Original Article

Artigo Original

Short-term phonological memory in preschool children

Memória de curto-prazo fonológica em crianças pré-escolares

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Keywords

Child; preschool
Child language
Short-term memory
Memory
Evaluation

ABSTRACT

Purpose: The purpose of this study was to design a short-term memory test, to describe quantitative performance in typically language developing children and to verify the relationship between the non-words repetition and oral phonological measure. **Methods:** The participants included 136 typically language developing children aged from 3 years to 6 years and 11 months old in this study, who were evaluated. The test consisted of 40 non-words of one, two, three, and four syllables. The subjects' repetitions were transcribed and the number of right answers was calculated for each age range. **Results:** The effect of age was observed in the test, as well as the effect of length, only for disyllabic non-words. The performance in the non-word repetition task showed correlation with the oral phonology measure. **Conclusion:** The test designed in this research was able to verify the short-term memory in typically language developing children and the results showed correlation between this memory and phonological performance.

Descritores

Pré-escolar
Linguagem infantil
Memória de curto-prazo
Memória
Avaliação

RESUMO

Objetivo: Elaborar um teste de memória de curto-prazo, descrever o desempenho quantitativo de crianças normais no referido teste e verificar a relação entre a repetição de não palavras e a fonologia dessas crianças. **Métodos:** Foram avaliados 136 sujeitos com desenvolvimento normal de linguagem, com idades entre 3 anos e 6 anos e 11 meses. O teste foi constituído de 40 não palavras de uma, duas, três e quatro sílabas. As repetições dos sujeitos foram transcritas e o número de acertos foi calculado para cada idade. **Resultados:** Ocorreu efeito de idade e efeito de extensão somente a partir de não palavrascom duas sílabas. O desempenho na repetição de não palavras apresentou correlação com o desempenho em prova de fonologia. **Conclusão:** O teste elaborado conseguiu verificar a memória de curto-prazo em crianças em desenvolvimento normal de linguagem e houve relação entre esse tipo de memória e o desempenho fonológico dos sujeitos.

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INTRODUCTION

The development of phonological short-term memory (PSTM) is essential for the development of child language, allowing the recollection and repetition of past events in the absence of their stimuli, acquisition of new knowledge, and integration of information[1]. This memory is in charge of storing and manipulating the necessary information to perform complex cognitive operations, such as learning, language understanding, and reasoning[2].

Memory deficits may lead to difficulties in understanding and in language learning, because the child cannot remember the heard information (language input) or process it fast enough[3].

The repetition of non-words (RNW) assesses the capacity of temporary phonological storage of PSTM[4]. For the right repetition to occur, it is necessary to discriminate the acoustic signal, the codification of this signal in phonological representation, and the active maintenance of the presented sequence for the articulation of the target non-word (NW)[5].

The RNW represents a sensitive measurement of the storage capacity of this memory in children aged less than six years old, i.e., in English and Spanish speakers[6,7]. However, the use of pseudowords facilitates their storage in PSTM, because of the phonological and/or morphological association with real words that exist in the studied language.

When performing the morphological association, the children decrease the extension of the item to be repeated, thus making it easier to repeat it and improving their performance in the test (e.g., lafo*dity* – dity represents a nominal suffix). Likewise, when performing the phonological association, a pseudoword is similar to a real word, and the child makes a semantic association, thus making it easier to store the sequence of phonemes for repetition (e.g., gat is similar to cat)[8], which does not occur with words.

Many studies observed that children with average language development demonstrated more correct RNWs with age[9-11]. Besides this aging effect, these studies also showed an extension effect, that is, the higher the number of syllables in the NW, the lower the number of correct answers. A study with normal English speaker children, aged six years old, demonstrated that there was no difference between monosyllables and disyllables. Significant differences occurred between the number of correct answers of NW formed by three and four syllables[11].

The good performance in this type of task depends on the phonological skills of the participant and on the preserved temporary storage system of the phonological information[12-14]. Moreover, RNW, especially from the age of six years, seems to be influenced by PSTM, articulatory precision, and the frequency of phonemes in the language. Therefore, the use of NWs with phonemes that are common in the language has a facilitating effect[15].

