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Systematic Review

A Systematic Literature Review of the Impact of Cognitive Stimulation Programs on Reading Skills in Children Aged between 6 and 12 Years Old

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Abstract: The scientific evidence regarding the possibility of transferring benefits derived from cognitive training focused on working memory and inhibitory control to reading skills in children aged 6 to 12 is inconclusive. This study carries out a systematic review of recent published studies on this topic with the aim of analysing the specific role of various cognitive stimulation programs in the growth of executive functions and reading performance in children from ages 6 to 12. Here, we present the main results reported in the most recent literature, where the impact of intervention programs on working memory and inhibitory control in children with typical development are analysed. Even though the effectiveness of executive function training programs in terms of close transfer is conspicuous, there is still a lack of convergence in recently published articles, especially regarding the effects of far transfer in reading comprehension after cognitive stimulation programs are applied.

Keywords: executive functions; reading skills; cognitive training; working memory; inhibitory control

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1. Introduction

In recent years, there has been growing interest in modulating different cognitive skills, such as executive functions, based on training programs in populations with diverse qualities and characteristics. However, a lack of consensus regarding the effectiveness of the applied programs can be observed, as outcomes vary based on the type of population, stimulated abilities, and intervention duration, among other factors. For this reason, this review performs an exhaustive analysis of the impact of different executive function training programs in populations without any type of neurodevelopmental difficulty or disorder.

1.1. Definition of Executive Functions

Executive functions are defined as a sequence of higher cognitive processes, such as working memory, inhibitory control, or cognitive flexibility [1,2]. Their neural correlates primarily take place in the prefrontal cortex [1,3,4] and, to a lesser extent, in the basal ganglia and cerebellum [1,5–7].

Working memory has been conceptualized as a cognitive process that involves the storage of a limited amount of information, while the same or other additional information is managed and/or manipulated [8–11]. According to Baddeley [9,10], this executive function is composed of three levels: a central component responsible for processing manipulated information, and two other components, one verbal and one visuospatial, derived from the central component [1,12,13].

Inhibitory control is defined as the ability to control and suppress inappropriate, distracting, or irrelevant responses to certain stimuli, as well as thoughts and emotions.

Thus, inhibitory control contributes to the development of other complex processes, such as reasoning, attentional capacity, planning, or problem-solving [12,14].

Cognitive flexibility refers to the ability to adapt easily to changing mental demands, goals, thoughts, and perspectives, and to change between activities that are being implemented. This executive function allows the confronting of new challenges when they arise unexpectedly, which in turn permits learning from mistakes [15–20].

These executive functions are crucial for performing simultaneous tasks aimed at achieving a specific goal, autonomously and independently [21]. Therefore, they can act as strong predictors of academic skills [9,22–26] and reading abilities [15,27–33]. However, it is worth noting that some authors claim that the relationship between cognitive flexibility and reading abilities might be less consistent than the associations between working memory, inhibitory control, and reading performance [16–18,34].

Consequently, the idea that executive functions, such as working memory and inhibitory control, can be trained by different cognitive stimulation programs has gained interest in recent years [22,35–40], especially because the impact of cognitive training of working memory and inhibitory control extends beyond executive functions, benefiting complex tasks and activities in the educational context, where executive functions play a crucial role [41–45]. Similarly, deficits in working memory [31,45–51] and inhibitory control [50,52] are associated with low academic performance. Therefore, difficulties in working memory and inhibitory control, as well as the underlying learning difficulties, could potentially be compensated for through cognitive training [53].

1.2. Definition of Reading Skills

Reading involves several sets of skills that must be mastered to achieve a successful level in said ability.

Grapheme-to-phoneme conversion, also known as decoding, is the root of reading and the defining ability of a reader's phonological skills. To master it, prereaders must assimilate, understand, and manipulate the correspondence between a given letter and the phoneme it represents [54,55], thus allowing for visual recognition of words [56]. Consequently, phonological awareness and letter identification in the early stages are considered one of the first predictors of reading skills development [24,54,55,57]. Specifically, the speed and accuracy of letter naming and phonological awareness shown by 5-year-olds can function as strong predictors of word reading at 6–7 years of age [57]. Authors such as De la Calle [58] find that, while word naming speed has a greater influence on the reading speed of 6-year-old children, phonological awareness is more involved in the accuracy demonstrated by these participants.

Reading fluency is defined as the ability to recognise words appropriately, with expression, intonation, and pacing appropriate to the text being read [59]. This skill unequivocally contributes to reading comprehension in children and adolescents [60,61]. However, reading fluency is not considered a strong predictor of reading comprehension [60,62,63]. This is due to the influence of numerous additional factors involved in reading comprehension, such as the content and characteristics of the text, or the syntactic, semantic, and pragmatic context in which the words or sentences are located [64].

Reading comprehension involves different coordinated and coherent complex cognitive processes that integrate the information received [56,65–69]. On the one hand, the reader must recognise the letters that compose each word of the text and the syntactic structure to which it belongs, and then extract the meaning from their mental lexicon [54,56,60,65–67,69,70]. On the other hand, readers have a requirement to construct a mental representation of the information they are reading, incorporate this information into their prior knowledge, and thus make inferences about the content of the text [54,56,65–69,71].

To achieve this, two main routes or pathways of word recognition and reading can be distinguished [55,56,72]. The initial route for prereaders and beginner readers is known as the sub-lexical pathway, and it is linked to the grapheme–phoneme conversion rules [55].

Once the sub-lexical pathway is developed and automatized, the lexical pathway is responsible for connecting the global spelling of known words with the reader's internal representation and meaning of that word, accelerating the processes of reading words and sentences [55,56,72]. However, even if the reader has reached a high level of automatized word recognition via the lexical pathway during reading, the sub-lexical pathway is still essential for the development of any reading activity, complementing the lexical pathway [55]. Therefore, when the reader is confronted with an unfamiliar or unusual word, or a pseudo-word, they require the use of the sub-lexical pathway to decompose the letters that compose the word [55,56,72].

From the developmental perspective, the first stages of reading acquisition are conditioned by the cognitive and psychological maturation of children [54,73]. However, it is important to note that, in languages based on the Latin alphabet, the knowledge and identification of letters are usually developed between the ages of 3 and 6 [54,57]. This period demands high levels of focused spatial attention, making the progressive decoding of letters a cognitively challenging task [72]. Likewise, phonological awareness and decoding are usually consolidated at around 8 and 9 years of age, a period in which children can apply the mechanisms of grapheme–phoneme conversion automatically, so that they no longer need complex cognitive strategies or highly demanding attention requirements to recognise the letters that make up the word [60,61,66,67]. From this period onwards, children move into a new period of development focused on the acquisition of richer vocabulary, while speed, accuracy, reading fluency, and ultimately comprehension are also trained. Therefore, some authors describe this period as the transition from learning to read to learning to comprehend [60], since reading words accurately and automatically allows for greater cognitive involvement in the processes of constructing meaning [61].

1.3. Role of Executive Functions in Reading

Working memory abilities, both central [29,74,75], verbal [76,77], and visuospatial [48,78,79], are significantly related to the multiple processes of literacy and text comprehension that children acquire and develop. For instance, reading speed may be relevant for visual word processing, to pronounce syllables and phonemes while temporarily storing new words from the text, and to be able to combine this information with the context and thus achieve text comprehension [24,32,80,81].

Similarly, the components of inhibitory control and attention are responsible for focusing on the letters appearing in the text, inhibiting irrelevant information from the text and from the reader's immediate environment, so that proficient reading accuracy and final text comprehension can be achieved [14,81–86].

Consequently, and considering the central role that reading plays in academic development, it is not surprising that inhibitory skills and working memory exhibit a positive relationship with academic performance [12,22,26,32,47,51,77,87,88]. Additionally, a relationship has been observed between poor performance on tasks requiring executive functions management and academic and learning difficulties [89,90], and vice versa [91].

