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A systematic review of the effects of executive function interventions on executive functions and language skills in school-age children with specific language impairment

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ABSTRACT

Background: Children with specific language impairment (SLI) have problems with non-linguistic areas such as executive function (EF) skills, in addition to language skills. EF skills are crucial for language development and processing. Conversely, language acquisition can also enhance EF skills, suggesting a bidirectional relationship. Speech therapists (STs) play a crucial role in providing interventions focused on EF skills for school-age children with SLI. Nevertheless, there is a scarcity of comprehensive evaluations regarding the effects of EF interventions for school-age children with SLI that enhance EF and language skills.

Objective: The purpose of this systematic review (SR) was to investigate which EF interventions have affected EF skills for school-age children with SLI and to investigate how improvements in EF skills could improve language skills in these children with SLI.

Materials and methods: This SR followed the Preferred Reporting Items for Systematic Reviews (PRISMA) guidelines with a descriptive-analytical approach. The protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO; CRD42024545361). Searched databases included ERIC, PubMed, APA PsycINFO, and ProQuest Dissertations and Theses. The authors used the Single-Case Experimental Design (SCED) and the Joanna Briggs Institute (JBI) critical appraisal tool for quality assessment.

Results: A total of 5,737 studies were retrieved, of which 4 studies were included in this review. The evidence supports the notion that EF interventions could improve EF skills (i.e., visuospatial WM, attention, inhibition, and cognitive flexibility) as well as language skills (i.e., language comprehension and production, particularly grammatical skills) in children with SLI aged 6 to 12 years. This study also indicates that while there are promising outcomes, the effects can be inconsistent and vary depending on the type of intervention and the specific skills targeted. EFs offer a cognitive framework that facilitates language acquisition, comprehension, and production throughout development and across different contexts.

Conclusion: EF interventions could have the potential to improve both EF skills and language skills. EF skills are essential for language development and processing, and vice versa. Therefore, STs could integrate EF interventions with traditional language interventions.

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Introduction

Executive functions (EFs) are a set of cognitive capacities that enable individuals to regulate goal-directed behavior, planning, mental flexibility, and self-monitoring. The term EF encompasses three main cognitive capacities: inhibition (deliberately overcoming a dominant response), working memory (WM; involving maintenance, monitoring, updating, and manipulation of short-term memory contents, as well as interference), and attentional set shifting.[1-2] EFs gradually develop and change across an individual's lifespan and can be improved at any time.[1]

The relationship between EF skills and language acquisition is a complex and multifaceted area of study, with research indicating a significant interplay between these cognitive domains. EF skills are crucial for language development and processing. Conversely, language acquisition can also enhance EF skills, suggesting a bidirectional relationship.[3-5] For instance, Filipe *et al.*[4] highlight that WM and cognitive flexibility have been shown to predict language abilities significantly in preschool children, explaining a substantial portion of the variance in language outcomes beyond age, gender, and nonverbal intelligence. WM is particularly important for tasks that require holding and manipulating information, such as understanding complex sentences. While inhibition is a critical EF component, its direct impact on language outcomes is less pronounced compared to working memory and cognitive flexibility. However, it plays a role in managing distractions and focusing on relevant linguistic information.

Children with specific language impairment (SLI) have a communication impairment in language skills that is markedly below age-appropriate and does not result from other developmental abnormalities such as hearing loss, cognitive impairment, or a clear neurological diagnosis.[6] Not only do children with SLI have problems with language, such as limited vocabulary, morphological errors, grammar and syntax challenges, and pragmatic difficulties,[7] but they also have problems with non-linguistic areas such as EF skills that might lead to social, literacy, and working memory challenges.[8-11]

In the past decade, there have been several systematic reviews and meta-analyses investigating EF skills in school-age children with SLI. Many children with SLI have difficulty with EFs compared to typically developing (TD) children.[8-11] A SR of Cama and Leon-Rojas[8] found that children with SLI have problems with WM, which includes phonological, auditory, and visual/verbal memory. Furthermore, attention deficits are prevalent, affecting their ability to focus and process information efficiently, and also the ability to plan and internalize speech is defective, contributing to difficulties in expressive skills both verbally and non-verbally.