The evaluation of PSTM also checks the processing skills of speech, including discrimination and hearing memory, formation of representations of hearing information, and motor speech planning, which can also justify the low performance in RNW tasks[16,17].

Many studies have demonstrated a positive correlation between PSTM and learning of new words. Such correlation exists, because the listener stores the phonological form of the new lexical item in his memory, and associates his or her semantic and syntactic references to this form[18,19].

PSTM is also correlated with syntactic development. The individual stores the main lexical items that will compose the sentence, while using the syntactic rules of each language. Afterward, the person performs the articulatory programming to produce speech[19]. Children with better performance in PSTM tasks present a longer repertoire of words and longer and more syntactically complex sentences[8,18].

The objectives of this study were to elaborate a PSTM test, given the lack of national studies that use NW instead of pseudowords, which analyze the same selected age group and considered the phonological development of Brazilian Portuguese (BP) language as a criterion of right/wrong answers, and to propose the use of a PSTM test by speech language pathologists, considering the numberless relationships between childhood language development and this type of memory.

The main objective of this study was to elaborate a test to verify PSTM in normal children aged from 3 to 6 years and 11 months old. With this goal, after the elaboration of the test, its effectiveness was tested by means of the application, description, and analysis of the participants' performance, considering the different age groups and the extension of the NW. Besides, given the narrow relationship between PSTM and language measures, the performance in this test was correlated to the phonological performance of the participants.

METHODS

Ethical aspects

This research was approved by the ethics committee of the institution, n. 152/03. All of those in charge of the children signed the informed consent.

Participants

This study was conducted with 136 children with normal language development (GP), in the age group from 3 to 6 years and 11 months old, divided into four groups as follows: GP1 (3 years old), GP2 (4 years old), GP3 (5 years old), and GP4 (6 years old), with 17 boys and 17 girls in each group.

All of them attended day care centers and municipal schools and were monolingual BP speakers. The participants were selected from the standardized tests of expressive vocabulary and phonology (comprised of tests that consist of naming figures and imitating words)[20].

Inclusion criteria for the study were as follows: expected performance for chronological age in the aforementioned language tests, absence of complaints related to communication difficulties, and previous speech language pathology and audiology and/or psychological care.

Material

The Phonological Short-Term Memory Test (PSTMT) elaborated for this research was based on the Children's Test of Non-word Repetition[21,22]; however, as demonstrated by some studies, there are facilitating factors that influence the PSTM and improve the performance in NW and pseudoword repetition tests[3,14,23]. Therefore, following some aspects were taken into account to develop the PSTMT in BP language:

- First of all, the choice was for RNW, with no similarity to real words in BP language. The use of pseudowords was ruled out to prevent the participants, especially those with more organized lexis, to use their lexical knowledge in associations; thus, favoring the storage and the sequential phonological organization of the pseudowords for its repetition[24,25].
- The NWs presented low articulatory complexity, being constituted only by consonant-vowel syllables. Studies have demonstrated that the increased complexity of the syllabic structure may negatively interfere in the repetition of the presented items[26].
- The phonemes acquired in the first years of phonological acquisition development of BP language were selected with the objective of decreasing the necessary articulatory demand for the repetition of phonological sequences in NWs.
- The age for the phonological acquisition of BP language was respected, using results from national studies concerning the phonological development in normal children[20], to avoid the classification of correct repetitions as incorrect ones, due to a developing phonological system. Therefore, omissions and substitutions of NW phonemes, which were still in the acquisition stage, were considered as correct answers.
- There was no occurrence of atonic syllables in pre-tonic position, because they are more often omitted[11,24].
- All of the NWs were stressed as paroxytones, representing the most recurring BP language standard.
- Syllables representing real BP monosyllables, were not selected, to avoid lexical recognition and facilitate repetition in the test[23].
- No phonemes were repeated in the same NW, thus avoiding the phonological similarity effect[27].

According to previous criteria, the PSTMT was constituted of 40 NWs, divided into four lists including groups of 10 NWs, with one, two, three, and four syllables. The used phonemes were as follows: /p/; /t/; /k/; /m/; /n/; /f/; /a/; /e/; /i/; /o/; /u/; /ɛ/ e /ɔ/.