1.4. Training of Executive Functions and Effects on Reading Skills

Given the above reported relationships between working memory, inhibitory control, and different types of reading skills, such as phonological processes [92,93], lexical processes [94,95], morpho-syntactic processes [93], reading fluency [60], or comprehension of written texts [17,60], numerous studies have recently explored whether the potential benefits of executive function training can also be transferred to other untrained skills of interest, such as academic skills and reading [22,35,36].

Authors such as Melby-Lervag et al. [35,36], Sala and Gobet [37], Shipstead et al. [96], and Simons et al. [39], following Mayer [97], categorize the effects derived from cognitive stimulation programs into two types of transfer. On the one hand, they define near transfer as the effects found in untrained cognitive processes that are underlying and closely related to trained skills. On the other hand, far transfer refers to post-training effects found in tasks tapping into skills that were not directly trained.

As an example of the latter, some studies find benefits in reading skills in typically developing children after receiving training in working memory or inhibitory control [15,31,98–101]. However, there is a discrepancy in the findings, as authors such as Astle et al. [102], Dunning et al. [42], Hardy et al. [103], and Roberts et al. [104] claim that executive function stimulation interventions do not show far transfer effects on reading comprehension or on other skills necessary to achieve this comprehension effectively, such as word decoding [37] or reading accuracy [48,81] and reading fluency [33,81,103].

1.5. The Present Study

Multiple reviews and meta-analyses have been released in the past few years, reporting the associations between executive functions and reading abilities, as well as the impact of various training programs on these skills. Specifically, these reviews have focused on the relationships between executive functions and reading skills in typically developing children [16,32,49,87,90,105], as well as the associations between executive functions and reading abilities in children with learning difficulties [17,89] and/or neuropsychological disorders [17,106]. Similarly, various review studies address the impact of working memory training on the reading performance of children and adolescents [18,22,35–38,107], the effects of reading skills training on executive functions [108], and the outcomes of mixed interventions targeting both working memory and reading skills on these abilities [109].

However, to the best of our knowledge, no recent study has examined the impact of working memory and inhibitory control training on reading skills in children without any type of difficulty and/or neurodevelopmental disorder. Thus, the main objective of this review is to examine and analyse the scientific literature published in the last 6 years regarding the impact of cognitive stimulation programs on the development of working memory and/or inhibitory control, and the potential transfers that may be observed to reading skills in children aged 6 to 12 years, globally and comprehensively.

2. Materials and Methods

2.1. Sample

This review study was conducted following the criteria described by Moher et al. [110] in Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA, cited by Aksayli [22]; Conesa et al. [111]; Melby-Lervag et al. [35,36]; Sala and Gobet [37,38]. Of the 3567 studies published between 2017 and 2022 in *Web of Science* [112], *Scopus* [113], and *ERIC* [114], a total of 16 were selected, all of them indexed in *Web of Science* [112], because of redundancy with other databases (see Figure 1 for a detailed description following a PRISMA flowchart).

2.2. Procedure and Analysis

Different key concepts were collected for the search in different thesauri, resulting in the search strategy with the following terms: (read* OR comprehension) AND ("execut* function*" OR "execut* control" OR "cogniti* skill*" OR "cogniti* function*" OR "cogniti* abilit*" OR "cogniti* control" OR "inhibit* control" OR inhibit* OR "self-regulat*" OR "working memory" OR "operat* memory") AND (child* OR "school age*" OR "early ages" OR adolescent* OR teen*) AND ("training" OR "intervention").

With this search strategy, between November and December 2022, a total of 3567 English-language papers published in the last 6 years were found: 1333 studies indexed in the *Web of Science* database [112], 894 in *Scopus* [113], and 1340 in *ERIC* [114]. These studies were incorporated into a shared folder from the *Google Drive* platform, so that all authors were able to review and manage the incorporated research papers.

Subsequently, the inclusion principles were elaborated by all authors following the PICO model described by Booth [115] for population, intervention, comparison, and outcomes. Participants in this study had to be children aged 6 to 12 years attending elementary (primary) school with typical development. This age range was chosen because, although executive functions develop throughout life [28,116], during this period there is an observable cognitive growth and frontal lobe activity in children [117,118], which gradually decreases later [82,119,120]. Similarly, it is also the approximate age at which children have developed the cognitive skills necessary to make sense of grapho-phonetic decoding and manage it automatically, so it is recommended to start the reading acquisition process in this period, always considering the maturational and neuropsychological development of children [108,121]. In addition, as inclusion criteria, we only considered peer-reviewed and empirical studies that addressed an active intervention in working memory and/or inhibitory control, and collected specific measures focused on the evaluation related to children's reading skills.

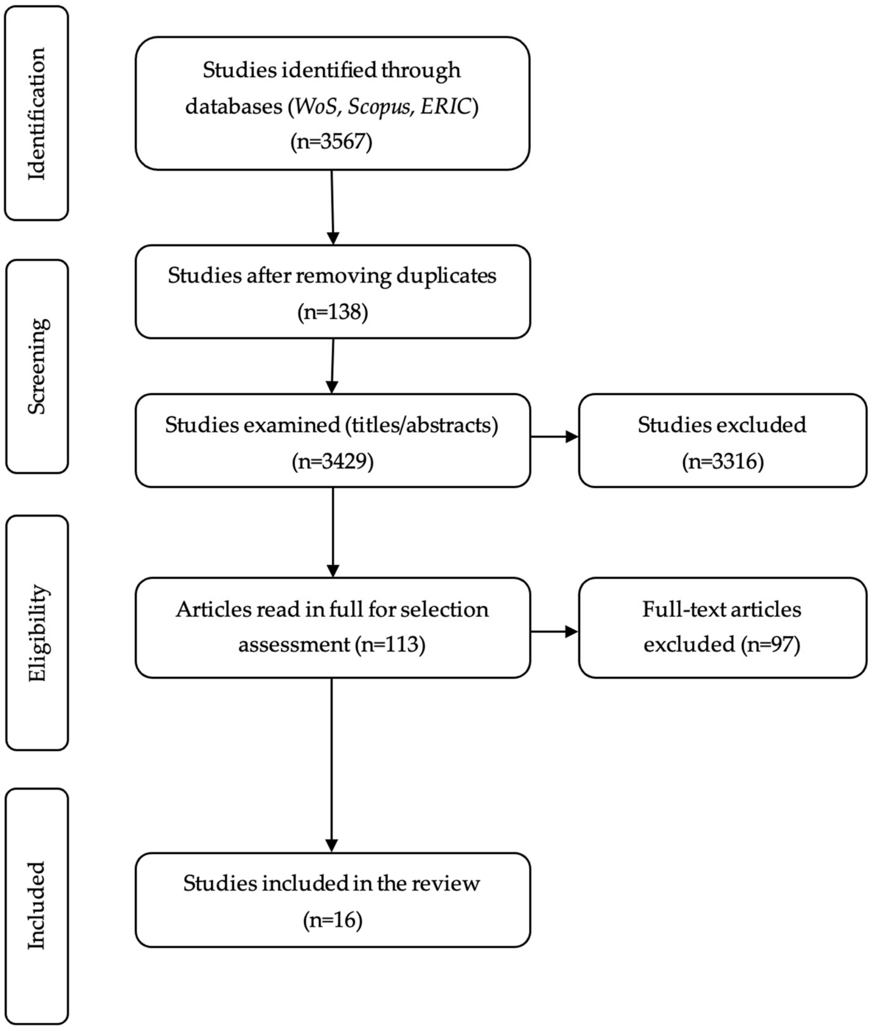

Figure 1. Flowchart for systematic reviews and meta-analysis following the PRISMA guidelines.

