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Original articles

Effects of working memory intervention on students with reading comprehension difficulties

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ABSTRACT

Purpose: to investigate the effectiveness of a working memory-based intervention proposal for reading comprehension.

Methods: 43 children divided into two groups according to their performance in a reading comprehension test – G1: children with reading comprehension difficulty; G2: children with no difficulties. All the children were evaluated regarding reading, writing, sentence reading comprehension, and phonological working memory - PWM (repetition of pseudo-words and digits). After this evaluation, children from G1 participated in an intervention program (15 meetings) that stimulated the PWM. Following the intervention, all the children were reevaluated. The results were compared intra- and intergroup, and pertinent statistical tests were applied, by adopting the significance level lower than 0.05%.

Results: after the intervention program, the children of G1 showed a significant improvement in all tests. In the intergroup analysis, at the time of evaluation, G1 was different from G2 in reading, writing and reading comprehension. In the reevaluation, G1 equaled G2 in reading and got closer to G2 in writing and reading comprehension.

Conclusion: PWM training brought benefits to children with academic difficulties. Thus, these strategies could be used in the classroom, aiming to promote learning.

Keywords: Short-Term Memory; Comprehension; Reading; Language; Rehabilitation of Speech and Language Disorders

INTRODUCTION

Reading is an ability involving a complex process of perception, memory, inference and strategic processing[1,2]. The most important functional systems recruited in the acquisition of written language are the sensorial, motor, language/speech, memory, and attention, which work cooperatively[1].

In many cases, even when word reading is effective (decoding), comprehension may be altered[3]. Many factors are important for reading comprehension: linguistic components (vocabulary, syntax, phonologic skills, among others)[4,5]; cognitive components (executive functions - working memory, attention, cognitive flexibility)[4-8]; and social variables (social context, motivations, expectations and others)[4,5]. Hence, reading, in its fullness, encompasses skills such as: being able to use and understand the language; recognizing graphic symbols and distinguishing them one from the other; understanding the text; going back to the text to find answers to their questions; looking for the intentions and points of view of the writer; having the attitude of reflecting upon what has been read, reading not only on the word level, but also on sentence and even text level[9].

According to the idea that reading implies understanding, a child who is able only to decode, i.e., to simply pronounce the words without reaching the comprehension of the ideas contained in them, cannot be considered as someone who actually reads. It is necessary, however, to consider that problems in decoding words impair reading comprehension, since the reader will need to allocate more information in their working memory for the decoding process, hindering the lexical access necessary to extract meaning from the text, which happens simultaneously with decoding[3].

Literature points out different ways to work with children with reading and writing difficulties, among which these can be mentioned: training phonological awareness ability[10-12], used especially in children with reading difficulty by phonological route (literacy process); working with various linguistic aspects, such as vocabulary and/or listening comprehension[12,13]; training based on producing narratives/sharing story reading[1,13,14]; and, training working memory (WM) ability[13-15].

Among the abovementioned different intervention programs that aim to develop/rehabilitate the reading processes, the ones dealing exclusively with WM training are scarce, even though literature describes the positive relation there is between WM and the acquisition of new words, WM and comprehension of more syntactically complex sentences, WM and phonological awareness, and WM and reading/writing/arithmetic development[15-19].

The studies encompassing WM as the main ability to be stimulated are researches whose samples are children/adolescents with attention deficit hyperactivity disorder[20,21] and children with autism spectrum disorder[22]. The goal of this information is to improve executive function abilities, ensuring advances in social and academic spheres. In these studies, WM training took place mostly through the use of programs especially developed for this purpose, such as Jungle Memory or CogMed. In 2019, a study was published reporting the effects of WM training in children with and without dyslexia[23]. They noticed that the training brought about positive changes only in the visuospatial sketchpad, as no improvement was observed in the phonological loop or in the central executive.