A meta-analysis by Estes *et al.*[9] also found that children with SLI experience word learning and sentence processing difficulties due to lower performance in phonological short-term memory (pSTM) compared to their peers on average. Meanwhile, a meta-analysis by Vugs *et al.*[10] found that children with SLI performed lower in visuospatial working memory (VSWM) than their peers on average, leading to nonverbal learning challenges. Additionally, a meta-analysis by Pauls & Archibald[11] found that children with SLI performed lower in inhibition and in cognitive flexibility than their peers on average, which might increase distractibility, reduce listening comprehensibility, and affect multiple elements of pragmatic skills. As a result, children with SLI had EF deficits that exceeded those of TD children and related to their language skills.

Speech therapists (STs) play a pivotal role in addressing EFs for school-age children with SLI.[12] EF interventions are essential as they address the cognitive and communicative challenges faced by children with SLI.[12-15] However, the effects can be inconsistent and vary depending on the type of intervention and the specific skills targeted. For example, EF interventions including WM training programs, including interactive and computerized,[12] WM training interventions including listening recall training task and odd one out span training task,[13] a computer-based EF training (Braingame Brian),[14] and Cogmed WM training.[15] Additionally, the results varied, encompassing both WM and language, with a particular focus on WM[12-15] and language.[12-13,15] Furthermore, some studies examined behavioral problem[14] and IQ.[15] Nevertheless, there is a scarcity of comprehensive evaluations regarding the effects of EF interventions for school-age children with SLI that enhance EF skills and language skills and how improvements in EF skills could improve language skills in these children.

The purpose of this SR was to investigate which EF interventions have affected EF skills for school-age children with SLI and to investigate how improvements in EF skills could improve language skills in these children with SLI. In the present SR, we sought to answer the following questions:

1) What EF interventions have affected EF skills for school-age children with SLI?
2) How could improvements in EF skills improve language skills in school-age children with SLI?

Materials and methods

This SR followed the PRISMA guidelines with a descriptive-analytical approach.[16] The protocol was registered in the PROSPERO (CRD42024545361).

Inclusion and exclusion criteria

This SR followed the criteria for the inclusion and exclusion of studies in this review based on population, intervention, comparison, outcome, and study design (PICOS) principles.

Types of participants

The target participants included children aged 6-12 years old who were diagnosed with SLI. We excluded participants with other diagnoses or mixed diagnoses in their developmental and medical histories, such as attention-deficit/hyperactivity disorder (ADHD), autism spectrum disorder (ASD), intellectual disability (ID), sensory disorders, brain damage, or seizures.

Types of intervention

The target interventions included EF interventions, programs, principles, trainings, or strategies used with school-age children with SLI. We did not consider programs that were not primarily focused on EF skills.

Types of comparators

We compared the intervention to other types of interventions, such as waiting lists, traditional language interventions, control groups, or no control group.

Types of outcomes

The target outcomes included EF skills, such as attention control, behavioral inhibition, and working memory, as a primary outcome and related to language skills. We excluded studies that did not measure EFs as primary outcomes.

Types of studies

We considered randomized or non-randomized controlled trials. Other types of research designs, such as expert opinions, case reports, and qualitative studies, were not considered.

Search strategy

The authors searched for the studies between 1 July and 31 October 2024. Searched databases included ERIC (3,492), PubMed (15), APA PsycINFO (4), and ProQuest Dissertations and Theses (1,782). To ensure that all existing literature on the research questions addressed by this review was included, we used reference tracking and hand searching. We also searched Brain Sciences (93), Child Language Teaching and Therapy (242), American Journal of Speech-Language Pathology (44), and Clinical Linguistics & Phonetics (69). The SR included studies that were published from 2014 to 2024. Full text was in English.

The searched terms were using booleans, truncations, and other operators: ("specific language impairment" OR "developmental language disorder" OR "primary language impairment") AND ("executive function" OR "attention" OR "inhibition" OR "shifting" OR "working memory") AND ("executive function intervention" OR "program" OR "principle" OR "training" OR "strategy").