Following removal of duplicates ($n = 138$), in the next step of the review, titles, abstracts, keywords, and the full text of the found studies were thoroughly and independently read by two authors (CR-R and EA), excluding those that did not meet the selected inclusion and exclusion criteria ($n = 3413$). Discrepancies regarding the inclusion or exclusion of the selected studies were discussed with a third author (JAD), who confirmed the final selection of the selected studies. Additionally, the bibliographic references included in the selected works were reviewed for the possibility of including new studies, although all those that met the inclusion criteria were previously selected. Therefore, the final compilation of articles for this review consisted of 16 experimental or quasi-experimental quantitative studies indexed in *Web of Science* [112].

Finally, the selected studies were categorized and coded in data sheets using Microsoft Excel [122] and IBM SPSS version 22 [123]. The data were organized according to the following categories: methodological variables, linked to the sample sizes of the selected studies and the instruments used for data collection; temporal and demographic variables, addressing the publication year of each article and the country in which each study was conducted; and categorical variables, related to the main findings found, which were coded based on the type of intervention and training tasks performed by the participants, as well as the type of transfer found after the interventions.

3. Results

Following the method described in the previous section, a total of 16 articles were selected, six of which implemented training in verbal and visuospatial working memory [44,53,124–127], one focused on verbal working memory interventions [33], two specifically targeted visuospatial working memory development [34,128], and two stimulated central working memory or did not specify the specific working memory skill they targeted [70,129]. It is noteworthy that two studies conducted combined training of working memory, inhibitory control, and cognitive flexibility [130] or working memory and inhibitory control [19], and only one of the selected studies addressed inhibitory control training individually [34]. Similarly, two of the selected studies carried out combined training of executive functions and reading processes simultaneously [62,71], while only one combined training in working memory with mathematical skills [101]. Finally, 13 of the selected studies opted for a quasi-experimental design, while only three studies followed an experimental design, which can ensure greater internal validity [131].

3.1. Measurement Instruments

3.1.1. Measurement of Executive Functions

Measurement of working memory: Different assessment instruments for working memory were identified in the selected studies, such as the *Wechsler Intelligence Scale for Children* (WISC) [132–135] or the *Automated Working Memory Assessment* (AWMA) developed by Alloway [136].

The WISC scale, designed for children aged 6 to 16 [137,138], was used in four of the 12 selected studies that assessed working memory [53,101,126,129]. It has been adapted to different formats and translated into different languages [139–143]. This scale includes 10 primary subtests and seven secondary subtests in its latest edition, with a reliability index ranging from 0.86 to 0.95 and a validity coefficient ranging from 0.65 to 0.89 [137,144]. The most commonly used WISC tasks in recent years for working memory assessment are *Digit Span* [53,101,126,129], a test that requires the repetition of number sequences in the same order (short-term memory) or in reverse order (working memory), with a test–retest reliability coefficient of 0.83 in its fourth edition [129]; *Visuospatial Span* [53], where a sequence of blocks is presented, and children are asked to repeat the sequence in the same order (short-term memory) or in reverse order (working memory), with a test–retest reliability of 0.87 [103,145]; and *Letter-Number Sequencing* [53,129], where a sequence of numbers and letters is presented, and participants must first recall the numbers in ascending order and then the letters in alphabetical order, with a test–retest reliability of 0.83 [129].

Measurement of inhibitory control: Regarding the instruments used in the five studies assessing inhibitory control, the Stroop colour-word interference test [146] or similar tests [34,53,62] was one of the most commonly employed. In this test, colour names are presented under congruent conditions (the written word matches the colour of the ink, such as the word “red” in red ink) and incongruent conditions (words appear written in a different colour, for example, the word “blue” written in red), requiring the participant either to read the written word or to name the colour in which the word is written, ignoring what is written. The difference in reaction time in both conditions is considered an index of inhibitory skills [52,147–150]. The Go/NoGo, which is widely used [34,101], involves participants pressing a button when presented with a specific target stimulus among a set of 10 stimuli, while refraining from pressing the button when presented with a non-target stimulus [101]. A variant of this test is the Stop Signal task, which requires pressing a key to the right or left in response to a green circle appearing on the right or left side of the screen and refraining from pressing any key when the circle appears in red [53].

3.1.2. Measurement of Reading Skills

Significant heterogeneity was identified in the assessment batteries and scales employed by the authors of the selected studies. One of the two articles that investigated reading accuracy assessment [62,101] used the *Test of Word Reading Efficiency* (TOWRE) [62], developed by Torgesen et al. [151], and intended for participants aged 6 to 18 years with a Cronbach's alpha above 0.70. This test provides reliability ranging from 0.89 to 0.97 depending on the age of the participants evaluated [125,152]. The remaining study used the *Revised Battery for the Assessment of Reading Processes* (Batería de Evaluación de los Procesos Lectores, Revisada, PROLEC-R, in Spanish) [101], designed by Cuetos et al. [56], applicable to children aged 6 to 12 years for the measurement of children's reading processes, yielding a Cronbach's alpha of 0.79.

In addition, of the 16 articles composing this review, 6 of them measured reading speed [19,34] and reading fluency [19,33,62,125,128]. Although no battery for speed and/or fluency reading stands out in this selection, Ralph et al. [125] employed the reading fluency subtask of the TOWRE test, mentioned above. The said test was also used in one of the studies [62] to assess phonological awareness, a skill evaluated in 3 of the 16 studies in this review [33,62,101]. Specifically, the PROLEC-R battery [101], the TOWRE test [62], or tasks designed specifically by the authors for the study [33] were used.

Finally, reading comprehension was the most notable variable in this sample, as it was assessed in 13 of the 16 selected articles [19,34,44,53,62,70,71,124–127,129,130]. Although in this case no specific battery stands out in terms of frequency of use within the selected articles, it is noteworthy for its high internal consistency the use of several tests. On the one hand, the *Wechsler Individual Achievement Test* (WIAT-II), employed by Jones et al. [44] in this review and designed by Wechsler [153], allows the assessment of academic performance in individuals aged 4 to 85 years with a test–retest reliability ranging between 0.85 and 0.98, depending on the age of the participants evaluated. On the other hand, the *Test of Reading Comprehension for Students in 1st to 6th grade* (Ein Leseverständnistest für Erst-bis Sechstklässler ELFE 1–6) [154], used by Johann and Karbach [34], reports a total Cronbach's alpha between 0.91 and 0.97 based on the sub-scales of word comprehension, sentence comprehension, and text comprehension, in addition to reading speed. Finally, the *Progressive Linguistic Complexity Test* (CLP) by Alliende et al. [64] was implemented in the study by Reina-Reina et al. [130] for measuring reading comprehension, reporting a Cronbach's alpha of 0.97.

3.2. Transfer of Working Memory Intervention

Eleven publications focused on the cognitive stimulation of working memory, as described in Table 1, and two were conducted in Argentina, while the rest were from other countries, including: Germany (n = 1); Australia (n = 1); Brazil (n = 1); China (n = 1); Denmark (n = 1); United States (n = 1); Italy (n = 1); United Kingdom (n = 1); and Sweden (n = 1). Concerning sample sizes, only three of these articles exceeded 100 participants, four had between 50 and 99 participants, and the rest had samples ranging from 7 to 47 children and adolescents. Moreover, eight of these studies implemented training in classrooms or educational centres, two carried out stimulation programs in the children's homes, and one conducted intervention in psychological laboratories or clinics. Table 1 presents in detail the characteristics of the sample of participants in each of the studies, as well as the research design, assessment instruments used, intervention location, duration, frequency, and conditions of training, as well as the results obtained by the authors, fidelity indicators, and effect size of the interventions.

Table 1. Studies illustrating the impact on near and far transfer of working memory training.