WM is the most frequently studied type of memory in the child population and it is related to executive functions and to oral and written language development. Currently, the best known WM model is the multicomponent working memory. This is a short-term memory involved in handling information so as to enable complex cognitive tasks to be performed[24].

In this multicomponent model, the WM is composed of four components: the central executive (its role, among others, is to focus attention on the task, and switch attention between two or more tasks); the phonological loop (it stores the information verbally coded); the visuospatial sketchpad (responsible for processing and storing visual and spatial information); and, the episodic buffer (the system responsible for the process that integrates information kept in the various WM subcomponents to those kept in the long-term memory)[24].

In more detail, the phonological loop (PL), as a working memory subcomponent, stores the information verbally coded and it has two divisions: a short-term storage (phonological storage or phonological loop) and the phono-articulatory loop (articulatory loop). The first one stores verbal information for a short period of time. The second one revives information contained in the phonological storage through the articulatory rehearsal (subvocal reverberation)[24].

This component's storing capacity is influenced by length (the lengthier the phonological information to be stored, the worse the performance), frequency (high frequency words are remembered more often than low

frequency ones), phonological similarity (sequence of words with similar sounds are harder to be remembered), semantic similarity[24], articulatory suppression effect (memory performance is worsened if the person performs a simultaneous task emitting letters, numbers or others)[25], irrelevant speech effect (worse performance when there is background noise - figure-ground ability)[26], age (gradual increase in memory capacity up until adolescence and the decrease of such ability in the elderly), and schooling (the greater the schooling, the better is the performance in the memory tasks)[24].

The phonological similarity and irrelevant speech effects impair the phonological storage, whereas the length and articulatory suppression effects have their origin in the articulatory rehearsal[24]. The age effect is positively related, in the case of children, to the process of maturing processing speed[27]. For the evaluation of PL, forward digit repetition, word repetition and pseudo-words tests are used[24]. The repetition of pseudo-words/non words evaluates more precisely the phonological storage, since their storage is devoid of lexical, semantic and syntactic influences[28].

The positive relation between WM and reading/writing has already been proved by various studies. Specifically, low performance in tasks evaluating phonological loop is related to difficulties in writing[29], difficulties in reading comprehension[7], and difficulties in arithmetic[19]. As for lower performance in more complex tasks, such as backward digit repetition (central executive), it is related to problems in reading and in reading comprehension[6,29].

Given the importance of the PL for written language, and the scarcity of intervention papers dealing exclusively with PL in children with reading/writing difficulties, the objective of this study was to investigate the efficacy of an intervention proposal based on stimulating working memory (phonological loop) for reading comprehension, as well as for decoding and writing words.

METHODS

This study is characterized as a parallel, randomized, controlled and open treatment clinical essay. Regarding ethical considerations, this study was approved by the Research in Human Beings Ethics Committee of the Hospital das Clínicas da Faculdade de Medicina de Ribeirão Preto, University of São Paulo, Brazil, with approval registry 2893/2011. In compliance with ethical issues, as it deals with collecting data involving children, the adults responsible for these children were informed about the evaluations to be made and the intervention program and, in case they agreed, the Informed Consent Form was signed.

Sample selection and composition

The initial sample of this study was composed of 127 children properly enrolled in either the fourth or fifth grade of elementary education from four municipal schools (all children were evaluated whose adults responsible for them authorized it). Of all the children evaluated at first, 84 were excluded from this study. Their exclusion was mostly due to the following variables: those responsible for the children abandoned the study at the time of intervention, the children were attending reading development stimulation groups, the children were attending speech-language-hearing/psycho-pedagogical therapy, or it was not possible to proceed with reevaluation in the case of the control group.

