et al. (2019) [35]	Ronimus et al. (2020) [36]	Kashani-Vahid et al. (2019) [37]	Salgarayeva et al. (2021) [38]
	Methods	Correctness of the domain expert content	Correctness of learning content	2.1.a	✓	✓	✓	✓	✓	✓
			Correctness of technical language	2.1.b	✓	✓	✓	✓	✓	✓
			Neutrality concerning irrelevant issues	2.1.c	N/A	N/A	N/A	N/A	N/A	N/A
		Appropriate feedback on progress	Feedback on performance and progress	2.2.a	✓	✓	✓	✓	✓	✓
			Visible results	2.2.b	✓	✓	✓	✓	✓	✓
			Multimodal feedback	2.2..c	✓	✓	✓	✓	✓	✓
		Appropriate rewards	Positive reinforcement	2.3.a	✓	✓	✓	✓	✓	✓
GAME SECTION	Quality	Proof of effectiveness and sustainable effects	Achieving the objective	3.1.a	✓	✓	✓	✓	✓	✓
			Retention of acquired learning	3.1.b	✓	✓	✓	✓	✓	✓
		Awards and ratings	Evaluation of the quality of play through recognition by professionals or other players	3.2.a	×	×	×	×	×	×
	Enjoyment	Ensure player engagement and experience	Immersive experience	A.1.a	✓	✓	✓	✓	✓	✓
			Fun and involvement	A.1.b	✓	✓	✓	✓	✓	✓
			Flow experience	A.1.c	N/A	N/A	N/A	N/A	N/A	N/A
			Multiplayer experience	A.1.d	N/A	N/A	N/A	N/A	N/A	N/A
		Ensure flow	Alignment between player skill and sense of challenge	A.2.a	✓	✓	✓	✓	✓	✓
			Adaptation of difficulty level	A.2.b	✓	✓	✓	✓	✓	✓
			Fostering motivation to play	A.2.c	N/A	N/A	N/A	N/A	N/A	N/A
			Progression of difficulty level	A.2.d	✓	✓	✓	✓	✓	✓
			Variety of play	A.2.e	✓	✓	✓	✓	✓	✓
		Establish an emotional connection	Emotional engagement	A.3.a	✓	✓	N/A	✓	N/A	N/A
		Sense of control	Mastery of the game	A.4.a	✓	✓	✓	✓	✓	✓
		Support social interactions	Selection between single player and multiplayer	A.5.a	×	×	×	×	×	×
		Ensure immersive experience	Multimodal sensory stimulations	A.6.a	✓	✓	✓	✓	✓	✓
			Full participation and involvement	A.6.b	✓	✓	✓	✓	✓	✓

Table 3. *Cont.*

Quality Criteria	Quality Aspects	Description	Code	Salah et al. (2016) [32]	Görgen et al. (2020) [34]	Ronimus et al. (2019) [35]	Ronimus et al. (2020) [36]	Kashani-Vahid et al. (2019) [37]	Salgarayeva et al. (2021) [38]
Media presentation	Attractive graphics	Graphics appropriate for the game purpose, application area, and target group	B.1.a	✓	✓	✓	✓	✓	✓
		Clear and non-distracting interface	B.1.b	✓	✓	✓	✓	✓	✓
	Appropriate sounds	Appropriate music and sound effects	B.2.a	✓	✓	✓	✓	✓	✓

Table 4. Qualitative criteria (for balance between the serious and game section) for each SG. ✓ = criteria identified; ✕ = Not identified; N/A = Not available.

Quality Criteria	Quality Aspects	Description	Code	Salah et al. (2016) [32]	Görgen et al. (2020) [34]	Ronimus et al. (2019) [35]	Ronimus et al. (2020) [36]	Kashani-Vahid et al. (2019) [37]	Salgarayeva et al. (2021) [38]
Integrated serious part with gameplay	Embedding characterizing goals into the gameplay	Synergy between learning and play	A.1.a	✓	✓	✓	✓	✓	✓
		Accordance between play elements and learning task	A.1.b	✓	✓	✓	✓	✓	✓
	Scientific foundation	Team working on game design	A.2.a	✕	✕	✕	✕	✕	✕
		Literature review	A.2.b	✓	✓	✓	✓	✓	✓
Interaction technology	Appropriate interaction technology	Appropriate technological tool of use	B.1.a	✓	✓	✓	✓	✓	✓
	Intuitive game mechanics and natural mapping	Presence of tutorials	B.2.a	✓	✓	✓	✓	✓	✓
		Intuitive use of game controls	B.2.b	✓	✓	✓	✓	✓	✓
		Adherence to reality	B.2.c	N/A	N/A	N/A	N/A	N/A	N/A
	No simplifying of the learning and/or training process due to technical features	Ease of use of the technological tool in achieving the objective	B.3.a	✓	✓	✓	✓	✓	✓
		Impossibility of cheating	B.3.b	N/A	N/A	N/A	N/A	N/A	N/A
	Avoid adverse effects	Low risk of stress and mental and physical complications	B.4.a	✓	✓	✓	✓	✓	✓
		Absence of technical bugs	B.4.b	N/A	N/A	N/A	N/A	N/A	N/A

3.5. The Procedure of Administration of SG Training

The procedures used for SG training are reported separately for each study in Table 2. Training using SG was performed for an average of 6 weeks (SD: 1.6; range: 4–8.8), with 6 weekly sessions (SD: 1.0; range: 3.3–7) of 22 min (SD: 13.8; range: 10–43). As shown in the table, the SG was performed on a tablet in almost of the cases, and sometimes also on a computer or smartphone. Only one study [34] explicitly requested that the training take place independently. However, the authors could not be sure whether there was any help from the parents. In five cases, the training was performed under the supervision of parents and teachers, and one study [37] did not report specific information about this aspect. The training took place at home and/or at school (depending on the preferences of the teachers and parents and on computer access restrictions). Two of the studies [36,38], demonstrated that the scores did not differ between the three groups trained in different locations. Interestingly, one study [35] found that even though the training took place at school for all the children, the majority (89%) also used the game at home, and a large number of the children also played during recess (24%) and in after-school clubs (16%), indicating good engagement.