Authors, Year	Participants	Design	Assessment Instruments	Training EF	Intervention Location	Training Conditions	Representative Findings Evidence	Little Evidence
Artuso et al. [70]	62 Italian children, *AR* = 9–10 years; *M* = 9.5 years.	CE PRE–I–POST	Adaptation of RMT [155]; Tasks designed by the authors to measure working memory; BIRT [156].	Training focused on (UWM) was designed by the authors.	School	20 sessions of 50 min each, for 4 weeks.	Benefits of WMT on UWM + RC (F (2,69) = 4.14, p = 0.02, η_p^2 = 0.11, d = 0.80) and RC (F (2,69) = 6.31, p = 0.003, η_p^2 = 0.16, d = 0.60) in POST, compared with PG.	There were no benefits of WMT on UWM in POST, compared with PG.
Hitchcock and Westwell [129]	148 Australian children, *AR* = 10.58–13.50 years; *M* = 12.25 years.	CE PRE–I–POST–FU	WISC-IV [132]; PAT-R [157].	CogMed [158].	School	45-min sessions, 5 times per week, for 5 weeks.	-	There were no benefits of WMT on VWM or RC in POST, or at 3 months FU, compared with PG and CG.
Johann and Karbach [34]	152 German children, *AR* = 8–11 years; *M* = 9.56 years.	E PRE–I–POST– FU	N-back task [159]; Spatial Span task [160]; Complex Span task [100]; ELFE 1–6 [154].	NeuroNation [161].	Home	21 sessions of 30 min, 3–5 times per week, for 4 weeks.	Benefits of game-based WMT on VWM (F (1, 62) = 6.58, $p < 0.05$, η_p^2 = 0.10, d = 0.87) and VSWM (F(1, 64) = 6.91, $p < 0.05$, η_p^2 = 0.10, d = 1.06) in POST, and on VSWM (F(1, 60) = 6.31, $p < 0.05$, ηp^2 = 0.10, d = 0.95) at 3 months FU, compared with CG.	There were no benefits of game-based WMT on RS or RC in POST, or on VWM, RS or RC at 3 months FU, compared with CG.
							Benefits of standard WMT on VWM (F (1, 62) = 4.79, $p < 0.05$, η_p^2 = 0.07, d = 0.92) in POST, and on VWM (F (1, 59) = 5.12, $p < 0.05$, η_p^2 = 0.08, d = 1.21) and VSWM (F (1, 60) = 6.31, $p < 0.05$, η_p^2 = 0.10, d = 1.04) at 3 months FU, compared CG.	There were no benefits of standard WMT on VSWM, RS or RC in POST, and on RS or RC at 3 months FU, compared with CG.
Jones et al. [44]	95 English children, *AR* = 9–14 years; *M* = 12.51 years.	CE PRE–I–POST– FU	AWMA [136]; WIAT [153].	CogMed [158].	School	20–25 sessions of 45 min each, 5 times a week, for 6–7 weeks.	Benefits of WMT on WM ($p < 0.001$) in POST, and WM (p = 0.04) at 3 months FU, compared with PG.	There were no benefits of WMT on RC in POST, or at 3 months FU, compared with PG.
Lopez and Aran [53]	20 Argentine children, *AR* = 6 years; *M* = 6.20 years.	CE PRE–I–POST	WISC-IV [133]; n-back task [162]; TMT [163]; Stroop task [164].	CogMed [158].	School	20–25 sessions, 5 times a week, for 3 months.	Benefits of WMT on VWM (p = 0.001), VSWM (p = 0.001), and UWM (p = 0.00) in POST, compared with CG.	There were no benefits of WMT on IC or RC in POST, compared with CG.
Novaes et al. [124]	43 Brazilian children with typical development or reading comprehension difficulties, *AR* = 8–10 years; *M* = n/s.	E PRE–I–POST	TCCAL–Let [165]; TDE [166].	Training focused on WM was designed by the authors.	School	15 sessions of 1 h each, twice a week, for 2 months.		There were no benefits of WMT on RC in POST in typically developing children.
Ralph et al. [125]	101 American children, *AR* = 10–13 years; *M*= n/s.	E PRE–I–POST– FU	MAP [167,168]; TOWRE [151].	CogMed [158].	Home	25 sessions of 30–45 min each, 5 times a week, for 5 weeks.	-	There were no benefits of WMT on RF or RC in POST, or at 6 months FU, compared with PG.
Siu et al. [33]	37 Chinese children, *AR* = 7–8 years; *M* = 7.5 years.	E PRE–I–POST	Tasks were designed by the authors to measure RF; Tasks used in previous studies to measure VWM [169,170].	Training focused on WMT was designed by the authors.	Home/University laboratory.	Sessions of 30 min, 4 times per week at home + one session of 60 min each, once a week in the laboratory, for 8 weeks.	Benefits of WMT on Chinese VWM (t (9) = −2.3, $p < 0.05$) English VWM (t (12) = −2.91, $p < 0.05$), and Chinese RF (t (9) = −7.58, $p < 0.001$; t (9) = −4.05, $p < 0.001$) in POST, compared with CG.	There were no benefits of WMT on Chinese and English PS, or English RF in POST compared with CG.

Table 1. *Cont.*

Authors, Year	Participants	Design	Assessment Instruments	Training EF	Intervention Location	Training Conditions	Representative Findings Evidence	Little Evidence
Sondergaard and de Lopez [126]	38 Danish children, *AR* = 8.3–10.7 years; *M* = 9.4 years.	E PRE–I–POST– FU	WISC-IV [171]; Danish adaptation of CLPT [172,173]; Odd-One-Out task [174,175]; Sentence Reading Test (Sætningslæseprøve 2) [175].	Training focused on WMT was designed by the authors.	School	12 sessions of 10 min each, 3 times a week, for 4 weeks.	Benefits of WMT on VSWM (g = 0.52) in POST, compared with PG.	There were no benefits of WMT on VWM or RC in POST, or on VWM, VSWM or RC at 12 months FU, compared with PG.
Studer-Luethi et al. [128]	86 Swedish children, *AR* = 8–12 years; *M* = 10.1 years.	CE PRE–I–POST– FU	Backward Colour Recall task [176]; RLPD [177].	Training focused on VSWMT was designed by the authors.	School	17–18 sessions of 15 min each, 3 times a week, for 6 weeks.	Benefits of VSWMT on VSWM (Δ = 0.82, p = 0.038) in POST, compared with PG.	There were no benefits of VSWMT on RF in POST, compared with PG.
Vernucci et al. [127]	89 Argentine children, *AR* = 9–10 years; *M* = 9.52 years.	CE PRE–I–POST– FU	CSRT [178]; adaptation of AWMA [179]; Reading to Comprehend [180].	Training focused on WMT was designed by the authors.	School	10–13 sessions of 20 min each, twice a week, for 7 weeks.	Benefits of WMT on VWM ($p < 0.001$, d = 0.714) in POST, and on VWM ($p < 0.001$, d = 1.17) at 6 months FU, compared with PG.	There were no benefits of WMT on VSWM or RC in POST, or at 6 months FU, compared with PG.