In this study's final sample, 43 children participated, divided in two groups according to their performance in the reading comprehension ability evaluation, carried out by means of the Auditory and Reading Comprehension Contrastive Test - reading comprehension sub-item (TCCAL - Let)[30]:

- G1 "Working Memory - Phonological Loop intervention group": 16 children (9 males - 56%). Initially, 20 children had been designated to compose this group; however, four of them were excluded for not being present in 75% of the meetings.
- G2 "Control group": 27 children (9 male - 33%), whose performance was classified as average in the TCCAL - Let test. This group was not submitted to any intervention.

For the selection of the final sample, the following inclusion criteria were used: being over eight years and under 10 years and 11 months old; being enrolled in either the fourth or fifth grade of elementary school; not being from the inclusion program (a child diagnosed with intellectual disability, autism spectrum disorder and others); absence of hearing loss of any type or degree; attending 75% or more of the intervention activities (participating in at least 11 meetings) - criteria for G1; and, undergoing evaluation and reevaluation tests - criteria for both G1 and G2. The exclusion criteria were the child presenting history of speech-language-hearing/psycho-pedagogical therapy for linguistic alterations, learning and/or speech, or participating in reading/writing stimulation groups.

Stages in the study and material/procedures for data collection

This study took place in three stages:

- Stage 1: initial evaluation (application of tests to evaluate working memory, reading, writing, reading comprehension, and auditory screening - the tests used are described below) and forming of the groups. Data collection took place in scheduled time and in agreement with those responsible for the students.

- Stage 2: carrying out of the intervention proposal for the working memory ability development, more specifically the phonological loop. Only the children of G1 participated (children with reading comprehension difficulties). This stage counted with 15 meetings (twice weekly) held at school, each one lasting for one hour, at fixed days and hours. The intervention program will also be described ahead.
- Stage 3: reevaluation of the children of G1 and G2, using the same tests to which they were submitted in stage 1.

In the following, the instruments used in evaluating (stage 1) and reevaluating (stage 3) are described:

Auditory screening

The purpose was to exclude children with possible hearing loss. The PA5 pediatric audiometer (brand Inter-acoustics) was used, with TDH-39 earphones. The pure-tone threshold audiometry consisted in air-conduction threshold research (lowest intensity a person hears). The frequencies researched were 500, 1000, 2000 e 4000 Hz. The child was considered to have "passed" the screening when their thresholds for these frequencies were inferior to 25 dB.

Auditory and Reading Comprehension Contrastive Test - reading comprehension sub-item (TCCAL - Let)[30].

This instrument made it possible to evaluate reading comprehension of simple/complex sentences. The test was used to divide the groups and to measure to what extent the PL abilities training had aided in reading comprehension ability.

The test contains six training items and 40 testing items. Each item is composed of a written sentence, followed by five alternative pictures to be chosen from. The task consists in reading the sentence and choosing, by making a mark on it, the picture that best corresponds to it. The written sentences vary in length (i.e., number of words) and in syntactic and lexical complexity (i.e., grammar structure and word variety).

Initially, the training questions were applied, which corresponded to sentences (A, B, C, D, E and F), until the task was understood. The test was concluded only after the 40 marked sentences were finished. For each adequate answer, a point was given, so that the total possible score for the test was 40.

The child's performance classification followed the authors' guidelines[31]. The child's performance was classified according to their age. Children with low or very low performance composed G1, and those with average or high performance were the G2 children.

School Performance Test (TDE)[32]

By means of this instrument, each child's reading and writing performance was quantified. The arithmetic task was not used.

The TDE is a psychometric instrument built for Brazilian students, elaborated, validated and standardized by Stein (1994). The writing subtest consists in writing one's own name and in the dictation of 34 words, presented separately at first, and afterwards followed by the reading of a sentence in which the word to be written is stressed. For each word correctly written, one point was given (maximum of 35 points). The reading subtest consists in presenting a stimulus sheet containing 70 words to be read, beginning with short words of consonant/vowel-structured syllables, and ending with more complex, low frequency words. Each correctly read word corresponded to one point (maximum of 70 points).

The gross score for each task was used for the statistical analysis.