3.6. Evidence of Efficacy

The results are reported in detail in Table 2; Table 5 reports the main findings of the studies examining the efficacy of the SG training. The results show that in all the studies, a significantly higher improvement in reading skills was observed in the group treated with SG compared with the control group, with only a few exceptions. The first was [36], in which the advantage of the group treated with SG with respect to the control group was evident only in the children with high self-efficacy that used reading SG. The second was [34], which found a greater reading gain in the group trained with SG than in the control group only in the reading of long and complex words, and not in the reading of simple and short words and pseudowords, as well as in phoneme–grapheme mapping. However, it should be noted that this study [34] was conducted on German children, who learn a highly consistent orthography, in which sublexical difficulties in reading relatively easy and short stimuli are generally less marked. This may have contributed to making the improvements less noticeable under the simpler conditions, compared with more difficult conditions, such as the reading of long and complex words.

Table 5. Efficacy of SG training. Plus (+) indicates a statistically significantly larger improvement in the group trained with the SG compared with the control group; Minus (−) indicates similar gains in experimental and control groups; Plus/Minus (+/−) indicates a larger gain improvement after SG training but limited only to specific circumstances.

ID	Authors	Spelling	Reading	Reading Comprehension	Language	Metaphonological Skills	Engagement
1	Salah et al. (2016) [32]	N/A	+	N/A	N/A	N/A	+
2	Görgen et al. (2020) [34]	−	+/−	−	N/A	+/−	+
3	Ronimus et al. (2019) [35]	−	+	−	N/A	N/A	+
4	Ronimus et al. (2020) [36]	N/A	+/−	N/A	N/A	N/A	N/A
5	Kashani-Vahid et al. (2019) [37]	N/A	+	+	+	+	N/A
6	Salgarayeva et al. (2021) [38]	−	+	−	N/A	N/A	N/A

Improvements in reading comprehension were investigated in only four studies, of which three [34,35,38] found no major improvement following training with SG, while one [37] found a significant effect on text comprehension. However, it is important to specify that none of the studies apply SGs as training for reading comprehension of meaningful sentences or texts.

Spelling improvement was investigated in only three studies [34,35,38], showing that the SG training did not produce greater improvements in writing than those found in the control group. In any case, including the improvement of spelling, it is important to note that none of the studies trained spelling skills with SGs, except for [32], which trained children to colour a letter shape on a screen by filling the gap with their fingers.

Improvements in phonological awareness were investigated in [34,37], showing a greater benefit of SG training, but only for more sensible measures and not for tasks that are usually easy in consistent orthographies, such as syllable counting and vowel length. Language was investigated only in [37], through the task of naming and word comprehension, showing greater gains in the experimental group.

It should be noted that only one study reported follow-up data [35], but only for the experimental group and these data covered three months. The children were nevertheless able to maintain their achieved level in reading and spelling over the three months after the intervention. However, the lack of a follow-up for the control group prevented us from drawing a conclusion as to the long-term effects of SG interventions.

3.7. Engagement Data

The participants' engagement was investigated in three studies [32,34,35].

The results of [32] highlighted a higher level of engagement among the children trained with SGs than in the control group and the presence of an experience of flow among the former; the participants had an enjoyable experience moving through the different levels of the different games on the platform.

In [35], an association between adult-observed emotional engagement and SG exposure time was found, suggesting that the children who enjoyed using the SG played the game more than those with low emotional engagement. However, only adult-observed cognitive engagement was related to learning gains in word decoding and reading fluency, and a higher success rate in the SG. It should be noted that the SG success rate mediated the effect of cognitive engagement on the gain in sentence reading fluency and (to a lesser extent) in word reading: the children who were able to focus and persist while playing tended to have higher success rates; and higher success rates further contributed to their reading development.

One study [34] reported that the children enjoyed the training and were motivated to continue the training after the scheduled training time. Parents consider SG training suitable for children's reading disorders and as a positive influence on children's reading ability. These results highlight that the story frame and reward system were the elements that most contributed to the children's interest in the SGs.

3.8. Risk-of-Bias Assessment

An independent assessment of the study quality was conducted by the authors of this review with the RoB 2 tool. The second and third authors independently assessed the methodological quality of the studies with the RoB 2 tool, obtaining a percentage of agreement P(a) = 96% and a Cohen's K of 0.90—an almost perfect agreement level [30]. Furthermore, although there was strong agreement, any differences were objectively concluded after a discussion between the first three authors.

The results of the quality rating of all the studies included in this review are summarized in Figure 2. In general, no concerns and/or high risk of bias were highlighted, except for [32], in domain 3 ("bias due to missing outcome data"), due to the absence of outcome raw data. The first and second researchers contacted the authors but did not receive a response.