Note: AR = Age Range; ARCCT = Auditory and Reading Comprehension Contrastive Test; AWMA = Automatized Working Memory Assessment; BIRT = Battery of Italian reading tests; CE = Quasi-experimental; CG = Control Group; CLPT = The Competing Language Processing Task; CSRT = Cognitive Self-regulation Tasks; E = Experimental; EF = Executive Functions; ELFE 1–6 = Reading Comprehension Test for First through Sixth Grades (*Ein Leseverständnistest für Erst—bis Sechstklässler*); FU = Follow-up; IC = Inhibitory Control; I = Intervention; M = Mean age; MAP = Measure of Academic Progress; n/s = Not specified; PAT-R = The Progressive Achievement Test in Reading); PG = Placebo Group; POST = Post-test; PRE = Pre-test; PS = Phonological Skills; RA = Reading Accuracy; RC = Reading Comprehension; RF = Reading Fluency; RLPD = Reading Learning Progress Diagnostics: A Curriculum-based Procedure (*Lernfortschrittsdiagnostik Lesen: ein curriculumbasiertes Verfahren*); RMT = Running Memory Task; RS = Reading Speed; RSCT = Reading Speed and Comprehension Task; SPT = School Performance Test; SST = Stop Signal Task; TMT = Trail Making Test; TOWRE = Test of Word Reading Efficiency; UWM = Updating Working Memory; VSWMT = Visuospatial Working Memory Training; VSWM = Visuospatial Working Memory; VWM = Verbal Working Memory; VWMT = Verbal Working Memory Training; WIAT-II = Wechsler Individual Achievement Test, 2^{sd} Edition; WISC = Wechsler Intelligence Scale for Children; WM = Working Memory; WMT = Working Memory Training; WPT = Words and Pseudowords Task.

These interventions varied in their findings: authors such as Artuso et al. [70], Johann and Karbach [31], Jones et al. [44], Lopez and Aran [53], Studer-Luethi et al. [128], and Vernucci et al. [127] found near-transfer benefits of computer-based working memory training on tasks assessing verbal and visuospatial working memory both immediately after training, with moderate (d = 0.52–0.714) [126,127] and large effect sizes (d = 0.80–1.21) [31,70], and 3 months [34,44] or 6 months after training [127]. In fact, some authors who explored the effect size of the results they obtained after training detailed how the benefits of training turn from moderate (d = 0.714) to large (d = 0.819) in the follow-up measure [127]. The opposite is the case in the study by Studer-Luethi et al. [128], as the results gradually decreased with the different training measures applied. On the other hand, Sondergaard and de Lopez [126] implemented a non-computerized, face-to-face intervention aimed at developing verbal and visuospatial working memory capacities, finding effects only in visuospatial working memory measures right after training, with a moderate effect size (g = 0.52), which did not persist 12 months after the intervention (d = 0.15). Siu et al. [33] implemented a more specific intervention, focusing only on verbal working memory, obtaining benefits in these abilities. However, studies such as those conducted by Hitchcock and Westwell [129] or Novaes et al. [124] did not find any effect on working memory compared to the control group or the placebo program, despite implementing interventions of similar duration to the previous studies.

When analysing the 11 selected studies implementing interventions focused on working memory stimulation, only one explored far-transfer effects on inhibitory control [53]. However, these authors did not find post-training transfer effects on this variable.

Similarly, of the four articles reviewing reading speed and fluency, only Siu et al. [33] reported gains after the intervention. In contrast, no significant differences were found after training in reading fluency or speed in three articles [34,124,125,128].

However, some authors did not calculate the concrete effect size of the training implemented, so the measures obtained were based exclusively on the psychometric evaluations applied [33,44,53,124,129].

Finally, it is worth noting that a considerable number of studies investigated the transfer to reading comprehension post-training, as this variable was considered in nine of the selected articles. Indeed, the transfer of working memory training to reading comprehension has been found in some articles [70], with a moderate effect size (d = 0.60), but numerous studies fail to find significant post-training effect on this variable [34,44,53,124–127,129].

3.3. Transfer of Inhibitory Control Intervention

Of the studies that conducted a cognitive stimulation program aimed at inhibitory control development, only one of them did so exclusively [34], as detailed in Table 2. This study was conducted in Germany, with 152 children who participated from home. Table 2 presents in detail the characteristics of the sample of participants in each of the studies, as well as the research design, assessment instruments used, intervention location, duration, frequency, and conditions of training, as well as the results obtained by the authors, fidelity indicators and effect size of the interventions.

In this research, the impact of a game-based inhibitory control training program was compared with that of a standard intervention in typically developing children. Both interventions show a significant impact on both trained and untrained measures of inhibitory control, with a large effect size (d = 1.09–2.47). However, only the children who participated in the game-based training showed differences compared to the control group in reading speed after training (d = 0.58), as well as in reading speed (d = 1.09) and sentence comprehension (d = 0.63) 3 months after training. Notably, the reading speed performance of children who participated in the game-based inhibitory control training significantly increased 3 months after the intervention, with large effect size benefits [34].

Table 2. Studies illustrating the impact on near and far transfer of inhibitory control.

Authors, Year	Participants	Design	Assessment Instruments	Training EF	Intervention Location	Training Conditions	Representative Findings Evidence	Representative Findings Little Evidence
Johann and Karbach [34]	152 German children, AR = 8–11 years; *M* = 9.56 years.	E PRE–I–POST–FU	Go/noGo task [181]; Flanker task [182]; Stroop-like task [52]; ELFE 1–6 [154].	NeuroNation [161].	Home	21 sessions of 30 min each, 3–5 times per week, for 4 weeks.	Benefits of game-based ICT on IC ($F(1, 58) = 7.01$; $p < 0.05$, $\eta_p^2 = 0.12$, $d = 2.04$; $F(1, 56) = 13.75$; $p < 0.001$, $\eta_p^2 = 0.20$, $d = 2.19$; ($F(1, 143) = 35.10$; $p < 0.001$, $\eta_p^2 = 0.20$, $d = 1.83$) and RF ($F(1, 137) = 5.35$; $p < 0.05$, $\eta_p^2 = 0.04$, $d = 0.58$) in POST, and on IC ($F(1, 56) = 7.66$; $p < 0.01$, $\eta_p^2 = 0.12$, $d = 2.47$; $F(1, 55) = 8.37$; $p < 0.01$, $\eta_p^2 = 0.13$, $d = 1.91$; ($F(1, 135) = 12.39$; $p < 0.01$, $\eta_p^2 = 0.08$, $d = 1.77$), RF ($F(1, 128) = 4.21$; $p < 0.05$, $\eta_p^2 = 0.03$, $d = 1.09$), and on RC ($F(1, 138) = 4.56$; $p < 0.05$, $\eta_p^2 = 0.03$, $d = 0.63$) at 3 months FU, compared with CG.	There were no benefits of game-based ICT on RC in POST, compared with CG.
							Benefits of standard ICT in IC ($F(1, 58) = 13.64$; $p < 0.001$, $\eta_p^2 = 0.20$, $d = 1.77$; ($F(1, 143) = 13.20$; $p < 0.001$, $\eta_p^2 = 0.09$, $d = 1.68$) in POST, and on IC ($F(1,56) = 5.21$; $p < 0.05$, $\eta_p^2 = 0.09$, $d = 1.78$; $F(1, 135) = 5.21$; $p < 0.05$, $\eta_p^2 = 0.04$, $d = 1.80$) at 3 months FU, compared with CG.	There were no benefits of standard ICT on RF or RC, in POST and at 3 months FU, compared with CG.

Note: AR = Age Range; E = Experimental; EF = Executive functions; ELFE 1–6 = Reading comprehension test for first through sixth grades (Prueba de comprensión lectora para estudiantes de 1° a 6° grado—*Ein Leseverständnistest für Erst—bis Sechstklässler*); FU = Follow-up; I = Intervention; IC = Inhibitory Control; ICT = Inhibitory Control Training; M = Mean age; PG = Placebo Group; POST = post-test; PRE = pre-test; RC = Reading Comprehension; RF = Reading Fluency.

3.4. Transfer of Combined Working Memory and Inhibitory Control Intervention

Of the retrieved articles, only two focused on the combined training of working memory and inhibitory control, as indicated in Table 3. These studies were conducted in Brazil (n = 1) and Spain (n = 1), both with a sample size exceeding 100 participants, who performed the intervention in their classrooms and educational centres. Table 3 presents in detail the characteristics of the sample of participants in each of the studies, the research design, assessment instruments used, intervention location, duration, frequency, and conditions of training, as well as the results obtained by the authors, fidelity indicators, and effect size of the interventions.