Brazilian Children's Test of Pseudo-word Repetition – BCPR[33]

This test evaluated the PL. It is composed of 40 pseudo-words divided into four categories, according to the number of syllables (from two to five), with 10 items for each category. The child was expected to repeat the words spoken by the evaluator (the child had only one attempt). For each correct answer, the child received one point. The answer was considered "correct" when the child had correctly repeated the whole sequence, and considered "incorrect" when there was omission, substitution or non-production of the meaningless word. The total number of correct answers was taken into account for the statistical analysis.

Meaningless Words Repetition Test - RPSS[34]

This is an instrument for evaluating the PL, as well. The test is composed of 30 words devoid of meaning, with simple syllabic structure. According to the variation in number of syllables (from one to six), the meaningless words were distributed in six lists, with five items for each list. For each correct answer (when the child was able to repeat the item just as it was presented), one point was given. The answer was considered "incorrect" when there was omission, substitution or non-production, in which cases no points were given. The final score was obtained in accordance with the total number of correct answers for each word.

Subtest 5 of Auditory Sequential Memory of the Illinois Test of Psycholinguistic Abilities - ITPA[35]

This subtest, used as well for evaluating PL, consisted in the forward repetition of 28 digit sequences. The sequences presented increased in complexity (from two to seven digits). In this test, two attempts are allowed to repeat each digit sequence. Two points were given for each item correctly answered in the first attempt, one point for each item correctly answered in the second attempt, and no points for the items incorrectly answered in both attempts. In this study, the child's gross score in the test was used.

Working Memory Intervention Program - phonological loop

In this intervention program, 15 one-hour long meetings were proposed, carried out in small groups (five children at the most) - (two meetings a week - the intervention lasting for the total of two months). It was composed of games- and ludic activities-based strategies for the development of five abilities: categorization; sequencing of simple and complex orders; creation of visual images; memorization of words and numerals; and, memorization of non words.

All the activities were developed by the authors of this study, based on existing national/international literature. The studying material were WM evaluation tests used by speech-language-hearing therapists and psychologists, textbooks with activity suggestions for WM rehabilitation, analysis of software available in Brazil, and cognitive rehabilitation material aimed at PL training.

Each of the five abilities was stimulated in three sessions. In the first one, the activities were carried out by means of auditory and visual stimuli (concrete material): object miniatures and concrete objects; in the second session, the same topic was approached, using auditory and visual stimuli, but this time with the support of images; and, in the third, last session of each ability worked on, the activities were composed only of auditory clues without visual stimulus resource. On Figure 1, there is a brief description of each session.

The 15 meetings were conducted always by the same person. In the activities, all the children were arranged in a circle so as to make it easier for the objects and/or stimulus images to be visualized, as well as for all the children to participate together. When the activity was individual, each child was called to come closer to the evaluator to handle (objects or images), as well as to answer in their turn, without being influenced or helped by the other participants.

Data analysis

Descriptive data analysis was used to characterize the sample. As for the quantitative analysis of each parameter evaluated, comparing the moment pre- and post-intervention (first and second evaluation, respectively) of each group (intragroup analysis), the Wilcoxon-test was used for paired samples, thus analyzing whether the performance in the tasks of that specific group had improved (in the case of G1, whether there had been improvement with the intervention program, and, in G2, whether the children had maintained their performance, or even improved it, though not being exposed).

The Mann-Whitney test was used for the analysis of performance between the groups (intergroup analysis) in each one of the two moments (pre-and post-intervention). Both tests used significance level of 0.05.