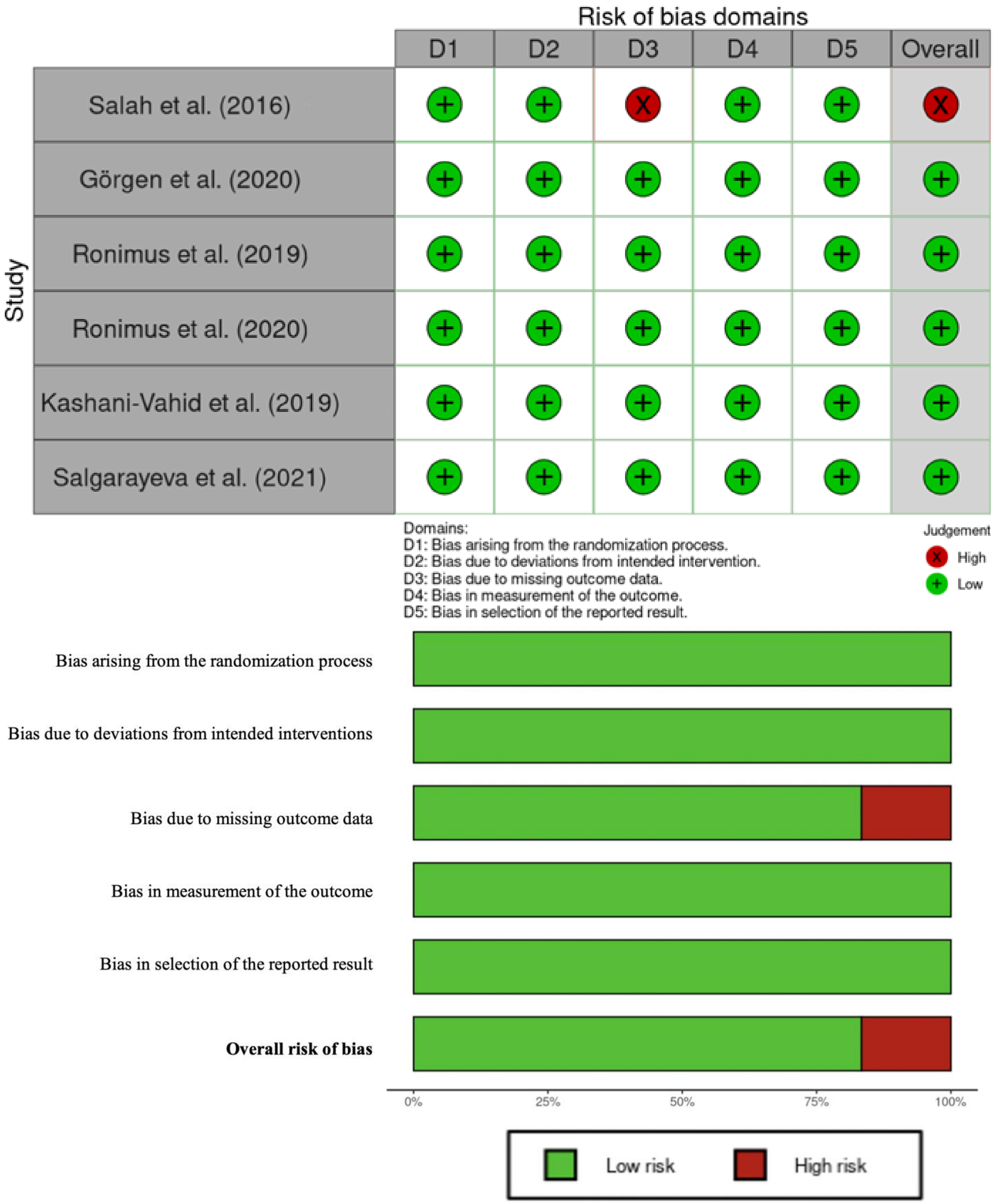

Figure 2. Result of the Cochrane risk-of-bias assessment (RoB 2) [32,34–38].

4. Discussion

The present systematic review highlights that very few studies (only six) have examined the efficacy of SGs in improving literacy disorders through a rigorous experimental design with pre- and post-tests, as well as randomized control trials. In fact, although several SGs have been developed to improve reading skills among children with learning disorders, controlled studies of efficacy are almost entirely lacking. It should be noted that all the studies included in this review were conducted in recent years. Specifically, one study was conducted in 2016, while others are dated after 2019. All the studies examined the effects of SGs in children with difficulties or deficits in literacy acquisition at a very early stage of schooling. Studies examining the efficacy of SGs in the subsequent phases of literacy acquisition (in older children) are lacking. Moreover, all the studies in this review were performed on pupils using consistent orthographies, and evidence of the effectiveness of SGs in opaque orthographies is lacking. Notably, orthographic opaqueness produces qualitative differences in reading and spelling skills [39–47] and, therefore, it is not certain whether the results can be generalized to opaque languages.

Moreover, the studies examined have some limitations. First, the studies do not allow the characterization of the type of reading deficit as phonological or superficial impairment. Therefore, it is not possible to verify the efficacy of SGs in terms of the function of the type of deficit. It should be noted that the SG included in the review trained only sublexical grapheme-to-phoneme (and vice versa) mapping or phonological awareness, and there are no SGs to improve lexical difficulties. Therefore, it is not possible to verify whether sublexical training was performed on children who suffered from a sublexical deficit. It should be noted that surface deficit is the most frequent disorder among children speaking a language with a consistent orthography [48–51] and, therefore, that SGs aiming to train lexical procedures might be more effective for these populations. It should be noted that the studies examined in the present review were conducted on languages with consistent orthographies, such as German or Finnish, and that it is possible that literacy gain after SG training would have been even more profitable following a lexical treatment. On the other hand, children mainly benefit from phonological awareness training in the earlier stages of literacy development or, in the case of more severely affected children [52–55], at the age of the participants in the studies in this systematic review.

Furthermore, there are no studies with evidence of the effectiveness of the use SGs to improve the comprehension of written texts, a skill that is very important to rehabilitate due to its major impact on academic and life success [56–58]. Moreover, none of the studies used reading aloud or spelling as training exercises. The unique exception was the letter painting task in the Salah study (2016), although this task did not examine the spelling process, but only visuo-constructive, perceptive, and motor skills. This is a limitation of these SGs. The practice of spelling could have guaranteed a greater literacy gain [59–61]. Regarding reading aloud, the availability of an oral word form might support further orthographic learning [62]. Moreover, reading aloud allows researchers to monitor precisely what children read and would, in turn, allow the characterization of reading deficits through the examination of reading profiles [44,63–65], as well as monitoring the reasons for eventual reading comprehension deficits. Automatic speech-recognition systems would allow the assessment of reading aloud [66], but this technology is still challenging [67] due to its limited reliability [67–69] and the difficulty in considering the variety of human speech and background noises [68,69]. Therefore, this may be a challenge in the future.

The results of the studies included in the present systematic review highlight that children with reading impairments benefit from digital-game-based reading training. The studies generally have a low risk of bias in all the domains investigated, except for the absence of outcome data in [32]. Furthermore, the experimental groups in the reviewed studies benefited exclusively from SG training, and no further classic face-to-face rehabilitation training with the operator was provided in support. Therefore, the effectiveness of training with SGs was proven even on its own. All the studies in this systematic review found a significantly higher improvement in reading skills among children trained with SGs compared with the control group, although this was sometimes evident only in the most difficult conditions. This was probably due to the already discrete performance in easy conditions, as well as to the high consistency of the orthographies of the languages spoken by the children in the studies.

It should be noted that the training using SGs was performed for an average of 6 weeks, with six weekly sessions of about 20 min. This highlights that very short and undemanding training might succeed in achieving satisfactory results by children with reading and spelling difficulties/disorders, at least in the first years of schooling. However, the lack of a follow-up prevents us from drawing a conclusion as to the long-term effects of SG interventions. In this regard, further studies are needed.

The experimental group did not improve more than the controls in spelling and text comprehension (except for one study, in reading comprehension), indicating the poor generalization of progress to untreated skills. The SG training did not have a significant impact on untrained literacy skills. Therefore, due to the different deficits associated with each literacy skill, different methods targeting the specific symptoms are needed [70–72]. Reading comprehension is effectively a different skill, which is also based on linguistic and inferential processes [73]. However, the lack of generalization of the effect of reading training on spelling outcomes is surprising. Several studies show strong parallels between reading and spelling performance, with item-specific difficulty in both tasks [74–76], as well as common deficits underlying reading and writing difficulties [75–80]. Moreover, several studies have demonstrated spelling improvements after reading training as a carry-over effect [81–83]. However, this research was on lexical learning and spelling, while the SGs in this systematic review focused only on sublexical processing. Therefore, SGs based on lexical reading training may be likely to generate greater carry-over effects on lexical spelling (and vice versa). In any case, according to the results of this systematic review, it is evident that SG training should be complemented by modules specifically targeting reading comprehension and spelling skills.

