Original Article

Relationship between percentage of consonants correct and phonological working memory in specific language impairment

Relação entre a porcentagem de consoantes corretas e a memória operacional fonológica na alteração específica de linguagem

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ABSTRACT

Purpose: To verify whether age influences phonological performance and working memory, and whether there is correlation between phonological working memory and severity of phonological disorders in children with language impairment. **Methods:** Participants were 30 children diagnosed with language impairment, with ages ranging from 4 to 6 years. Data from the assessment of phonological working memory and phonology (measured by the Percentage of Consonants Correct – Reviewed) were collected and statistically analyzed. **Results:** Age did not influence phonology and phonological working memory, but there was positive correlation in the comparison between performances on phonological working memory and both phonology tasks. **Conclusion:** Age does not support the improvement of phonological abilities and phonological working memory. However, there is positive correlation between phonological working memory and the severity of phonological disorders, suggesting that the better the speech production, the better the phonological working memory.

Keywords: Child language; Language; Language development disorders; Language tests; Memory, short-term; Age effect

INTRODUCTION

Language impairment (LI) is a primary impairment, and cannot be justified by other pervasive developmental impairments. The child may have difficulties in higher mental functions, but in much lower degree than those presented in language. The cases resulting from these alterations may characterize either language delay (LD) or specific language impairment (SLI)[1,2].

In LD, language development occurs in the same order as in typical development, but with a delay considering the chronological age. SLI, on the other hand, is characterized by a deviation in language development, because specific language skills can be acquired in a different order from that observed in normal development. Hence, some abilities might be better developed than others, and the child presents specific difficulties in some aspects of language[2].

Inclusion criteria for SLI comprise performance below the expected for chronological age in at least two standardized tests, and performance intellectual coefficient (IQ) over 80 in an intelligence test[2].

A remarkable characteristic is the heterogeneity of linguistic expressions. However, it is frequent the maintenance of developmental phonological processes and the presence of idiosyncratic processes[3], restricted vocabulary[4], linguistic processing deficits[5], working memory deficits[6], and impaired linguistic comprehension[7].

In recent studies, phonological working memory is pointed out as a possible clinical marker of this disorder[8]. This deficit would be one of the factors that affect lexical acquisition,

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Conflict of interests: None

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Received: 4/20/2011; **Accepted:** 8/29/2011

morphosyntactic performance, and sentence comprehension in this population[6,8].

Regarding phonology, recent studies comparing the performance of children with LI and their chronological peers indicate that their phonological profile is characterized by maintenance of developmental processes and production of idiosyncratic phonological processes[3], besides preference to producing disyllabic words[9], and omission of unstressed syllables[10].

Literature cites the use of the Percentage of Consonants Correct (PCC) to qualitatively determine the severity of phonological impairment. Based on PCC results, it is possible to classify the phonological disorder as mild (more than 85% of correct consonants), mild-moderate (between 65% and 85%), moderate-severe (between 50% and 65%), and severe (lower than 50%)[11].

PCC considers phoneme omissions, substitutions and distortions as errors, and it is indicated for children with speech sound disorder between 3 and 6 years of age. However, in order to compare speakers of several ages with distinct speech characteristics, the PCC Revised (PCC-R) was proposed, considering only substitutions and omissions as errors[11].

Working memory is a information management system, which refers to a hypothetical concept in which the information is held for a short period of time while is used in cognitive tasks[12,13].

Working memory is composed by four integrated components: central executive, phonological loop, visuo-spatial sketchpad, and episodic buffer. Concisely, the central executive is responsible for regulating the flow of information, process and store information. The phonological loop (phonological buffer) stores phonological information for a restrict time (auditory information transformed into phonological code), and is responsible for the articulatory control (articulatory rehearsal or reverberation), which keeps information active on memory. Meanwhile, the visuo-spatial sketchpad is responsible for processing and maintaining visual and spatial information. The episodic buffer integrates all these information with long-term memory, making it conscious[12,13].

The phonological loop or phonological working memory (PWM) corresponds to the working memory that stores a limited number of phonological information while performing tasks that require them. PWM capacity depends on the acquisition of phonological and articulatory properties of the language[14].

In a literature review, it was verified that, during language development, there is improvement on the performance in phonological working memory tasks as age increases, due to an upgrade on the retention capacity of these information[14]. However, the performance of children with SLI is affected by lexicality and phoneme frequency effects[15].

A research with children between 5 and 7 years of age diagnosed with speech sound disorder showed that those with poorer phonological working memory performance had more unintelligible speech. This fact allowed the researchers to conclude that there is a relationship between phonological working memory and severity of the phonological disorder[16].

In a study with bilingual children between 7 and 10 years of age, with and without SLI, whose first language was Spanish and the second was English, it was found that SLI children adequately repeat a significantly lower number of nonwords when compared to typically developing children, indicating that SLI children have phonological working memory deficits[17].