As a result of the implementation of these mixed training programs, positive results in near-transfer effects can be observed, reporting medium and large benefits after training in verbal working memory (d = 0.53) and inhibitory control (d = 0.99) in children from disadvantaged socioeconomic contexts. However, the impact of this type of training does not transfer to visuospatial working memory abilities [19].

Far transfer can also be observed in these variables, as after-training improvements can be observed in reading speed and fluency in children from low socioeconomic contexts, with moderate effect sizes (d = 0.61), but not in children from high socioeconomic contexts [19]. Benefits in reading comprehension are also found [130], with moderate effect sizes ($\eta_p{}^2$ = 0.071), after a controlled intervention with a validated commercial computerized cognitive training platform (CogniFit Inc., San Francisco, CA, USA). However, Weissheimer et al. [19] did not find a significant impact of the training program on reading comprehension in children after training, regardless of the socioeconomic context of the participants.

In addition, Reina-Reina et al. [130] explored the inter-individual differences that participants showed after completing the computerized cognitive training. The only covariate that modulated the effect of intervention on executive functions was the age of the participants, indicating that the effects of training were more significant in the younger population.

3.5. Transfer of Combined Intervention in Executive Functions and Academic Skills

Finally, among the 16 empirical studies included in this review, three focused on combined training, stimulating executive functions, and either reading or mathematical skills, as described in Table 4. These studies were conducted in American (n = 1), Italian (n = 1), and Spanish (n = 1) populations. Additionally, two of these studies were implemented in the educational centres of the participants, and the remaining one conducted the training program in their homes. Table 4 presents in detail the characteristics of the sample of participants in each of the studies, as well as the research design, assessment instruments used, intervention location, duration, frequency, and conditions of training, as well as the results obtained by the authors, fidelity indicators, and effect size of the interventions.

Carretti et al. [71] and Horowitz-Kraus et al. [62] explored the near-transfer effects post-training of a program aimed at developing working memory and reading comprehension, as well as a similar program combined with phonological-based training. After the implementation of these interventions, near-transfer effects are observed in both variables after the intervention [62,71], as well as 2 months after this implementation [71].

Similarly, children who participated in a training program for working memory and mathematical skills in the study by Sanchez-Perez et al. [101] showed an increase in inhibitory control scores obtained after training.

Table 3. Studies illustrating the impact on near and far transfer of combined training of working memory and inhibitory control.

Authors, Year	Participants	Design	Assessment Instruments	Training EF	Intervention Location	Training Conditions	Representative Findings: Evidence	Representative Findings: Little Evidence
Reina-Reina et al. [130]	196 Spanish children, AR = 9–12 years; *M* = 9.9 years.	CE I–POST	CLP [64,183]; Spanish academic curriculum [184].	CogniFit Inc. [185].	School	Sessions of 15–20 min each, 3–4 times per week, for 8 weeks.	Benefits of EFE on CL (F (1, 190) = 14.61, $p < 0.001$, $\eta_p^2 = 0.071$) in POST.	-
Weissheimer et al. [19]	121 Brazilian children, AR = 8–10 years; *M* = n/s.	CE PRE–I–POST–FU	Adaptation of the n-back task (adaptation of Spatial Span task; Dogs and Monkeys task; Test d2 [186]; RSCT [187]; WPT [188].	Training focused on EFT was designed by the authors.	School	10 sessions of 20–25 min each, for 5–7 weeks.	Benefits of EFT on VWM (F (1, 55) = 6.865, $p = 0.011$, $d = 0.53$), IC (F (2, 210) = 5.374, $p = 0.024$, $d = 0.99$), RS (F (1, 120) = 6.022, $p = 0.029$, $d = 0.61$), in POST, and at 3 months FU, in children from low socioeconomic backgrounds compared with PG.	There were no benefits of EFT on VSWM, RF, or RC in POST, or at 3 months FU, in children from low socioeconomic backgrounds compared with PG. There were no benefits of EFT on VWM, VSWM, IC, RS, RF, or RC in POST, or at 3 months FU, in children from high socioeconomic backgrounds compared with PG.

Note: AR = Age Range; CE = Quasi-experimental; CLP = Progressive Linguistic Complexity Test (*Test de Complejidad Lingüística Progresiva*); EF = Executive Functions; EFT = Executive Functions Training; I = Intervention; M = Mean age; POST = post-test; PRE = pre-test; RC = Reading Comprehension; RF = Reading Fluency.

Table 4. Studies illustrating the impact on near and far transfer of combined training of executive functions and academic skills training.

Authors, Year	Participants	Design	Assessment Instruments	Training FE	Intervention Location	Training Conditions	Representative Findings: Evidence	Representative Findings: Little Evidence
Carretti et al. [71]	48 Italian children, AR = 8–9 years; *M* = 8.54 years.	CE PRE–I–POST–FU	Adaptation of UFRC [189]; DARC [190]; MTRA [191].	Italian adaptation of Garcia-Madruga et al. [192].	School	10 sessions of 40 min each, twice a week, for 5 weeks.	Benefits of WMT + RC on UWM ($p = 0.001$, $d = 1.14$) and RC ($d = 0.76$) in POST, and on WM ($p = 0.002$, $d = 1.49$) and RC ($d = 1.75$) at 2 months FU, compared to CG and PG.	-
Horowitz-Kraus et al. [62]	54 American children with reading difficulties, ADHD and reading difficulties, and typical development, *AR* = n/s; *M* = 9.76 years.	E PRE–I–POST	TOWRE-2 [151]; RAP [193]; GORT-III [194]; D-KEFS Stroop Task [147].	RAP [193].	Home	20 sessions of 15–20 min each, 5 times per week, for 4 weeks.	Benefits of EFT + RC on PP (t (18) = −0.721, $p = 0.480$), RA (t (18) = −6.727, $p < 0.001$; t (18) = −5.776, $p < 0.001$), and RF (t (18) = −4.574, $p < 0.001$) in POST.	There were no benefits of EFT + RC on IC or RC in POST.
Sanchez-Perez et al. [101]	104 Spanish children, *AR* = 7–12 years; *M* = 9.17 years.	CE PRE–I–POST	WISC-IV [133]; Dot Task [195]; Go/noGo task [196]; PROLEC-R [56].	Training focused on EFT + MT was designed by the authors.	School	30-min sessions each, twice a week, for 13 weeks.	Benefits of WMT + MT on IC (F (1,81) = 12.80, $p = 0.001$, $\eta_p^2 = 0.14$, $d = 0.61$), and RAS (F (1,86) = 9.76, $p = 0.002$, $\eta_p^2 = 0.10$, $d = 0.61$) in POST, compared to GC.	There were no benefits of WMT + MT on VWM in POST, compared to GC.

Note: ADHD = Attention Deficit Hyperactivity Disorder; AR = Age Range; CE = Quasi-experimental; CG = Control Group; DARC = Diagnostic Assessment of Reading Comprehension; D-KEFS = Delis-Kaplan Executive Function System; E = experimental; EF = Executive Functions; EFT = Executive Functions Training; FU = Follow-Up; GORT-III = Gray Oral Reading Test; I = Intervention; IC = Inhibitory Control; M = Mean age; MT = Mathematical Skills Training; MTRA = MT Test for reading assessment in the school; n/s = Not specified; PD = Phonological decoding; POST = post-test; PP = Phonological Processing; PRE = pre-test; PROLEC-R = Reading Process Assessment Battery—Revised (*Batería de Evaluación de los Procesos Lectores—R*); RA = Reading Accuracy; RAS = Reading skills; RAP = Reading Acceleration Program; RC = Reading Comprehension; RF = Reading Fluency; RS = Reading Speed; TOWRE = Test of Word Reading Efficiency; UFRC = Updating Following a Relevant Criterion; UWM = Updating Working Memory; VWM = Verbal Working Memory; WISC = Wechsler Intelligence Scale for Children; WM = Working Memory; WMT = Working Memory Training.