The results show that the SGs were perceived as having adequate difficulty levels, user friendliness, and task explanation by children and significant adults. This is an important finding because a level of higher learning improvement was reported for SGs that are perceived as useful, easy, and uncomplicated, and fun and enjoyable [84]. These characteristics guarantee the feasibility of independent SG training in home environments, with online notifications of children's training progress. Thanks to the innovative features of SGs, such as their adaptivity, immediate feedback, and reward, the training does not need an external instructor. In this way, it is possible also to relieve the families' workload and the stress related to supervising their children at home [85]. However, caution is required, because it is impossible to verify whether the children performed the exercises independently or received help from their caregivers. This approach would bring an effect on the reliability of the results. However, the possibility of children carrying out their training independently at home has numerous advantages which outweigh the aforementioned risks. First of all, SG training can be useful for children who do not have access to special reading support or for bridging the gap until individual support can be provided. Moreover, these characteristics guarantee the possibility of intensive training several times a week, with a significant impact on rehabilitative success rates. Significant gains in word reading among dyslexic children also required very intensive training [86]. Moreover, the development of efficient SGs might allow all children to obtain maximum results, without depending on the skill of the individual clinician, guaranteeing equal opportunities for all children with learning disabilities. This does not mean that classical rehabilitation face to face with a clinical neuropsychologist must be abandoned; rather we suggest that SG training might be a useful instrument to support the work of clinicians. The use of SG training for children with learning disorders might ensure intensive and continuous exercises and inclusive opportunities.

Moreover, SGs have the advantage of being motivational and enjoyable for children. Several studies have highlighted the importance of engagement to achievement [87,88]. If a game supports its players' engagement, encouraging them to perform well, the training effects can be stronger. There are several reasons to explain the impressive enthusiasm that

SGs generate, one of which is the presence of rewards: games enable the release of key neurotransmitters, such as dopamine [89,90].

Furthermore, SGs always challenge players by testing them at the right level of difficulty: the challenge component always exists, and the task is never too easy; rather, it gradually adapts to the skill level of the player, and the continuous and informative feedback guides the player during trials or when performing specific tasks. The level of difficulty always guarantees that the individual plays to the limit of their abilities, in their "proximal zone of development" [91]: the individual plays (and learns) each challenge without feeling discouraged, while at the same time receiving feedback to monitor their progress. Since children with learning disorders show low levels of motivation [92,93] and are reluctant to engage in routine intervention methods [94], the strong motivation to use the program reported in the reviewed studies is very encouraging. The reviewed studies highlight the high level of engagement and flow in SG training: the children enjoyed the training and were motivated to continue after the scheduled training time; consequently, they obtained greater reading improvements. This highlights the importance of developing enjoyable, motivational, and attractive SGs for children.

All the SGs examined displayed several elements of gamification. The most frequent were clear and attainable goals, simple and clear rules, informative and continuous feedback, immersive experiences, reward systems (e.g., avatar customization), interactive and dynamic user interfaces, a sense of control, the adaptability of the learning content and player challenge–skill balance, the narrative context (e.g., a superhero trying to save a city), problem-solving, fantasy environments, and graphics. The results of [34] highlight that the story frame and reward system were the elements that most contributed to the children's interest in the SG (in line with [35,95–97]). Notably, often, the SGs examined provided only immediate correct/incorrect feedback after each trial, but no information on which areas needed more practice or on the overall level of performance or the progress made in skills development. This latter characteristic might encourage children to try their best and support their motivation to improve their learning [98,99].

It should be noted that the use of feedback in SGs allows the improvement not only of motivation and self-efficacy but also of metacognitive strategies, i.e., self-regulation techniques used by students to monitor their learning processes. Their use is considered one of the basic predictors of academic success as they enhance learning (e.g., [100]). This is not only a gamification feature, increasing the enjoyment of and engagement with games, but also a serious feature of metacognitive enhancement.

To further increase motivation, children could be more actively involved by taking on a more active role, as suggested by Ronimus et al. [97]. Moreover, no SG foresees the involvement of peers: making the acknowledgment of progress visible to all or creating challenges between peers could make activities more motivational and attractive. Future SGs could include this feature.

The next challenge for informatics enterprises and learning researchers will be to develop more motivational and attractive SGs for literacy learning. Moreover, as highlighted in a recent systematic review [101], the games must meet the specific needs of dyslexics, as well as providing interface characteristics to reduce visual discomfort, such as font, spacing, background, etc. (for a more detailed description, see Table 4 in [101]) and cognitive fatigue [102–104].

However, this systematic review is not free of limitations. In particular, the limited quantity of studies used in this systematic review requires a note of caution, despite their satisfactory quality. Notably, the small number of studies did not allow a meta-analysis. Moreover, follow-up data were not available. Nevertheless, the findings from this systematic review are advantageous in encouraging further research exploring the impact of digital technology on the improvement of reading skills in children with learning disorders.

5. Conclusions

This systematic review proves (for the first time) that the use of SGs might be a new and effective learning method for enhancing reading and metaphonology skills, as well as engagement and motivation to learn for students with learning disabilities. However, SGs specially developed for children with learning disorders are still few in number and do not include the training of some fundamental literacy skills, such as lexical processing, spelling, or written text comprehension. The studies examined here highlighted the scarce generalization of trained skills to untrained skills, making even more urgent the need to develop SGs to enhance the various skills involved in literacy acquisition.

This systematic review highlights the potential of SGs to provide an authentic and effective learning experience for children with learning disabilities, in which fun and learning are integrated perfectly and synergistically [105]. The implementation of literacy training in SGs based on gamification and engagement guarantees an enjoyable reading experience, literacy improvement, and a strong motivation to engage in reading–writing exercises in rehabilitation. However, some of the elements of gamification should be improved, such as the graphics and user interface and, in general, the designs of the games and the complexity of their content.

The possibility of using SGs to improve learning skills at home without an external instructor might simplify access to individual rehabilitation for many children. Serious games can also be used as additional tools for individual therapy to increase the frequency of support and the chances of success, and as compensation in cases where face-to-face individual therapy does not occur frequently due to economic reasons or long waiting lists in the national health system.