Study selection and data extraction

The two review authors (N.W. and T.K.) searched and eliminated duplicates, including documents indexed in two or more databases as well as nonoriginal publications like books, book chapters, and journals. We were then responsible for study selection during the first screening phase, independently assessing the title and abstract of all documents to find those of potential relevance. The selection process includes documents with sufficient information for screening (title and abstract). In a second screening process, using full texts, we independently determined which studies met the inclusion criteria for this review. When we could not reach a consensus, a third review author (S.C.) was consulted as necessary, whose decision was final. In the last process, we independently extracted the main characteristics of the included studies using a designed template.

Data analysis

This SR used a descriptive analysis approach. We did not analyze subgroups or subsets or carry out a meta-analysis of the studies due to heterogeneous studies.

Quality assessment

To assess the quality of the studies, we used the SCED[17] for single-subject studies (Table 1) and the JBI critical appraisal tool[17] for quasi-experimental studies (Table 2).

Table 1. Risk of bias for single subject study using the SCED.

Study	Clinical history	Target behaviors	3 phases	Baseline	Treatment phase	Data record	Inter-rater reliability	Assessor independence	Statistical analysis	Replication	Generalization	Total score
Shahmahmood Toktam *et al.* 2018[12]	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	8 (moderate)

Note: *Y: yes, N: no.*

Table 2. Risk of bias for quasi-experimental studies using the JBI quasi-experimental studies checklist.

JBI quasi-experimental studies checklist	**Henry *et al.* (2022)[13]**	**Vugs *et al.* (2017)[14]**	**Holmes *et al.* (2015)[15]**
1. Is it clear in the study what is the "cause" and what is the "effect" (i.e., there is no confusion about which variable comes first)?	Y	Y	Y
2. Were the participants included in any comparisons similar?	Y	NA	Y
3. Were the participants included in any comparisons receiving similar treatment/care, other than the exposure or intervention of interest?	N	NA	N
4. Was there a control group?	Y	N	Y
5. Were there multiple measurements of the outcome both pre- and post-intervention/ exposure?	Y	Y	Y
6. Was follow-up complete and if not, were differences between groups in terms of their follow-up adequately described and analyzed?	Y	Y	N
7. Were the outcomes of participants included in any comparisons measured in the same way?	Y	Y	Y
8. Were outcomes measured in a reliable way?	Y	Y	Y
9. Was appropriate statistical analysis used?	Y	Y	Y
Overall appraisal	8/9 (Low risk)	6/9 (Moderate risk)	7/9 (Moderate risk)

***Note**: Y: yes, N: no, NA: not applicable*

The SCED comprises 11 items, with 10 of them focusing on assessing the methodology and statistical analysis quality. It classifies studies scoring between 9-11 as good quality, those scoring 6-8 as moderate quality, and any scoring under 5 as poor quality.[17]

The JBI quasi-experimental studies checklist comprises 9 items: certainty of cause and effect, pre-homogeneity verification, exposure to the same environment outside of the intervention, presence or absence of a control group, pre- and post-intervention effect measures, description of dropouts, equivalence of outcome measures, appropriateness of outcome variable measures, and statistical analysis methods. The JBI checklist assesses each item by assigning a score of 1 for yes, 0 for no, and 0 for unclear or not applicable items. There is a high risk of bias if 20-50% of items score yes, a moderate risk if 50-80% of items score yes, and a low risk if 80-100% of items score yes.[18]

The two review authors (N.W. and T.K.) independently assessed the studies. Any disagreement was resolved by consensus, and whenever this was not possible, a third review author was consulted (S.C.), whose decision was final.