The NWs created for the test were judged by speech language pathologists, who were also post-graduate students in language, as to the similarity with real BP words. The judged NWs that represented a 20% or more percentage of association with real BP words were excluded. New NWs were created, and then judged again. Three judgments were necessary to conclude the final PSTMT used in this study (Appendix 1).

Procedure and analysis

All participants were individually assessed in two sessions. In the first session, vocabulary and phonology were evaluated[20] (inclusion criteria) and in the second session, PSTMT was applied. After the phonological test was analyzed, the Percentage of Consonants Correct – Revised (PCC-R) was calculated. This measure was used afterward to correlate the performances in the phonology test and the PSTMT.

Expressive Vocabulary and Phonology[20]

The expressive vocabulary and the phonological pattern of participants were assessed to verify if the phonological and lexical developments were age appropriate.

Percentage of Consonants Correct – Revised

The PCC-R was calculated from the phonological test. It is a numerical measure that allows verification of the level of commitment and intelligibility of speech and communication[28,29].

In this study, PCC-R was used, because this index sums up all the correct answers in naming tests and phonological imitation, even in normal individuals[16,29]; thus, enabling the correlation analysis between phonological and memory tests.

Phonological Short-Term Memory Test

Each NW was pronounced once by the examiner, who asked the child to repeat it immediately. The lists of NWs were presented, with one to four syllables, in this order. Data were registered in a digital recorder, and then phonetically transcribed into a specific protocol (Appendix 1), so that the number of correct answers could be calculated. Repetition was considered to be correct if the subject produced the same sequence of phonemes of the NW. If the answer did not coincide with the target, mistakes made by the child were verified in the phonological test. In case, the change or omission carried out in the imitation of the NW was similar to omissions or substitutions from the phonology test, the response was considered as correct. When the change or omission in the NW imitation did not coincide with omissions or substitutions in the phonology test, the answer was considered as wrong.

One point was attributed to each item repeated correctly, and zero point to those repeated incorrectly[6]. The points were added for each part of the test (monosyllables, disyllables, trisyllables, and polysyllables) and for the total. For each part, maximum score was 10 points and for the total test, maximum score was 40 points.

For the statistical analysis, Pearson's correlation test and linear regression analysis were used. The adopted significance level was 5% ($p<0.05$).

RESULTS

The means of PCC-R for total GP in imitation and naming tests were 95.91% and 95.54%, respectively (Table 1). A moderate correlation was observed between the performance in PSTMT and PCC-R in naming and imitation tests, for the ages of 3 to 6 years old (Table 2).

Table 1. Means of Percentage of Consonants Correct – Revised in the phonological test by age group

Age group (years)	PCC-R Naming (%)	PCC-R Imitation (%)
3:0 to 3:11	92.80	92.40
4:0 to 4:11	94.76	95.00
5:0 to 5:11	97.54	97.69
6:0 to 6:11	97.04	98.52
Total	95.54	95.91

Caption: PCC-R = Percentage of Consonants Correct – Revised

Table 2. Results of the Pearson's correlation and the Percentage of Consonants Correct – Revised, Imitation and Naming, and correct answers in the Phonological Short-Term Memory Test by age group

	PCC-R Imitation		PCC-R Naming	
	r	p-value	r	p-value
PSTMTxPCC-R 3 years old	0.464	0.006*	0.436	0.01*
PSTMTxPCC-R 4 years old	0.069	0.696	0.274	0.11
PSTMTxPCC-R 5 years old	0.075	0.707	0.266	0.09
PSTMTxPCC-R 6 years old	0.411	0.012*	0.396	0.02*
PSTMTxPCC-R total	0.129	0.139	0.174	0.04*

*p-value<0.05

Caption: PCC-R = Percentage of Consonants Correct – Revised; PSTMT = Phonological Short-Term Memory Test

For the items with two, three, and four syllables, the mean of correct answers was higher for older children, except for the age group of 4 years old. The result for participants at the age of 4 years was associated with an asymmetric distribution and more variability in the number of correct answers for monosyllables (Table 3). These data were confirmed from the inferential analysis described previously.

In all NWs, except for monosyllables, there was significant decrease in the mean of correct answers for all age groups (Figure 1).

There was a moderate correlation between the number of syllables of NWs and the correct answers of PSTMT, except for monosyllables (Table 4).