This study highlights a new challenge for research on learning disabilities: the development of technological tools with the characteristics of gamification for the training of all aspects of literacy in children with learning disorders, as SGs are highly effective, pleasant, and motivating rehabilitative tools.

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References

1. Lundqvist, A.; Grundstrom, K.; Samuelsson, K.; Ronnberg, J. Computerized training of working memory in a group of patients suffering from acquired brain injury. *Brain Inj.* **2010**, *24*, 1173–1183. [CrossRef] [PubMed]
2. Rego, P.A.; Moreira, P.M.; Reis, L.P. New Perspectives in Information Systems and Technologies. In *Architecture for Serious Games in Health Rehabilitation*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 307–317.
3. Abt, C.C. *Serious Games*; University Press of America: Lanham, MD, USA, 1987.
4. Botte, B.; Matera, C.M.; Sponsiello, M. Serious Games between simulation and game. A taxonomy proposal. *J. E Learn. Knowl. Soc.* **2009**, *5*, 11–22.
5. Dipace, A. *Simulazioni e Giochi Digitali Per L'apprendimento*, 1st ed.; Progedit: Bari, Italy, 2016.
6. Ke, F. Designing and integrating purposeful learning in game play: A systematic review. *Educ. Technol. Res. Dev.* **2016**, *64*, 219–244. [CrossRef]
7. Michael, D.R.; Chen, S.L. *Serious Games: Games That Educate, Train, and Inform*, 2nd ed.; Thomson Course Technology: New York, NY, USA, 2005.
8. Yu, Z. A meta-analysis of use of serious games in education over a decade. *Int. J. Comput. Games Technol.* **2019**, *2019*, 4797032.

9. Bonvino, A.; Trotta, E.; Calvio, A. "Il mio nome è Game, Serious Game". Tra Serious Game e Scienza Psicologica. Teorie e risvolti applicativi. *Nuova Second* **2022**, *2*, 223–234.
10. Mayo, M.J. Games for science and engineering education. *Commun. ACM* **2007**, *50*, 30–35. [CrossRef]
11. Manera, V.; Ben-Sadoun, G.; Aalbers, T.; Agopyan, H.; Askenazy, F.; Benoit, M.; Bensamoun, D.; Bourgeois, J.; Bredin, J.; Bremond, F.; et al. Recommendations for the use of serious games in neurodegenerative disorders. *Front. Psychol.* **2017**, *8*, 1243. [CrossRef]
12. Sokolov, A.A.; Grivaz, P.; Bove, R. Cognitive deficits in multiple sclerosis: Recent advances in treatment and neurorehabilitation. *Curr. Treat. Options Neurol.* **2018**, *20*, 53. [CrossRef]
13. Ern, A.M. The Use of Gamification and Serious Games within Interventions for Children with Autism Spectrum Disorder. Bachelor's Thesis, University of Twente, Enschede, The Netherlands, 2014.
14. Derks, S.; Willemen, A.M.; Sterkenburg, P.S. Improving adaptive and cognitive skills of children with an intellectual disability and/or autism spectrum disorder: Meta-analysis of randomised controlled trials on the effects of serious games. *Int. J. Child-Comput. Interact.* **2022**, *33*, 100488. [CrossRef]
15. Zheng, W.; Zhao, Z.; Zhang, Z.; Liu, T.; Zhang, Y.; Fan, J.; Wu, D. Developmental pattern of the cortical topology in high-functioning individuals with autism spectrum disorder. *Hum. Brain Mapp.* **2021**, *42*, 660–675. [CrossRef]
16. Papanastasiou, G.; Drigas, A.; Skianis, C. Serious Games: How do they impact special education needs children. *Tech. Educ. Humanit.* **2022**, *2*, 41–58. [CrossRef]
17. Kara, N. Bibliometric and Content Analysis of Research Trends on the Use of Serious Games to Assist People with Disabilities. *J. Comput. Educ. Res.* **2021**, *9*, 278–299. [CrossRef]
18. World Health Organization. *International Statistical Classification of Disease and Health Related Problems*, 10th ed.; World Health Organization: Geneva, Switzerland, 2016.
19. American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders*, 5th ed.; American Psychiatric Association: Washington, DC, USA, 2013.
20. Politi-Georgousi, S.; Drigas, A. Mobile Applications, An Emerging Powerful Tool for Dyslexia Screening and Intervention: A Systematic Literature Review. *iJIM* **2020**, *14*, 4–17. [CrossRef]
21. Boekaerts, M. The crucial role of motivation and emotion in classroom learning. In *The Nature of Learning: Using Research to Inspire Practice*; OECD: Paris, France, 2010; pp. 91–111. [CrossRef]
22. Panic, M.; Ford, J.D. A review of national-level adaptation planning with regards to the risks posed by climate change on infectious diseases. *OECD Nations. Int. J. Environ. Res. Public Health* **2013**, *10*, 7083–7109. [CrossRef] [PubMed]
23. Agha, R.A.; Fowler, A.J.; Limb, C.; Whitehurst, K.; Coe, R.; Sagoo, H.; Jafree, D.J.; Chandrakumar, C.; Gundogan, B. Impact of the mandatory implementation of reporting guidelines on reporting quality in a surgical journal: A before and after study. *Int. J. Surg.* **2016**, *30*, 169–172. [CrossRef] [PubMed]
24. Page, M.J.; McKenzie, J.E.; Bossuyt, P.M.; Boutron, I.; Hoffmann, T.C.; Mulrow, C.D.; Shamseer, L.; Tetzlaff, J.M.; Akl, E.A.; Brennan, S.E.; et al. The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *Syst. Rev.* **2021**, *10*, 89. [CrossRef]
25. Ouzzani, M.; Hammady, H.; Fedorowicz, Z.; Elmagarmid, A. Rayyan—A web and mobile app for systematic reviews. *Syst. Rev.* **2016**, *5*, 210. [CrossRef]
26. Caserman, P.; Hoffmann, K.; Müller, P.; Schaub, M.; Straßburg, K.; Wiemeyer, J.; Bruder, R.; Göbel, S. Quality criteria for serious games: Serious part, game part, and balance. *JMIR Serious Games* **2020**, *8*, e19037. [CrossRef]
27. Sterne, J.A.; Savović, J.; Page, M.J.; Elbers, R.G.; Blencowe, N.S.; Boutron, I.; Cates, C.J.; Cheng, H.Y.; Corbett, M.S.; Eldridge, S.M.; et al. RoB 2: A revised tool for assessing risk of bias in randomised trials. *BMJ* **2019**, *366*, 4898. [CrossRef]
28. Higgins, J.P.T.; Sterne, J.A.C.; Savović, J.; Page, M.J.; Hróbjartsson, A.; Boutron, I.; Reeves, B.; Eldridge, S. A revised tool for assessing risk of bias in randomized trials. In *Cochrane Methods*; Cochrane Database of Systematic Reviews; Chandler, J., McKenzie, J., Boutron, I., Welch, V., Eds.; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2016; (Suppl. S1). [CrossRef]
29. Higgins, J.P.; Savović, J.; Page, M.J.; Sterne, J.A. *Revised Cochrane Risk-of-Bias Tool for Randomized Trials (RoB 2)*; RoB2 Development Group; John Wiley & Sons, Ltd.: Hoboken, NJ, USA, 2019.
30. Cohen, J.A. coefficient of agreement for nominal scales. *Educ. Psychol. Meas.* **1960**, *20*, 37–46. [CrossRef]
31. Landis, J.R.; Koch, G.G. The Measurement of Observer Agreement for Categorical Data. *Biometrics* **1977**, *33*, 159–174. [CrossRef] [PubMed]
32. Salah, J.; Abdennadher, S.; Sabty, C.; Abdelrahman, Y. Super Alpha: Arabic Alphabet Learning Serious Game for Children with Learning Disabilities. In *Serious Games*; JCSG: Lecture Notes in Computer Science; Marsh, T., Ma, M., Oliveira, M., Baalsrud Hauge, J., Göbel, S., Eds.; Springer: Cham, Switzerland, 2016; p. 9894. [CrossRef]
33. Katz, L.; Frost, R. The reading process is different for different orthographies: The orthographic depth hypothesis. *Adv. Psychol.* **1992**, *94*, 67–84.
34. Görgen, R.; Huemer, S.; Schulte-Korne, G.; Moll, K. Evaluation of a digital gamebased reading training for German children with reading disorder. *Comput. Educ.* **2020**, *150*, 103834. [CrossRef]
35. Ronimus, M.; Eklund, K.; Pesu, L.; Lyytinen, H. Supporting struggling readers with digital game-based learning. *Educ. Technol. Res. Dev.* **2019**, *67*, 639–663. [CrossRef]
36. Ronimus, M.; Eklund, K.; Westerholm, J.; Ketonen, R.; Lyytinen, H. A mobile game as a support tool for children with severe difficulties in reading and spelling. *J. Comput. Assist. Learn.* **2020**, *36*, 1011–1025. [CrossRef]