Based on the exposed, the purpose of this study was to verify whether age influences phonological performance and working memory, and also whether the performance on phonological working memory test is correlated to the severity of phonological disorders in children with language impairment.

METHODS

Participants were 30 children of both genders with ages ranging from 4 to 6 years, diagnosed with language impairment. Children were enrolled in speech-language therapy at the Laboratory of Language Development and Disorders of the School of Medicine of Universidade de São Paulo (USP). This outpatient service attends mostly users of the public health system. Each of the three age groups comprised ten children, all of whom lived nearby the laboratory and attend regular preschool.

The diagnosis was based on internationally adopted exclusion (hearing loss, neuromotor, cognitive or pervasive developmental disorders) and inclusion (performance under the expected for chronological age in at least two standardized tests) criteria. The tests used were: expressive vocabulary[18], phonology[19], fluency[20], pragmatics[21], production and comprehension of prepositions[22], and mean length utterance[23].

The Raven's Progressive Matrices test[24], applied by a qualified professional, was used to assess IQ. The test assesses nonverbal intelligence and is internationally used in cases of language disorders.

Data collection used the ABFW Phonology test[19] and the Phonological Working Memory test[25]. These tests were applied on the child's last assessment and they were registered in their laboratory's records. When this research was conducted, children had had, in average, 23 months of language therapy. The Percentage of Consonants Correct was calculated (according to PCC-R criteria) based on imitation and naming tasks from the ABFW Phonology test.

The Phonological Working Memory (PWM) test was developed to assess the performance of children between 3 and 6 years of age. The child is asked to repeat predetermined nonwords which are composed by the first phonemes acquired in Brazilian Portuguese (/p, m, k, f, n, t/). These nonwords are divided into four groups, according to their length (one, two, three or four syllables)[25].

Data were tabulated and, for each child, the following information were obtained: age, imitation PCC-R, naming PCC-R, and percentage of correct answers on the PWM test.

This research and its term of free and informed consent were approved by the Ethics Committee for the Analysis of Research Protocols of the General Hospital of the School of Medicine of Universidade de São Paulo, under protocol number 535/06.

Statistical analyses were carried out using Pearson's correlation coefficient to compare the performance in all tasks,

Paired t-test and Analysis of Variance (ANOVA) to compare each variable between groups, since normality prerequisites were assumed (Kolmogorov-Smirnov >0.05). The significance level adopted was 5% ($p<0.05$).

RESULTS

Considering children's performance on both tests, the descriptive analysis showed that the mean correct answers tends to increase with age (Tables 1 to 4). However, the ANOVA did not find statistical difference for imitation ($F=1.415$, $p=0.260$), naming ($F=3.082$, $p=0.062$), and phonological working memory ($F=2.117$, $p=0.140$).

The descriptive analysis of phonological working memory showed that the length of nonwords had a negative influence on the number of correct answers. In order to verify whether this effect is statistically relevant, the Mauchly's test was used. As the sphericity hypothesis was violated, the Greenhouse and Geisser correction was used, with significant effect ($F_{(2.237)}=142.24$, $p<0.001$, $\chi^2=0.697$, power=1.00). Contrasts analysis revealed a decreasing linear tendency ($F_{(1.29)}=142.42$, $p<.001$), which allows us to conclude that increasing the number of syllables implies a gradual decrease on mean correct answers in this test. Because the values for statistical power and effect size (χ^2) are considered good, it is possible to say that the difference found actually occurs in the population.

For phonology, the descriptive data suggested a better performance on imitation than on naming task for all ages, which was confirmed by the Paired t-test ($t(29)=3.837$; $p<0.05$).

However, the comparison between the percentages of correct answers in these tests indicated that positive correlation between performance on phonological working memory for both phonology tasks (Table 5).

DISCUSSION

The results indicate that in this population age didn't favor the improvement of phonological abilities and working memory, but the performance on these abilities showed a positive correlation.

These findings are different from those related to typical language development regarding age, because this is one of the variables able to predict a good working memory performance[25]. This means that, in typical development, the expansion of the capacities of phonological retention, phonological and lexical acquisition are related to age, but in children with LI

Table 1. Descriptive analysis of performance by age group in imitation's Percentage of Consonants Correct - Reviewed

Age	n	Minimum	Maximum	Mean	SD
4 years	10	20.6	84.1	55.5	20.5
5 years	10	30.8	92.5	66.1	18.0
6 years	10	35.5	98.1	70.2	21.6

Note: SD = standard deviation

Table 2. Descriptive analysis of performance by age group in naming's Percentage of Consonants Correct - Reviewed

Age	n	Minimum	Maximum	Mean	SD
4 years	10	0.0	94.4	38.4	31.4
5 years	10	31.1	83.3	56.9	15.8
6 years	10	31.1	95.6	65.0	23.9