To check if the mean of correct answers in the PSTMT was related with the independent variables, such as age and phonological performance (PCC-R - Imitation and Naming), a linear regression model was used. The regression equations obtained for each age are found in Table 5.

From the Q-Q Plot graph (Figure 2), linearity was observed, thus proving a normal distribution of the variables that are present in the created model, and the tendency to gather data.

Regression analysis verified that the number of syllables was a predictive variable for the performance of RNW for normal children (Table 5). Therefore, for the age of 3 years ($\hat{y}$=11.147–1.144x), with one extra syllable, there was a mean decrease of 1.144 correct answers in the PSTMT. Likewise, for children aged 4 years old, the model ($\hat{y}$=10.971-1.150x) represented a decrease of 1.150 correct answers in the PSTMT when an extra syllable was added. At the age of 5 years ($\hat{y}$=10.750-0.638x), it was observed that with an extra syllable, there was a mean decrease of 0.638 correct answers. For the age of 6 years, the equation ($\hat{y}$=10.382-0.332x) estimated a decrease of 0.332 correct answers in PSTMT with the addition of one extra syllable.

The elaborated regression model confirmed that with the addition of a syllable, the number of correct answers in PSTMT decreased, and such decrease was more prevalent among the youngest children, indicating that they would be more sensitive to the extension effect.

DISCUSSION

The highest means of correct RNWs with aging represent an increased capacity of PSTM storage during childhood. These results were also found in other studies with children presenting normal language development who were English, Spanish, and BP speakers[3,7,11,12].

The means of correct repetitions in PSTMT were higher than the means of other international studies, which may be related to phonotactic differences and/or to the velocity of articulation[3,7,11].

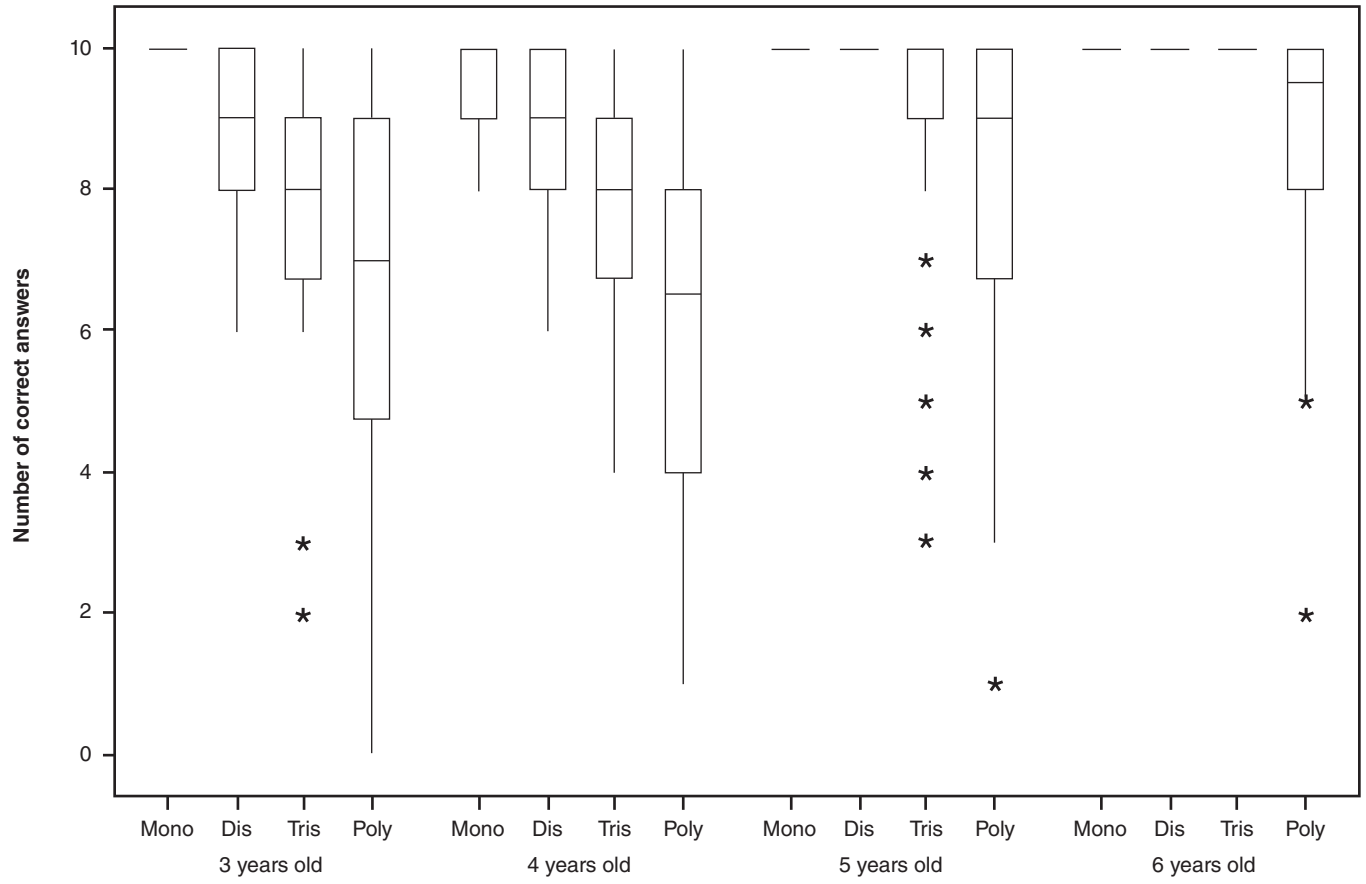
A proper performance in a PSTM task, especially related to NWs, depends on good hearing perception skills, because phonetic information should be represented in phonological information, sequentially correct, to be repeated[11]. With age, children improve their knowledge concerning syllabic structures and the possible combinations of language sounds, and this phonological knowledge facilitates the RNWs[12,13,24,25]. Likewise, when the sequence of phonemes or syllables is very common in the language, children present better RNW[7,14-16].