37. Kashani-Vahid, L.; Taskooh, S.K.; Moradi, H. Effectiveness of "Maghzineh" cognitive video game on reading performance of students with learning disabilities in reading. In Proceedings of the 2019 International Serious Games Symposium (ISGS), Tehran, Iran, 26 December 2019; pp. 13–17.
38. Salgarayeva, G.I.; Iliyasova, G.G.; Makhanova, A.S.; Abdrayimov, R.T. The Effects of Using Digital Game Based Learning in Primary Classes with Inclusive Education. *Eur. J. Contemp. Educ.* **2021**, *10*, 450–461.
39. Ellis, N.C.; Hooper, A.M. Why learning to read is easier in Welsh than in English: Orthographic transparency effects evinced with frequency-matched tests. *Appl. Psycholinguist.* **2001**, *22*, 571–599. [CrossRef]
40. Ellis, N.C.; Natsume, M.; Stavropoulou, K.; Hoxhallari, L.; Van Daal, V.H.; Polyzoe, N.; Tsipa, M.L.; Petalas, M. The effects of orthographic depth on learning to read alphabetic, syllabic, and logographic scripts. *Read. Res. Q.* **2004**, *39*, 438–468. [CrossRef]
41. Marinelli, C.V.; Horne, J.K.; McGeown, S.; Zoccolotti, P.; Martelli, M. Does the mean adequately represent reading performance? Evidence from a cross-linguistic study. *Front. Psychol.* **2014**, *5*, 903. [CrossRef]
42. Marinelli, C.V.; Romani, C.; Burani, C.; Zoccolotti, P. Spelling acquisition in English and Italian: A cross-linguistic study. *Front. Psychol.* **2015**, *6*, 1843. [CrossRef]
43. Marinelli, C.V.; Romani, C.; Burani, C.; McGowan, V.A.; Zoccolotti, P. Costs and benefits of orthographic inconsistency in reading: Evidence from a cross-linguistic comparison. *PLoS ONE* **2016**, *11*, e0157457. [CrossRef] [PubMed]
44. Marinelli, C.V.; Romani, C.; McGowan, V.A.; Giustizieri, S.; Zoccolotti, P. Characterization of reading errors in languages with different orthographic regularity: An Italian–English comparison. *J. Cult. Cogn. Sci.* **2023**. [CrossRef]
45. Mauti, M.; Marinelli, C.V.; O'Connor, R.J.; Zoccolotti, P.; Martelli, M. Decision times in orthographic processing: A cross-linguistic study. *Exp. Brain Res.* **2023**, *241*, 585–599. [CrossRef] [PubMed]
46. Patel, T.K.; Snowling, M.J.; de Jong, P.F. A cross-linguistic comparison of children learning to read in English and Dutch. *J. Educ. Psychol.* **2004**, *96*, 785–797. [CrossRef]
47. Ziegler, J.C.; Perry, C.; Ma-Wyatt, A.; Ladner, D.; Schulte-Körne, G. Developmental dyslexia in different languages: Language-specific or universal? *J. Exp. Child Psychol.* **2003**, *86*, 169–193. [CrossRef]
48. Marinelli, C.V.; Angelelli, P.; Notarnicola, A.; Luzzatti, C. Do Italian dyslexic children use the lexical reading route efficiently? An orthographic judgment task. *Read. Writ.* **2009**, *22*, 333–351. [CrossRef]
49. Marinelli, C.V.; Arduino, L.S.; Trinczer, I.L.; Friedmann, N. How different reading habits influence lines, words and pseudowords bisection: Evidence from Italian and Hebrew. *Psychology* **2019**, *10*, 2051–2061. [CrossRef]
50. Angelelli, P.; Judica, A.; Spinelli, D.; Zoccolotti, P.; Luzzatti, C. Characteristics of writing disorders in Italian dyslexic children. *Cogn. Behav. Neurol.* **2004**, *17*, 18–31. [CrossRef]
51. Wimmer, H.; Mayringer, H. Dysfluent reading in the absence of spelling difficulties: A specific disability in regular orthographies. *J. Educ. Psychol.* **2002**, *94*, 272–277. [CrossRef]
52. Galuschka, K.; Ise, E.; Krick, K.; Schulte-Körne, G. Effectiveness of treatment approaches for children and adolescents with reading disabilities: A meta-analysis of randomized controlled trials. *PLoS ONE* **2014**, *9*, e89900. [CrossRef]
53. Georgiou, G.K.; Parrila, R.; Papadopoulos, T.C. Predictors of word decoding and reading fluency across languages varying in orthographic consistency. *J. Educ. Psychol.* **2008**, *100*, 566. [CrossRef]
54. Mann, V.; Wimmer, H. Phoneme awareness and pathways into literacy: A comparison of German and American children. *Read. Writ.* **2002**, *15*, 653–682. [CrossRef]
55. Wolf, K.M.; Schroeders, U.; Kriegbaum, K. Metaanalyse zur Wirksamkeit einer Forderung der phonologischen Bewusstheit in der deutschen Sprache. *Z. Für Pädagogische Psychol.* **2016**, *30*, 9–33. [CrossRef]
56. Garnier, H.E.; Stein, J.A.; Jacobs, J.K. The process of dropping out of high school: A 19-year perspective. *Am. Educ. Res. J.* **1997**, *34*, 395–419. [CrossRef]
57. Snowling, M.; Adams, J.W.; Bishop, D.V.; Stothard, S.E. Educational attainments of school leavers with a preschool history of speech-language impairments. *Int. J. Lang. Commun. Disord.* **2001**, *36*, 173–183. [CrossRef] [PubMed]
58. OECD. *Education at a Glance 2013: OECD Indicators*; OECD Publishing: Paris, France, 2013. [CrossRef]
59. Berninger, V.W.; Vaughan, K.; Abbott, R.D.; Begay, K.; Coleman, K.B.; Curtin, G.; Hawkins, J.M.; Graham, S. Teaching spelling and composition alone and together: Implications for the simple view of writing. *J. Educ. Psychol.* **2002**, *94*, 291–304. [CrossRef]
60. Graham, S. Should the natural learning approach replace spelling instruction? *J. Educ. Psychol.* **2000**, *92*, 235–247. [CrossRef]
61. Wanzek, J.; Vaughn, S.; Wexler, J.; Swanson, E.A.; Edmonds, M.; Kim, A.H. A synthesis of spelling and reading interventions and their effects on the spelling outcomes of students with LD. *J. Learn. Disabil.* **2006**, *39*, 528–543. [CrossRef]
62. Share, D.L. Orthographic learning at a glance: On the time course and developmental onset of self-teaching. *J. Exp. Child Psychol.* **2004**, *87*, 267–298. [CrossRef]
63. Hendriks, A.W.; Kolk, H.H.J. Strategic control in developmental dyslexia. *Cogn. Neuropsychol.* **1997**, *14*, 321–366. [CrossRef]
64. Trenta, M.; Benassi, M.; Di Filippo, G.; Pontillo, M.; Zoccolotti, P. Analysis of error profile in a regular orthography: Role of reading deficit and strategic control. *Cogn. Neuropsychol.* **2013**, *30*, 147–171. [CrossRef] [PubMed]
65. Marinelli, C.V.; Martelli, M.; Pizzicannella, E.; Zoccolotti, P. What do reading times tell us about the effect of orthographic regularity? Evidence from English and Italian readers. *Psychol. Educ.* 2023; *in press*.
66. Kim, I.S. Automatic speech recognition: Reliability and pedagogical implications for teaching pronunciation. *Educ. Technol. Soc.* **2006**, *9*, 322–334.