Results

Figure 1 illustrates a methodology flowchart. The preliminary database and hand search in relevant journals yielded a total of 5,737 articles relevant to the topic. The authors removed the duplicates from these articles, leaving a total of 1,330. During the initial screening, we excluded 1,320 studies from these publications. We systematically filtered the full-text articles for eligibility assessment using the PICOS design. After a thorough review of the 10 articles, the search yielded four matches for the inclusion/exclusion criteria defined in the methods.[12-15]

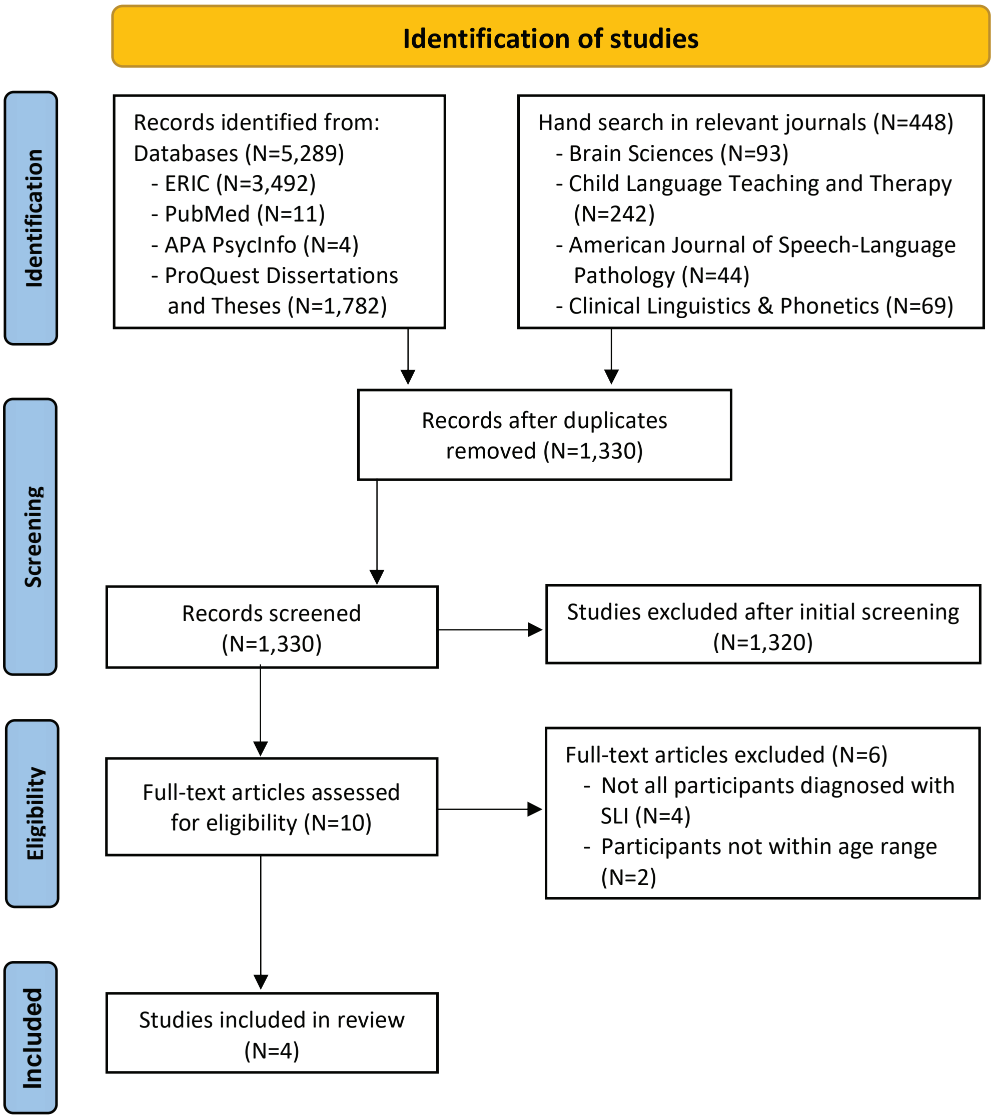

Figure 1*. Methodology flowchart.*

Table 3 demonstrates the included studies. Three studies were conducted in Europe, i.e., the UK,[13-14] and the Netherlands.[15] One study was conducted in Asia, in Iran.[12] According to levels of evidence at Johns Hopkins Nursing Evidence-Based Practice,[19] our review identified three studies using quasi-experimental design (Level II)[12-14] and one study using single case design (Level III).[12]