The mean of correct answers in PSTMT decreased with the increase in number of syllables for all age groups and for the total number of children, thus confirming the extension effect (Table 5). The performance only decreased from the items with two syllables(Table 4), and the decrease in correct answers were more intense amongst younger children, which indicated that they would be more sensitive to this effect. Such a decline was consistent with the model of temporary storage capacity of this type of memory[1,18,22].

The regression analysis also enabled to prove that PCC-R, in the naming test, was a predictive variable for the performance of PSTM (Table 5). Such a result corroborates studies stating that phonological skills of the child, positively influence the temporary storage of phonological information in PSTM[12,13,15,26].

Table 3. Mean of correct answers in the Phonological Short-Term Memory Test by age and extension of the non-word

Age group (years)	Monosyllables	Disyllables	Trisyllables	Polysillables	Total
3:0 to 3:11	9.88	9.00	7.79	6.47	33.15
4:0 to 4:11	9.62	8.82	7.82	6.12	32.38
5:0 to 5:11	9.91	9.76	8.85	8.09	36.62
6:0 to 6:11	9.91	9.76	9.71	8.82	38.21
Total	39.32	37.35	34.18	29.50	140.35



Caption: Mono = monosyllables; Dis = disyllables; Tris = trisyllables; Poly = polysillables

Figure 1. Number of correct answers in the Phonological Short-Term Memory Test per non-word for each age group

Table 4. Results of the Pearson's correlation between the extension of non-words and the performance in the Phonological Short-Term Memory Test

	r	p-value
MonosyllablesxPSTMT	0.113	0.19
DisyllablesxPSTMT	0.401	0.00*
TrisyllablesxPSTMT	0.465	0.00*
PolysillablesxPSTMT	0.404	0.00*

*p-value<0.05

Caption: PSTMT = Phonological Short-Term Memory Test

Table 5. Regression equations of the number of correct answers in the Phonological Short-Term Memory Test

Age group	Estimated equation	95%CI
3:0 to 3:11 years old	$\hat{y}$=11.147-1.144*x*	(-1.305; -0.983)
4:0 to 4:11 years old	$\hat{y}$=10.971-1.150*x*	(-1.301; -0.999)
5:0 to 5:11 years old	$\hat{y}$=10.750-0.638*x*	(-0.791; -0.486)
6:0 to 6:11 years old	$\hat{y}$=10.382-0.332*x*	(-0.429; -0.236)
3:0 to 6:11 years old	$\hat{y}$=10.813-0.816*x*	(-0.964; -0.668)