67. Li, J.; Deng, L.; Haeb-Umbach, R.; Gong, Y. Robust automatic speech recognition. In *A Bridge to Practical Applications*, 1st ed.; Elsevier: Amsterdam, The Netherlands, 2016. [CrossRef]
68. Forsberg, M. *Why Is Speech Recognition Difficult*; Chalmers University of Technology: Gothenburg, Sweden, 2003.
69. Petkar, H. A review of challenges in automatic speech recognition. *Int. J. Comput. Appl.* **2016**, *151*, 23–26. [CrossRef]
70. Moll, K.; Landerl, K. Double dissociation between reading and spelling deficits. *Sci. Stud. Read.* **2009**, *13*, 359–382. [CrossRef]
71. Moll, K.; Wallner, R.; Landerl, K. Kognitive Korrelate der Lese-, Leserechtschreib-und der Rechtschreibstörung. *Lern. Und Lernstörungen* **2012**, *1*, 7–19. [CrossRef]
72. Vellutino, F.R.; Fletcher, J.M.; Snowling, M.J.; Scanlon, D.M. Specific reading disability (dyslexia): What have we learned in the past four decades? *J. Child Psychol. Psychiatry* **2004**, *45*, 2–40. [CrossRef]
73. Mastropieri, M.A.; Scruggs, T.E.; Graetz, J.E. Reading comprehension instruction for secondary students: Challenges for struggling students and teachers. *Learn. Disabil. Q.* **2003**, *26*, 103–116. [CrossRef]
74. Angelelli, P.; Marinelli, C.V.; Zoccolotti, P. Single or dual orthographic representations for reading and spelling? A study of Italian dyslexic-dysgraphic and normal children. *Cogn. Neuropsychol.* **2010**, *27*, 305–333. [CrossRef]
75. Marinelli, C.V.; Cellini, P.; Zoccolotti, P.; Angelelli, P. Lexical processing and distributional knowledge in sound-spelling mapping in a consistent orthography: A longitudinal study of reading and spelling in dyslexic and typically developing children. *Cogn. Neuropsychol.* **2017**, *34*, 163–186. [CrossRef]
76. Behrmann, M.; Bub, D. Surface dyslexia and dysgraphia: Dual routes, single lexicon. *Cogn. Neuropsychol.* **1992**, *9*, 209–251. [CrossRef]
77. Marinelli, C.V.; Angelelli, P.; Martelli, M.; Trenta, M.; Zoccolotti, P. Ability to Consolidate Instances as a Proxy for the Association Among Reading, Spelling, and Math Learning Skill. *Front. Psychol.* **2021**, *12*, 761696. [CrossRef] [PubMed]
78. Zoccolotti, P.; De Luca, M.; Marinelli, C.V.; Spinelli, D. Testing the specificity of predictors of reading, spelling and maths: A new model of the association among learning skills based on competence, performance and acquisition. *Front. Hum. Neurosci.* **2020**, *14*, 573998. [CrossRef]
79. Zoccolotti, P.; Angelelli, P.; Marinelli, C.V.; Romano, D.L. A network analysis of the relationship among reading, spelling and maths skills. *Brain Sci.* **2021**, *11*, 656. [CrossRef]
80. Zoccolotti, P.; De Luca, M.; Marinelli, C.V. Interpreting developmental surface dyslexia within a comorbidity perspective. *Brain Sci.* **2021**, *11*, 1568. [CrossRef] [PubMed]
81. Brunsdon, R.K.; Hannan, T.J.; Nickels, L.; Coltheart, M. Successful treatment of sublexical reading deficits in a child with dyslexia of the mixed type. *Neuropsychol. Rehabil.* **2002**, *12*, 199–229. [CrossRef]
82. Lorusso, M.L.; Facoetti, A.; Molteni, M. Hemispheric, attentional, and processing speed factors in the treatment of developmental dyslexia. *Brain Cogn.* **2004**, *55*, 341–348. [CrossRef]
83. Lorusso, M.L.; Facoetti, A.; Paganoni, P.; Pezzani, M.; Molteni, M. Effects of visual hemispherespecific stimulation versus reading-focused training in dyslexic children. *Neuropsychol. Rehabil.* **2006**, *16*, 194–212. [CrossRef]
84. Udeozor, C.; Russo Abegão, F.; Glassey, J. An evaluation of the relationship between perceptions and performance of students in a serious game. *J. Educ. Comput. Res.* **2022**, *60*, 322–351. [CrossRef]
85. Cui, S.; Zhang, C.; Wang, S.; Zhang, X.; Wang, L.; Zhang, L.; Yuan, Q.; Huang, C.; Cheng, F.; Zhang, K.; et al. Experiences and attitudes of elementary school students and their parents toward online learning in china during the COVID-1 pandemic: Questionnaire study. *J. Med. Internet Res* **2021**, *23*, 5. [CrossRef] [PubMed]
86. Berends, I.E.; Reitsma, P. Remediation of fluency: Word specific or generalised training effects? *Read. Writ.* **2006**, *19*, 221–234. [CrossRef]
87. Finn, J.D.; Zimmer, K.S. Student engagement: What is it? Why does it matter? In *Handbook of Research on Student Engagement*; Springer: Boston, MA, USA, 2012; pp. 97–131.
88. Fredricks, J.A.; Blumenfeld, P.C.; Paris, A.H. School engagement: Potential of the concept, state of the evidence. *Rev. Educ. Res.* **2004**, *74*, 59–109. [CrossRef]
89. Mathiak, K.A.; Klasen, M.; Weber, R.; Ackermann, H.; Shergill, S.S.; Mathiak, K. Reward system and temporal pole contributions to affective evaluation during a first person shooter video game. *BMC Neurosci.* **2011**, *12*, 66. [CrossRef]
90. Kätsyri, J.; Hari, R.; Ravaja, N.; Nummenmaa, L. The opponent matters: Elevated fMRI reward responses to winning against a human versus a computer opponent during interactive video game playing. *Cereb. Cortex* **2013**, *23*, 2829–2839. [CrossRef]
91. Vygotsky, L.S. *Mind in Society: The Development of Higher Psychological Processes*; Harvard University Press: Cambridge, MA, USA, 1978.
92. Morgan, P.L.; Fuchs, D.; Compton, D.L.; Cordray, D.S.; Fuchs, L.S. Does early reading failure decrease children's reading motivation? *J. Learn. Disabil.* **2008**, *41*, 387–404. [CrossRef]
93. Polychroni, F.; Koukoura, K.; Anagnostou, I. Academic self-concept, reading attitudes and approaches to learning of children with dyslexia: Do they differ from their peers? *Eur. J. Spec. Needs Educ.* **2006**, *21*, 415–430. [CrossRef]
94. Holmes, W. Using game-based learning to support struggling readers at home. *Learn. Media Technol.* **2011**, *36*, 5–19. [CrossRef]
95. Jamshidifarsani, H.; Garbaya, S.; Lim, T.; Blazevic, P.; Ritchie, J.M. Technology-based reading intervention programs for elementary grades: An analytical review. *Comput. Educ.* **2019**, *128*, 427–451. [CrossRef]
96. Ke, F.; Abras, T. Games for engaged learning of middle school children with special learning needs. *Br. J. Educ. Technol.* **2013**, *44*, 225–242. [CrossRef]