The present SR involved a total of 94 participants, with sample sizes ranging from 10 to 47. All studies included only children aged between 6 and 12 years. All participants had received a diagnosis of SLI (which can be used interchangeably with developmental language disorder (DLD) or primary language impairment (PLI), which identified by a psychological assessment or a psychiatric diagnosis.[12-15] Severity levels were reported in only one study, ranging from mild to severe SLI.[12]

The studies included in this review examined EF interventions, including WM training programs, including interactive and computerized,[12] WM training interventions, including listening recall training task and odd one out span training task,[13] a computer-based EF training (Braingame Brian),[14] and Cogmed WM training.[15] Speech-language pathologist was clearly reported as an interventionist in one study.[12] However, the researcher and researcher assistant were reported in of Henry *et al.*,[13] Vugs *et al.*,[14] and Holmes *et al.*[15] The duration of sessions ranged from 5 weeks[12] to 8 weeks.[15]

Shahmahmood Toktam *et al.* focused on WM, pSTM, morpho-syntax skills, and executive WM.[12] Henry *et al.* focused on WM tasks and language comprehension.[13] Vugs *et al.* focused on tasks of three trained EFs (visuospatial WM, inhibition, and cognitive flexibility), other untrained neurocognitive functions (verbal WM, attention, planning, and fluency), and parents' and teachers' ratings of EF and behavioral problems.[14] Holmes *et al.* focused on STM, WM, language, and IQ.[15]

Table 3. Included studies.

Author(s) Year Country	Design	Participants	Intervention methods	Interventionist	Duration	Outcomes	Results
Shahmahmood Toktam *et al*. (2018)[12] Iran	A single-subject experimental design	Total: 10 participants Age: 6-8 years olds Persian-speaking children Diagnosis: mixed receptive and expressive language impairment Severity: moderate to severe	1. WM training (interactive and computerized (auditory components of WM training software, persian version of robomemo, and a WM training program)) 2. Language intervention	A speech-language pathologist	15 sessions (three 60-minute sessions per week for five weeks)	- WM - pSTM - Morpho-syntax skills	Direct WM remediation can lead to beneficial changes in WM skills including NWR and BDS and morpho-syntactic language skills.
Henry *et al.* (2022)[13] United Kingdom	A pre-test/ intervention/ post-test/ 9-month follow-up design	Total: 47 participants (the experimental group =24 and the control group =23) Age: 6-10 years olds English-speaking children	WM training interventions (listening recall training task and odd one out span training task)	Researcher	18 sessions over of around 10 min three times a week (total 3 h)	- EWM - WM tasks - Language comprehension	Children who received WM training interventions showed significantly higher WM scores and language comprehension at both time points than children in the active control group.
Vugs *et al*. (2017)[14] Netherlands	A pre-test/ intervention/ post-test/ 6-month follow-up design	Total: 10 participants Age: 8-12 years olds Dutch-speaking children	A computer-based EF training (Braingame Brian)	Research assistant	25 sessions over 6 weeks	Tasks of three trained EFs (visuospatial WM, inhibition, cognitive flexibility) - Other untrained neurocognitive functions (verbal WM, attention, planning and fluency) - Parents and teachers' ratings of EF and behavioral problems	Children with SLI showed significant improvement on a task of cognitive flexibility directly after training, as well as a positive trend for improvement in the visuospatial storage component of WM and inhibition.
Holmes *et al*. (2015)[15] United Kingdom	A pre-test/ intervention/ post-test design	Total: 27 participants (the experimental group =12 and the control group =15) Age: 8-11 years olds English-speaking children	Cogmed working memory Training	Research assistant (Cogmed trainer)	20 45-min sessions for 8 weeks	- STM - WM - Language - IQ	Both children who received the Cogmed WM interventions and children in the control group showed significant post-training gains on visuospatial storage (or visuospatial short-term memory).