Caption: 95%CI = 95% confidence interval

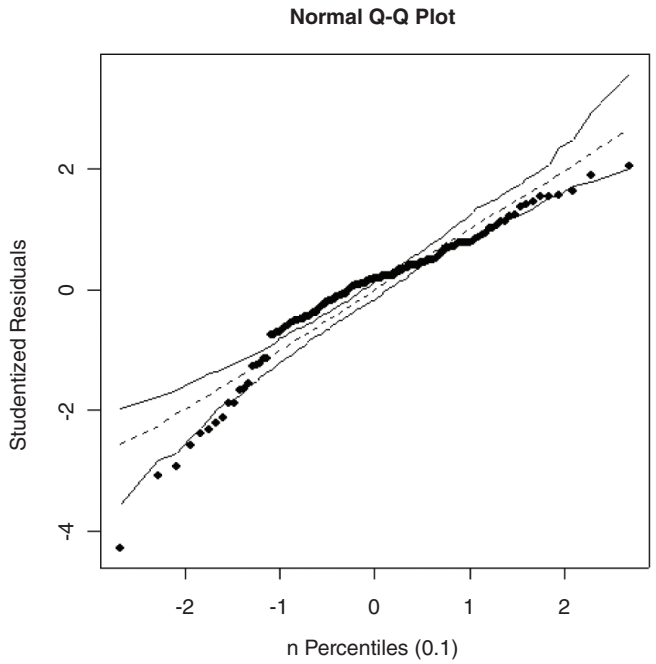


Figure 2. Envelope graph to adjust the linear regression model of the number of correct answers in the Phonological Short-Term Memory Test

Even though the sample was not random and the procedures were adequate to test the PSTM in Brazilian children, the authors will perform other studies to verify the psychometric parameters of the PSTMT, thus enabling its validation.

Besides, new studies should be carried out to examine the clinical convenience of the PSTMT. Nowadays, its characteristics are investigated among children with phonological disorders and others specifically related to language.

CONCLUSION

The authors elaborated a test that allowed verification of the capacity to repeat NWs among normal children, BP speakers, aged between 3 years and 6 years and 11 months old. The performance in the PSTMT presented a direct relation with age, extension of the NWs and better performances in phonological tests.

**AR was in charge of the project, data collection, formatting and analysis; DMBL supervised data collection, oriented the study design, accompanied collection and collaborated with data analysis and general guidance of the stages of execution and elaboration of the manuscript.*

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Appendix 1. Teste de Memória de Curto Prazo Fonológica

Nome:_____ Idade:_____

D.N.: ___/___/____ Data Av.:___/___/___

Teste de Memória de Curto-Prazo Fonológica (Rodrigues e Befi-Lopes,2007)

MONOSSÍLABOS				
Estímulos	Transcrição da Resposta	Análise da Resposta a partir dos P.F.	Acerto	Erro
pu				
mó				
ca				
mi				
fú				
fi				
có				
ni				
té				
fó				
nº total				
% total				

TRISSÍLABOS				
Estímulos	Transcrição da Resposta	Análise da Resposta a partir dos P.F.	Acerto	Erro
quifápi				
mocáfi				
nitépu				
cafópi				
nicófa				
pequífo				
tefápi				
nefápu				
nifúco				
pecófa				
nº total				
% total				

DISSÍLABOS				
Estímulos	Transcrição da Resposta	Análise da Resposta a partir dos P.F.	Acerto	Erro
mípe				
nifa				
fúpe				
téfi				
púme				
quíne				
níte				
múpo				
quífa				
fópi				
nº total				
% total				

POLISSÍLABOS				
Estímulos	Transcrição da Resposta	Análise da Resposta a partir dos P.F.	Acerto	Erro
nipofáte				
pefacóni				
mopeníca				
fipotéma				
mopecâne				
tefapúmi				
cofanípe				
micapúfo				
puquitéfa				
necafípu				
nº total				
% total				

Total de Acertos no Teste:	
% Total de Acertos no Teste:	

*Foram acentuadas as sílabas tônicas na escrita ortográfica