97. Ronimus, M.; Kujala, J.; Tolvanen, A.; Lyytinen, H. Children's engagement during digital game-based learning of reading: The effects of time, rewards, and challenge. *Comput. Educ.* **2014**, *71*, 237–246. [CrossRef]
98. Butler, D.L.; Winne, P.H. Feedback and self-regulated learning: A theoretical synthesis. *Rev. Educ. Res.* **1995**, *65*, 245–281. [CrossRef]
99. Hattie, J.; Timperley, H. The power of feedback. *Rev. Educ. Res.* **2007**, *77*, 81–112. [CrossRef]
100. Binaghi, G.; Guida, M. Psychoeducational strategies in school context to support students with specific learning disorders in a sample of children aged 6 to 16. In *Education and Technology Support for Children and Young Adults with ASD and Learning Disabilities*; IGI Global: Hershey, PA, USA, 2021; pp. 51–72.
101. Abu Bakar, N.A.; ChePa, N.; Sie-Yi, L.L. Criteria for the Dyslexic Games: A Systematic Literature Review. *J. Hum. Cent. Technol.* **2023**, *2*, 32–42. [CrossRef]
102. Shabbir, N.; Bhatti, Z.; Hakro, D.N. Serious Game User Interface Design Rules for dyslexic children. In Proceedings of the MACS 2019—13th International Conference on Mathematics, Actuarial Science, Computer Science and Statistics, Karachi, Pakistan, 14–15 December 2019; Volume 4, pp. 62–67.
103. Bhatti, Z.; Shabbir, N. Serious Game model for dyslexic children. *Sukkur IBA J. Comput. Math. Sci.* **2022**, *6*, 72–78. [CrossRef]
104. Bakar, S.N.S.A.; Mahamarowi, N.H.; Mustapha, S. Game-Based Learning as a Teaching and Learning Tool for Dyslexic Children. In Proceedings of the 2022 IEEE 10th Conference on Systems, Process Control (ICSPC), Malacca, Malaysia, 17 December 2022; pp. 50–55.
105. Charsky, D. From edutainment to serious games: A change in the use of game characteristics. *Games Cult.* **2010**, *5*, 177–198. [CrossRef]