The results Shahmahmood Toktam *et al.* showed that direct WM remediation can lead to beneficial changes in WM skills including non-word repetition (NWR) and backward digit span (BDS) and morpho-syntactic language skills.[12] Focusing on WM as the primary target of intervention can improve the children's participation in treatment (attention), as well as their linguistic comprehension and production skills, especially their grammatical skills. Furthermore, the findings showed that language intervention also led to an improved grammatical receptive and expressive functioning of all participants, though it did not notably change the participant's performances in WM tasks, including the word list recall and backward word span tests.

The results of Henry *et al.* found that children who received WM training interventions showed significantly higher WM scores and language comprehension at both time points than children in the active control group.[13] Improvements not only in two trained tasks (direct effects) and six untrained working-memory tasks (near-transfer effects) but also sentence comprehension and receptive grammar assessments. The researchers chose face-to-face delivery because it can enhance children's motivation and focus their attention on input, thereby creating an ideal environment for training participation. This may be especially crucial for the executive-load component of the executive working memory activities assigned to the trained group. This shows that the focus and/or enjoyment of the activity, as well as motivation, maybe more important than the mode of delivery in achieving favorable outcomes. The intervention program demonstrated advantages: it involved short sessions over a short period, caused little disruption in the school day, and was enjoyed by children.

The results of Vugs *et al.* found that children with SLI showed significant improvement on a task of cognitive flexibility directly after training, as well as a positive trend for improvement in the visuospatial storage component of WM and inhibition.[14] At 6-month follow-up, the children performed significantly better on the visuospatial storage component of WM, inhibition, and cognitive flexibility. The study observed significant improvement at the 6-month follow-up in two neurocognitive functions, sustained attention and attention control, which were not part of the program's training. Regarding the behavioral ratings, both parents and teachers reported significantly fewer attention problems. Moreover, parents reported significantly fewer problems with WM and metacognition, thought problems, externalizing behavioral problems, and overall behavioral problems.

The results of Holmes *et al.* found that both children who received the Cogmed WM interventions and children in the control group showed significant post-training gains on visuospatial storage (or visuospatial short-term memory).[15] Children in the LLA (low language ability) group improved significantly on one of the two verbal STM measures (digit span but not word span), although group interaction training was not significant. Low verbal IQ scores were strongly and specifically associated with greater gains in verbal STM. One possibility is that these children's daily practice on several Cogmed tasks that require them to remember the order of spoken information (letters and numbers) may help them come up with simple ways to practice, which in turn improves their verbal STM performance. Following training, children with higher verbal IQs made greater gains in visuospatial short-term memory. Verbal abilities may be critical in developing new strategies to meet the complex demands of visuo-spatial working memory.

Discussion

The first purpose of this SR was to investigate which EF interventions have affected EF skills for school-age children with SLI. The evidence supports the notion that EF interventions could improve EF skills (i.e., visuospatial WM, attention, inhibition, and cognitive flexibility) as well as language skills (i.e., language comprehension and production, particularly grammatical skills) in children with SLI aged 6 to 12 years. This study also indicates that while there are promising outcomes, the effects can be inconsistent and vary depending on the type of intervention and the specific skills targeted.

Two studies found that computer-based EF training, including Braingame Brian[14] and Cogmed WM training[15] improved the trained visuospatial WM of school-age children with SLI. Klingberg *et al.* investigated the effect of computer-based WM training in children with ADHD.[20,21] The results indicated that these children improved in visuospatial WM tasks. Therefore, our SR supports the use of computerized interventions, which could be used in clinical settings for STs to enhance WM.