	Session no.	Name of the game	Brief description of the games/plays
CATEGORIZATION	1st	Box game	* categorizing the miniatures (e.g., animals, food...)
			* memorizing the sequence of the miniatures presented
	2nd	House pictures game	* categorizing the various pictures according to their place in the house
			* memorizing the sequence of the miniatures presented
			* guessing the picture: naming the picture by means of clues
	3rd	Word category game	* categorizing the list of stimulus words by colors, emotions, etc.
			* memorizing the sequence of words without visual support
VISUAL IMAGES	4th	Characteristics of the objects	* observing the details of the miniature presented and then recalling as many details as possible
			* driving observation towards certain details of the object and then answering the questions
	5th	Image of the drawing	* observing the details in the drawing presented and then recalling as many details as possible
			* driving observation towards certain details of the image and then answering the questions
	6th	Story play	* narrating a story with many details (without visual support) and then making questions
			* reproducing a new story told; this reproduction should have many details
ORDERS	7th	Commander's game	* the researcher gave orders along with the gesture (e.g., stand up from the chair) and the children should do it
			* repeating the orders given by the researcher, but without doing what was told, or the gesture
	8th	Butler game	* organizing the images according to the orders given by the researcher
			* repeating the action sequences given by the researcher, with length being increased
	9th	Music Band	* playing the musical instruments repeating the sequence presented by the researcher
			* developing a sequence with the musical instruments for the other child to repeat
WORDS/ DIGITS	10th	Detective	* after visually analyzing the miniatures, the child was supposed to "guess" which object had been removed from the box
			* memorizing the sequence of the miniatures presented
	11th	Seven-error game	* an image was presented and the researcher, through verbal explanation, helped the child to analyze the image
			Then, another image was presented and the child was supposed to "find" which errors there were, naming them
	12th	Parrot's Play	* repeating a list of words spoken by the researcher
			* repeating various sequences of digits spoken by the researcher
NONWORDS	13th	Foreigner's Play	* inventing "strange" names for the miniatures and then tell a story
			* speak the sequence of "strange" objects presented
	14th	Table Play	* filling in the blanks of the table with the "strange words" dictated by the researcher
			* reading the "strange words" in the cards, memorizing them and then repeat them without visual support
	15th	Echo play	* the child was supposed to repeat the "strange" word spoken by the evaluator and make up another word beginning with the last consonant of the researcher's word
			* repeating the sequences of "strange" words spoken by the researcher

Figure 1. Brief description of each session of the working memory intervention program – phonological loop used in this study

RESULTS

In Table 1, the average score of each group in all the parameters approached in this paper is described (reading comprehension, writing, reading and PL). The statistical analysis is in relation to intragroup performance, i.e., whether there was a difference in performance in each group between the two evaluations (each child's performance is compared to themselves in the first and second evaluation). It has been observed that G1 presented significant improvement in all parameters evaluated, whereas G2 only presented improvement in certain PL tasks.

In Table 2, the intergroup performance (between the groups) in the moment of evaluation (pre) and, afterwards, in reevaluation (post) is compared. It has been observed that, in the first evaluation, G1 differed from G2 in reading, writing, and reading comprehension tasks. However, in the reevaluation, G1 equaled G2 in the reading parameter, and neared G2 regarding reading comprehension and writing capacity. In the other parameters, there was no difference.

Table 1. Intragroup comparison in the various tests applied in the moment of evaluation and reevaluation

Tasks performed in evaluation and reevaluation	G1				P-value	G2				P-value
	Pre (evaluation)		Post (reev.)			Pre (evaluation)		Post (reev.)		
	Average	SD	Average	SD		Average	SD	Average	SD	
TCCAL – let	28	7.4	34	7.1	**0.0001***	36	1.8	37	2.3	0.2
Writing	14	5.9	17	6.4	**0.0003***	22	5.1	22	5.4	0.06
Reading	52	13.1	58	12.6	**0.0007***	62	5.5	63	4.1	0.4
Forward digit repetition	23	5.4	25	8.4	**0.02***	25	5.9	27	4.8	**0.001***
Pseudo-words repetition	34	3.4	37	2.1	**0.0007***	36	3.2	37	2.9	0.4
Meaningless words repetition – SSRS	21	2.3	24	2.8	**0.02***	22	2.7	23	2.8	**0.007***