Note: SD = standard deviation

Table 3. Descriptive analysis of performance by age group in Phonological Working Memory

Age	n	Minimum	Maximum	Mean	SD
4 years	10	22.5	75.0	48.5	17.1
5 years	10	37.5	97.5	58.5	22.7
6 years	10	30.0	100.0	67.8	22.46

Note: SD = standard deviation

Table 4. Average performance by age group in each test

Age	PCC-R		PWM				
	Imitation (%)	Naming (%)	One syllable	Two syllables	Three syllables	Four syllables	Total
4 years	55.5	38.4	89.0	62.0	31.0	12.0	48.5
5 years	66.1	56.9	91	68.1	44	22	58.5
6 years	70.2	65.0	98	77	53	35.5	67.8

Note: PCC-R = Percentage of Consonants Correct - Reviewed; PWM = Phonological Working Memory

Table 5. Pearson correlation coefficient for Phonology and Phonological Working Memory

	r	p-value
PCC-Rim x PWM	0.530	0.001*
PCC-Rnam x PWM	0.554	0.001*

* Significant values (p<0.05) – Pearson correlation

Note: PCC-Rim = imitation's Percentage of Consonants Correct - Reviewed; PCC-Rnam = naming's Percentage of Consonants Correct - Reviewed; PWM = Phonological Working Memory

this process will depend on other factors, due to the rupture on the development sequence[2].

However, the PCC-R was pointed as a predictor[25], which was confirmed here, since the better the phonological performance, the more correct answers were found on phonological working memory[13,14,16]. These findings agree with literature both for typical development and for speech sound disorder, since the worse the intelligibility, the worse the phonological working memory performance[16]. Hence, it is evident that phonological processing is impaired on these children[8,15].

When phonological working memory is related to the imitation task, a direct relation was verified, because the child needs to discriminate phonemes and retain the information to reproduce it immediately[14]. In the naming task, on the other hand, there is an indirect interference, because it occurs during lexical acquisition[6,8].

In this study a negative effect was found regarding the length of nonwords, corroborating studies related to the performance of typically developing children[14], children with speech sound disorder[16] and children with SLI[6,15].

The fact that SLI children show a more limited phonological working memory capacity and less success when the demand of phonological information to be stored increases, bases the discussion that this impairment has consequences in other language areas, such as lexical improvement and sentence comprehension[6].

Taking the phonological working memory deficit into account[6,15], the better performance found on the imitation task may be easily understood by the fact that, in imitation, the child has the model of phonological pattern to reproduce, which might help his/her production. On the naming task, no facilitator is provided, and he child needs to access only the lexical knowledge and the phonological scheme previously stored.

As limitation of this study, it is possible to mention the narrow age range considered, once it might be interesting to research this relationship on children older than 6 years (when it is possible to confirm SLI diagnosis), in order to observe whether this correlation remains.

The results presented here indicate that speech-language pathologists should be aware of the phonological aspects since the assessment, because a child with language impairment whose phonology is very affected will probably have phonological working memory impairments. Consequently, his/her development will be harder on associated abilities, which might affect even reading and writing acquisition. Hence, it is essential to consider the length of words and phrases that are used in therapy, in order to achieve the best from therapy.

CONCLUSION

This study allows the conclusion that, for language impaired children, age does not favor the improvement of phonological abilities and phonological working memory. However, there is positive correlation between phonological working memory and the severity of phonological disorders in these children, which means that the better the speech production, the better the phonological working memory performance.

RESUMO

Objetivo: Verificar se há influência da idade no desempenho fonológico e na memória operacional e se há correlação entre o desempenho em prova de memória operacional fonológica e o índice de gravidade da alteração fonológica em crianças com alteração específica de linguagem. Métodos: Participaram deste estudo 30 sujeitos com diagnóstico de alteração específica de linguagem, com idades entre 4 e 6 anos. Foram coletados dos prontuários dados referentes ao desempenho nas provas de memória operacional fonológica e fonologia (utilizando o índice de Porcentagem de Consoantes Corretas – Revisado). Análises estatísticas pertinentes foram realizadas. **Resultados:** Não houve influência da idade para a fonologia e para a memória operacional, mas houve correlação positiva na comparação do desempenho na prova de memória operacional fonológica com ambas as tarefas da prova de fonologia. **Conclusão:** A idade não favorece o aprimoramento das habilidades fonológicas e de memória operacional fonológica. Porém, há correlação positiva entre a memória operacional fonológica e o índice de gravidade da alteração fonológica, o que significa que quanto melhor a produção de fala, melhor o desempenho da memória operacional fonológica.

Descritores: Linguagem infantil; Linguagem; Transtornos do desenvolvimento da linguagem; Testes de linguagem; Memória de curto prazo; Efeito idade

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