Furthermore, Holmes *et al.* found that visuospatial WM improved, especially in individuals with higher baseline verbal IQs and non-word repetition scores.[15] This result demonstrated that the complex demands of visuospatial WM tasks required strong verbal skills. Children with strong language abilities may find it simpler to employ verbal labels to recode stimuli such as spatial locations or colors, giving them additional ways to preserve memory items. A meta-analysis of Vugs *et al.* found that there was a correlation between more severe language impairment and greater impairment in visuospatial storage.[4] However, Vugs *et al.* did not report verbal IQs or non-word repetition scores.[14]

Three studies also found that computer-based EF training, including interactive and computerized,[12] Braingame,[14] as well as training interventions including listening recall training tasks and odd one-out span training tasks on paper-based materials, improved attention skills in school-age children with SLI.[13] There were several explanations for this finding. For example, Shahmahmood Toktam *et al.*[12] found that WM training programs indirectly improved attention skills by improving one of the WM-related tasks (i.e., backward digit span, BDS). Likewise, Vugs *et al.* found that EF intervention enhanced two tasks related to neurocognitive functions that were not addressed in the program, such as sustained attention and attention control.[14] Besides, Henry *et al.* found that face-to-face delivery was used for social engagement, which may increase children's motivation and focus attention on input, creating an environment that is conducive to training adoption.[13]

Interesting, the study of Vugs *et al.* was only one study that investigated the trainability of inhibition and cognitive flexibility.[14] Following the training and during the 6-month follow-up, they noticed a significant enhancement in cognitive flexibility performance, as well as a positive tendency toward improved inhibition. Like Van der Oord *et al.* this study investigated the effect of computerized EF training focused on improving three EFs: WM, inhibition, and cognitive flexibility in children with ADHD.[22] EF intervention utilizing games could enhance children's motivation and cognitive performance. Leading to neuroplastic changes, especially in regions such as the prefrontal cortex, which is essential for inhibition.[23]

Also, Van der Oord *et al.* incorporated gamification aspects to augment children's motivation and potentially amplify their cognitive performance throughout training.[22] Gaming enhances the release of striatal dopamine, which is believed to enhance arousal and cognitive control functions, particularly during EF training.[24] It should be noted that the average performance of the children with SLI in inhibition and cognitive flexibility was lower than that of their peers.[5] Hence, the EF intervention should enhance the capacity for inhibition and cognitive flexibility.

On balance, the findings indicate that several interventions effectively improved EF skills, including computer-based programs (Braingame Brian, Cogmed, and other interactive computerized training) and paper-based materials with listening recall and odd-one-out span tasks. These interventions demonstrated improvements in visuospatial working memory, attention, inhibition, and cognitive flexibility, though with varying consistency.

The second purpose of this SR was to investigate how improvements in EF skills could improve language skills in school-age children with SLI. The evidence presented in the four studies also supports the notion that EF skills are essential for language development and processing, and vice versa.

Henry *et al.* found an improvement in sentence comprehension. Also, it should be noted that this study found an improvement in attention skills in children with SLI.[13] It is possible that EF interventions, such as listening recall training tasks and odd one-out span training tasks on paper-based materials, which improve attention control, can lead to better concentration during sentence processing. This ensures that the individual remains focused on the meaning of the sentence without being sidetracked by irrelevant stimuli, which enhances overall comprehension. In line with Gillam *et al.*[25] and Montgomery *et al.*,[26] the relationship between WM and sentence comprehension is a complex interplay involving various cognitive functions such as fluid reasoning, controlled attention, and long-term memory for language knowledge. In this association, WM acts as a mediator, facilitating the integration and processing of information necessary for understanding sentences. However, Montgomery *et al.*[26] encouraged interventionists to address underlying language skills such as syntax and sentence comprehension directly rather than trying to improve WM through training. They suggested methods for implicit and explicit interventions to reduce WM demands and improve language, respectively.