Regarding transfer to untrained skills, interventions focused on working memory and reading comprehension showed a positive impact on reading accuracy and fluency after training [62]. Additionally, Carretti et al. [71] confirmed the results obtained using Cohen's d [121]. Thus, the experimental group showed a medium effect (d = 0.76) on reading comprehension performance after training, which became large (d = 1.75) two months after the intervention. However, the active control group only showed a small effect size for these measures. On the other hand, although Horowitz-Kraus et al. [62] did not calculate effect sizes in their intervention results, they supported the measurements of cognitive assessments with neuroimaging evaluations. Thus, they reported that, although the three training groups—children with reading difficulties, participants with ADHD and reading difficulties, and the typically developing population—showed an increased activation of certain brain areas after training, the observed changes in the connectivity between neural circuits were different for each group. On the one hand, training had a direct positive effect on functional connectivity related to memory—para-hippocampal gyrus—and attention—right and left insula. On the other hand, children with reading difficulties only showed a post-training change in the neural circuits of the right and left insula, where attentional skills partially take place, although they did not show increased functional connectivity after training in brain areas related to executive functions, such as the right and left superior frontal lobe. Finally, participants with ADHD and reading difficulties demonstrated a post-training change in executive function related areas—right and left superior frontal gyrus—and in attention related neural circuits—right and left insula—that were more functionally connected [62].

Finally, it is noteworthy that children who collaborated in the study by Sanchez-Perez et al. [101], who participated in an intervention based on executive functions and mathematical skills, showed benefits in reading speed and accuracy after training. Although these authors did not calculate the effect size of the intervention on untrained skills, they applied several multiple linear regression analyses to test for specific effects of the training activities. In this way, they reported a significant contribution of the working memory component of the intervention, as opposed to the mathematical tasks in the training, to benefits in reading skills and inhibitory control in typically developing children who participated in the intervention [101].

4. Discussion

The main objective of this study was to examine and analyse the recent findings regarding the impact of working memory and/or inhibitory control stimulation in typically developing children aged 6 to 12 years, as well as the transfer of this type of training to untrained skills, such as reading abilities.

4.1. Working Memory Interventions

Recent studies evidence a positive impact of working memory training on trained cognitive skills [19,33,34,44,53,70,126–129]. These results are consistent with previous findings, in which near-transfer effects were observed after training in children between 6 and 12 years of age [31,48,99,100,102,104] and preschool-aged participants [42,197].

The transfer from working memory training to inhibitory control was not as evident. Recent studies have not reported such transfer in typically developing children [19,34,53], aligning with previous results in children with ADHD [100,197].

In fact, authors such as Butterfuss and Kendeou [17], Chang [61], Kieffer et al. [198], Klingberg et al. [199,200], Miyake et al. [2,20], and Roughan and Hadwin [201] justify that inhibitory control and working memory are reciprocally related. In other words, in working memory tasks, inhibitory control is necessary to filter out irrelevant information. Similarly, to maintain attention in a task, the working memory is necessary to retain the required information for task completion.

More specifically, the selected studies revealed gains from working memory training in phonological skills [33], reading accuracy or speed [19,33,124], and reading comprehension [70,124,125] in typically developing children. These findings are consistent with previous studies that have reported similar results [31,98,99], asserting the close relationship between working memory and reading [29,32,48,76,77].

Nevertheless, it is possible that there was a sleeper effect on reading skills [46,99,202], with benefits reported only in the long term, but not immediately after training. It is worth mentioning, however, that in the study by Ralph et al. [125] participants in the control group dropped out of the experiment after post-test evaluations. Given that reading exhibits a trajectory of gradual improvement, it is possible that the control groups in these studies would have also demonstrated these improvements in the follow-up phase [125].

Despite these findings, other recent intervention studies have reported that improvements are only observed in trained working memory tasks, but not in tasks that would not have been part of the intervention, such as reading skills [34,104,125] or reading comprehension [19,34,44,53,126,127,129]. These studies are in line with previous research conducted by Astle et al. [102], Dunning et al. [42], and Roberts et al. [101] (see also meta-analyses [35–38]).

The lack of convergence in the transfer of working memory training on reading performance is justified in some studies by the influence of the compensation effect [19,34,53,70,71,124,127,129], in which greater development of cognitive skills and reading performance is observed in children who presented poor performance before participating in the intervention [18,100,203–207]. This factor could also explain the absence of results in some meta-analyses that analysed participants as a group, making it difficult to observe the compensation effect, as seen in studies conducted by Melby-Lervag et al. [35,36], or Sala and Gobet [37,38].

Furthermore, the effectiveness of cognitive stimulation interventions on reading skills may be related to the use of linguistic materials [33]. Non-linguistic tools, such as digits, shapes, or images, used in some interventions here [19,44], do not promote an increase in post-training reading performance. Therefore, further research is needed to thoroughly examine the role of linguistic components in cognitive stimulation programs, as the presence of linguistic materials does not always predict a positive impact on verbal working memory or reading performance in children [35,126].

Another possible factor contributing to this lack of convergence may be attributed to the use of different reading comprehension assessment batteries. Measurement tools that incorporate images to guide responses may impose low cognitive demands, which might not allow researchers to observe the possible benefits of training [126]. In this regard, it has been argued that reading comprehension measurement tasks that require complex inferences about the text might also require cognitive capacities related to working memory [16,189,208].

Similarly, the relevance of participants' training times should be highlighted. Authors such as Jones et al. [44] and Sondergaard and de Lopez [126] report that participants' limited adherence to the intervention hampers the far transfer to skills related to inhibitory control and children's reading performance, in line with Hardy et al. [103], Klingberg et al. [199], Loosli et al. [31], or Thorell et al. [197]. These results also coincide with the established minimum threshold of at least 10 training sessions over a period of 5 to 8 weeks [103].

4.2. Inhibitory Control Interventions

Among the studies analysing the impact of inhibitory control stimulation programs in typically developing children, Johann and Karbach [34] compared the effects of gamified executive function training versus standard training. These authors concluded that both types of training impact the performance in trained and untrained inhibitory control tasks similarly, consistent with previous evidence [197,209].

However, no transfer of inhibitory control intervention to tasks related to working memory was found [34], in line with previous interventions [197]. Possibly, this lack of benefits may be due to the fact that gamified interventions necessarily include different tasks in each session, which may prevent transfer from one domain of executive function to another [210].

Regarding the far transfer of this type of stimulation program to reading skills, Johann and Karbach [34] found benefits of computerized inhibitory control training on reading speed in the short and long term. These results support findings showing the relationship between inhibitory control and phonological skills and decoding [16,211,212], reading fluency or accuracy [50,213], or reading comprehension [50,61,198].

In the case of Johann and Karbach's study [34], it is possible that there was also a sleeper effect on reading comprehension demonstrated by children after gamified training, since gains were only observed 3 months after the intervention, and not immediately [46,99,202].

Similarly, Johann and Karbach [34] observed a possible compensatory effect [18,19,71,100,129,203–207], as the analysed population with lower performance in pre-test measures demonstrated greater gains post-intervention.

Although the benefits of computerized inhibitory control stimulation can be observed in reading skills, these results have not been found in recent studies implementing standard cognitive interventions [34]. These findings are consistent with similar research in which executive functions were trained in isolation, limiting the transfer to other complex cognitive tasks such as reading [214]. In this sense, some authors argue that the use of gamified cognitive stimulation programs may increase the necessary cognitive demand and, therefore, facilitate distant transfer to academic skills [34].