Wilcoxon test - * statistical difference considering $\alpha = 0.05$
SD = Standard Deviation/ TCCAL – Let = Auditory and Reading Comprehension Contrastive Test - reading comprehension sub-item / Reev. = reevaluation

Table 2. Intergroup comparison in the various tests applied in the moment of evaluation and, afterwards, in reevaluation

Tasks performed	Evaluation (pre)				P-value	Reevaluation (post)				P-value
	G1		G2			G1		G2		
	Average	SD	Average	SD		Average	SD	Average	SD	
TCCAL – let	28	7.4	36	1.8	**0.00001***	34	7.1	37	2.3	**0.007***
Writing	14	5.9	22	5.1	**0.00001***	17	6.4	22	5.4	**0.006***
Reading	52	13.1	62	5.5	**0.0004***	58	12.6	63	4.1	0.06
Forward digit repetition	23	5.4	25	5.9	0.1	25	8.4	27	4.8	0.3
Pseudo-words repetition	34	3.4	36	3.2	0.07	37	2.1	37	2.9	0.9
Meaningless words repetition - SSRS	21	2.3	22	2.7	0.3	24	2.8	23	2.8	0.4

Mann-Whitney test - * statistical difference considering $\alpha = 0.05$
SD = Standard Deviation/ TCCAL – Let = Auditory and Reading Comprehension Contrastive Test - reading comprehension sub-item

DISCUSSION

This study developed and proposed the application of an intervention program with WM-based activities, specifically the PL in children who presented reading comprehension difficulties, analyzing whether improvement in PL ability would aid in reading comprehension.

The discussion and analysis of the results related to the effectiveness of this proposal were organized in order to discuss two aspects: intragroup comparison, in which each group was compared and analyzed to itself, according to its initial and final score; and, intergroup comparison, i.e., G1 was compared to G2 in the first and second evaluation moment. These two aspects were initially approached in relation to reading and writing activities, and posteriorly in relation to the performance in PL evaluation tasks (pseudo-words, non words and forward digit repetition).

In the intragroup comparison, the results have shown that G1 presented significant improvement in all evaluated variables (reading, writing, reading comprehension, and PL), indicating that the therapeutic program proposed here was an important factor for such improvement. As for the children in G2, they presented improvement only in certain PL tasks (forward digit repetition and meaningless words repetition).

Significant improvement in academic aspects of reading/writing and reading comprehension in G1 may be explained by the existing relation between working memory and learning aspects. Literature reports that working memory is essential to reading development, and that children with difficulties at school have deficits in this ability[5-8,15-19].

The WM is responsible for storing information until it is processed[24]. Therefore, if a child with alteration in this type of memory reads a more complex sentence, it will be difficult for them to store it until other cognitive

processes involved in language comprehension and production take place, thus causing reading comprehension to be impaired, as well as its posterior reproduction.

Hence, the activities intervening in phonological memory have shown to be efficient and effective in benefiting both the comprehension aspects and the reading/writing abilities. One of the few studies found that related working memory training with some type of difficulty in academic domains[15] reports that WM training had brought benefits to children with learning difficulties, including those with difficulties in arithmetic. The authors confirmed the effectiveness of WM training through the application of instruments for behavioral evaluation (e.g., WM evaluation through psychometric tests) and electrophysiological tests, as the modification of the wave in the P300 test after the training (lower latency, greater amplitude and better wave definition). However, another study, which verified the efficacy of WM training in children with dyslexia, did not obtain the same result[23].