Shahmahmood Toktam *et al.* found an improvement in linguistic comprehension and production skills, especially their grammatical skills.[12] Also, it should be noted that this study found an improvement in attention skills in children with SLI. Attention, as part of the broader EF system, helps individuals focus on relevant linguistic information, manage distractions, and process language with precision. It is probable that WM training, which improves attention, is the underlying mechanism for language skill growth in response to a range of linguistic intervention activities.[27]

Furthermore, the findings of Shahmahmood Toktam *et al.*[12] are consistent with the findings of Holmes *et al.*[14] Their WM training method for a sample of low-WM children resulted in near transfer to other WM activities and far transfer to mathematics and English. This indicated that there are cross-domain interactions between language and WM, which is consistent with the findings of Ebert and Kohnert and supports cognitive theories of language.[28] However, the study by Henry *et al.*[29] found no significant far-transfer effects on mathematics and reading skills following WM training, except for a notable improvement in reading comprehension. Positive results could suggest that EF skills, such as cognitive flexibility and inhibitory control, play significant roles in language development. Inhibitory control may be crucial for language development because it enables children to concentrate on interpretations of a message.[30] Additionally, it could be necessary for communicative perspective-taking.[31] Cognitive flexibility was a predictor of the narrative structure.[32] It is crucial to consider how these EF skills affect language development. Children may therefore be able to utilize language more flexibly if they have cognitive flexibility. Therefore, the question of whether low-WM children experience near transfer to other WM activities and far transfer to mathematics and English is a complex one, with research providing mixed results. While some studies suggest potential benefits of WM training, others highlight limitations in the transfer effects, particularly in far transfer to academic skills such as mathematics and English.

Overall, the results of the current research, which are consistent with previous reports, indicate that EF interventions have shown potential in improving EF skills in these children. EFs and language are closely intertwined in cognitive processes. It should be the notion that EFs provide the cognitive framework that supports language acquisition, comprehension, and production throughout development and across different contexts. EF skills such as the ability to retain information (working memory), focus and process relevant linguistic information precisely without being distracted (attention), filter out irrelevant information (inhibition), and shift focus between activities (cognitive flexibility) were found to be crucial foundations for enabling more effective communication.

For school-age children with SLI, STs could integrate EF interventions with traditional language interventions, as language skills have little bearing on EFs. EF skills are essential for language development and processing. Conversely, language acquisition may also improve EFs, indicating a bidirectional relationship.[9-11] Therefore, our finding suggests that STs should not neglect EFs because EF interventions may not only successfully enhance children with SLI but also indirectly affect their language skills. However, more research is needed to better understand the bidirectional relationship between EF and language skills in children with SLI, as well as to provide more tailored speech therapy to these individuals.

Limitations and future research

This present SR has several limitations. First, we only selected articles in English. Other languages might yield complementary results. Secondly, there have only been four recent studies published to date, which included one single-subject design[11] and three quasi-experimental studies.[13-15] The randomized controlled trial study, which is widely regarded as the gold standard of experimental research, was notably absent. Therefore, it should be concerned about the limited sample size, making findings difficult to generalize to the population. Thirdly, the evidence from the four included studies in this review focuses on school-age children with SLI, meaning that the findings are not generalizable to preschool children or adults with SLI. Further research is required to determine the effects of EF interventions on individuals with SLI under 6 or above 12, as well as how improvements in EFs could improve language skills in young and adult children with SLI. Finally, we must recall that STs implemented the interventions,[12] a fact not explicitly stated in some studies.[13-15] Therefore, further research is necessary to define the interventionist clearly for STs to know their role in intervening both in language and EF areas. There should be an understanding of STs' experiences remediating developmental EF impairments with SLI, as well as their confidence and expertise in this domain.

Conclusion

In conclusion, this present SR indicates that EF interventions could enhance both EF and language skills in school-age children with SLI. The research suggests that, although there are encouraging results, the benefits may be variable and depend on the type of intervention and the specific skills addressed. Cognitive processes intricately connect EFs and language. EF skills are assumed to provide the cognitive framework that underpins language acquisition, comprehension, and production throughout development and across various contexts. School-age children with SLI could benefit from EF interventions in conjunction with traditional language interventions. STs must not overlook EFs, as interventions targeting them may not only effectively improve EF skills but also indirectly influence language skills. Further research is needed to better understand the bidirectional relationship between EFs and language skills in children with SLI and to provide more individualized speech therapy for these individuals.

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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Ethical approval

The study was approved for exemption review by the Ethics Committee, Faculty of Associated Medical Sciences, Chiang Mai University (CMU), Thailand (AMSEC-66EM-009).

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