Along the same lines, authors such as Diamond [215] and Roughan and Hadwin [201] report that there are some factors supporting the improvement of executive functions in cognitive interventions, such as perceived joy, feelings of social belonging, support, and self-efficacy experienced during training. These factors are related to increased adaptability, discipline, and concentration, which significantly increase in gamified stimulation compared to standard interventions. This could explain why only the game-based training group demonstrated better long-term reading speed performance compared to the standard training group or the control group.

4.3. Combined Interventions in Working Memory and Inhibitory Control

Regarding far transfer effects, children showed benefits in speed, fluency [19], and reading comprehension [130] after the intervention. These results align with prior studies that underscore the fundamental role of inhibitory control [50,213], attention [216], and working memory [31,207] in children's reading processes. In contrast to the results reported by Reina-Reina et al. [130] and Weissheimer et al. [19], no benefits were found for inhibitory control and reading comprehension after the applied intervention.

However, it is important to consider that participants from a more disadvantaged socioeconomic background demonstrate a greater impact of cognitive stimulation programs on executive functions and reading skills [19,130]. Interestingly, these results are in line with previous research conducted with children and adolescents, which explored the effects observed in participants of different socioeconomic status [217,218]. Together, these findings suggest that cognitive stimulation protocols may be effective in partially counteracting these social differences [101,219].

4.4. Combined Interventions in Executive Functions and Academic Skills

Several studies have also examined the impact of combined programs focused on the development of working memory and reading comprehension. Near transfers are present in trained skills in typically developing children [71], supporting previous contributions under similar conditions [192].

Similarly, these mixed working memory and reading comprehension interventions also seem to produce far transfer in short and long-term measures, in reading speed and accuracy, as well as in inhibitory control, in typically developing children, children with reading difficulties, or participants with ADHD and reading difficulties [62].

Carretti et al. [71] and Horowitz-Kraus et al. [62] also report the relevant role that the compensation effect can play in the analysed children, where participants who initially showed poor performance obtained greater benefits in the short and long term [18,19,100,129,203–207].

Interventions stimulating working memory and mathematical skills have also been implemented in recent years [101], showing near benefits in central working memory and far transfers to reading skills and inhibitory control in typically developing children. Interestingly, Sanchez-Perez et al. [101] found that post-training reading benefits were significantly related to performance in working memory rather than mathematical tasks, in line with prior results such as those reported by Cain et al. [29], Engle et al. [76], Holmes et al. [48], Peng et al. [32], Shiran and Breznitz [79], and Swanson and Howell [77].

However, in Carretti et al. [71], Horowitz-Kraus et al. [62], and Sanchez-Perez et al. [101], the combined training activities were not independent, so it was difficult to determine which of the trained skills had a greater impact. In line with these authors, a recent study implemented an intervention focused on working memory and phonological skills independently [81].

4.5. Limitations and Future Research

Some limitations encountered during the systematic review process are worth mentioning. First, our work relied exclusively on studies that analysed the performance of typically developing children, as seen in some recent reviews [17,22,35,37,38]. Therefore, it would be interesting for future review studies to consider the impact of cognitive stimulation protocols in diverse clinical populations, such as in the work of Church et al. [89], Farah et al. [106], Horowitz-Kraus [109], Melby-Lervag et al. [36], Peng et al. [49], Swanson and Orosco [105], and Titz and Karbach [18], to determine how much training influence children with different neuropsychological characteristics.

Second, the conclusions presented here are limited by the intrinsic characteristics of systematic reviews. To delve further into the explored topics, a meta-analysis could be very informative in the future, as the statistical component would allow for a quantitative perspective to synthesise and generalise the evidence reported here—in the form, for example, of a summary effect size.

Finally, and related to the previous point, only 7 out of the 16 selected studies (i.e., less than half) reported the size of the concrete effect on the dependent variables [19,34,70,71,126,127,130]. For this reason and given that the results were measured only through psychometric assessments, it was difficult to robustly determine the impact of cognitive stimulation on reading skills in half of the sample [33,44,53,62,101,124,125,128,129]. Therefore, including a larger sample of studies in future reviews could be a potential way to obtain a more reliable assessment of the impact of executive function training programmes on different reading skills. However, despite the absence of such statistical analyses, some of the selected studies compared their results with active control groups [19,44,71,125–129], or supported their findings with neuroimaging data [62]. This type of research design allows the detection of possible confounding variables that could influence the results obtained, which greatly increases the consistency and degree of internal validity of the reported findings.

In addition,, and taking into account the limitations of the articles selected for this review, future neuroimaging studies exploring the possible far transfer of executive function stimulation programs would be very informative, and helpful in determining the specific role these trainings play in increasing cognitive capacities [62,102,220–223].

As the main limitation of the studies selected for this review, it is worth mentioning that the sample sizes in Artuso et al. [70], Jones et al. [44], Pasqualotto et al. [81], Siu et al. [33] were relatively small compared to some previous studies [104]. However, moderate changes from the Cogmed program can be detected with 12 participants per group [145].

Moreover, some studies selected report limitations, such as having only a passive control group [33,70,101] or a placebo or active control group with non-adaptive training [126]. Interventions in which participants are assigned to three independent groups allow testing of the data obtained under different experimental conditions. In line with this, some contributions, such as those made by Carretti et al. [71] or Hitchcock and Westwell [129], enable, on the one hand, verification of whether certain factors can act as extraneous variables, such as attention directed towards the experimenter or expectations reached in training [224]. On the other hand, they allow checking for any placebo effect in the applied assessment measures. For example, scores from questionnaires directed to teachers and families may be influenced by their perception of children's development [103].

It is worth mentioning that, due to the possible sleeper effect that may manifest in the development of reading skills after cognitive stimulation interventions [46,99,202], some studies incorporated in this review emphasize the importance of conducting longitudinal studies with short- and long-term assessments to confirm if these effects may appear months after training [19,70,101].

Finally, sometimes difficulties may arise in distinguishing between the specific effects of cognitive stimulation interventions combined with some other type of academic training. Therefore, studies implementing combined training might want to consider applying the interventions independently, at least for some period during the research, as seen in Pasqualotto and Venuti [81].

For all these reasons, we strongly believe that future research delving into cognitive stimulation programs in school populations would benefit from considering the limitations reported in the literature published to date. This way, the intrusion of extraneous variables that may occur in empirical research could potentially be largely avoided, obtaining the highest possible consistency and internal and external validity.

5. Conclusions

The objective of this research was to review and analyse the recently published findings regarding the impact of working memory and/or inhibitory control stimulation in children aged 6 to 12, as well as the transfer of this type of training to untrained skills such as reading abilities.

Although, at present, there is still some lack of convergence in the impact of executive function training on reading skills, half of the selected articles report that there has been a compensatory effect in the results obtained. Thus, it seems that there is an evident positive impact of such interventions on the reading skills of children showing some difficulty related to executive functions and/or reading abilities.

Interestingly, in some circumstances, a sleeper effect occurs, and these benefits are not visible until a few months after the training. Therefore, longitudinal analyses exploring possible long-term gains from these trainings would be interesting, although this is uncommon.

It is worth noting that, in the studies reporting far benefits of executive function training in reading skills of children without any difficulty, either linguistic components are included in materials, or a compensatory effect has occurred. Similarly, the use of combined training programs of executive functions and academic skills is advised, so that the trained tasks are more numerous, and the potential effects of far transfer are favoured. Integrated interventions in the school routine combined with a phonological, mathematical, or reading focus alongside executive function training seem to be significant for typically developing children.

Finally, it would be convenient to address some of the common limitations found in recent studies. This would minimize the intrusion of extraneous variables that may influence the reported results, and thus obtain the highest possible consistency and internal and external validity.

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