The difference between the results presented here and those from previous studies[15,23] may be justified by the type of sample used. In both this study and that of Zhang et al. (2018)[15], the sample was made of children with "learning difficulties", i.e., they were children with low academic achievement due to a variety of reasons (inadequate school teaching, low stimulation, emotional changes, and others); in other words, it was an heterogeneous group. The investigation by Maehler et al. (2019)[23] studied the evolution of children who had supposedly presented the diagnosis of dyslexia, i.e., they were children with an average intellectual estimate, but who presented deficits in reading due to an alteration of neurodevelopment (conditions that represent an alteration in brain development).

In relation to the performance of the groups in the three instruments evaluating PL, it was observed that both groups presented significant improvement in reevaluation. This datum exemplifies the age effect, which interferes in PL performance. In the case of the child, age is positively related to performance in PL, i.e., the older the child, the better their PL capacity will be[24,27] - maturing process of the cognitive development.

In the intergroup evaluation, it was observed that in the first moment (evaluation) the groups differed only in reading, writing and reading comprehension tasks, as there was no difference in the PL evaluating tasks. As for the moment of reevaluation, G1 quantitatively neared the G2 children; though still inferior in writing and in reading comprehension, they equaled in the reading task (decoding).

A datum to be discussed is the similar performance between the groups in the PL evaluating tasks in the moment of evaluation. In this study, there was not observed an initial deficit in PL in children with reading comprehension difficulties, a datum different from other studies comparing WM between children with/without difficulties in academic domains. The difference in results between this study and others found in literature may be related to the diversity of the sample regarding age (evaluation of children in the beginning of their literacy process)[19], level of seriousness of learning disorders[16,17], complexity of the tests used for WM evaluation (e.g., backward digit repetition)[6,23,29], or due to statistical analysis (correlation tests)[7,36].

In this study, an initial difference in the performance in PL between the groups was not observed, as its sample was composed of already literate children, whose age was over eight years. Furthermore, the tests used evaluated only the PL, and were not as complex as those used to evaluate the central executive (backward digit, sequencing of numbers and letters, and others). Nevertheless, the improvement in performance in academic abilities after PL training demonstrates how important this ability is to the learning process and to the efficacy of this therapeutic program.

Concerning reading comprehension (decoding), the G1 children equaled those in G2 and neared them in the reading comprehension task. This datum demonstrates that PL ability is important to the whole reading process, from decoding to comprehension. As reading is developed, the ability to decode is reached first, while the comprehension of sentences/texts come posteriorly[9]; such fact is confirmed by this study, in which G1 equaled G2 firstly in word decoding, and then advanced in reading comprehension.

Regarding writing, in spite of G1's improvement with PL training, it did not equal G2. Such evolution in writing in G1 suggests that, as the reading ability was improved, the children may have enlarged their reading universe, coming to a greater contact with words and how they are written, diminishing the recurrence of misspellings.

One of the main limitations of this study is the non-reevaluation six months and one year after the intervention program was applied, in order to analyze whether the effects found in the short-term were maintained, and whether the children in G1 managed

at some moment to equal G2 in writing and in reading comprehension.

Some Brazilian authors claim that studies involving specifically PL training in children with learning difficulties must be carried out, in order to confirm its scientific efficacy, just as there already is a consensus in literature concerning the positive relation between phonological awareness-based therapy and the literacy process[7]. Other authors also mention that the choice for which type of therapy will be performed in the cases of alterations in academic domains should be carefully made, since some programs benefit more the children with difficulties in their literacy process, whereas others bring better benefits for children in a more advanced reading/writing level. Each training modality has a potential benefit[13].

CONCLUSION

This study has demonstrated that the intervention program with WM-based activities, specifically PL, brings benefits to children who presented reading comprehension difficulty, and they improved decoding (reading) and writing capacity. The strategies used here are simple activities that may be carried out in the classroom with the objective of improving cognitive capacity of children, diminishing the prevalence of school-related difficulties; they may also be used as part of a rehabilitation program for children with learning disorders.

This study not only confirms that PL ability is important to the learning process, but also shows that including simple strategies for the development of cognitive abilities in the classroom may change the educational scenario in Brazil.

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