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Relationship between hearing capacity and performance on tasks of speech perception in children with hearing loss

Relações entre medidas de capacidade auditiva e desempenho em tarefas de percepção da fala em crianças com deficiência auditiva

Natália de Camargo[1]
Beatriz Castro Andrade Mendes[1]
Beatriz Cavalcanti de Albuquerque Caiuby Novaes[1]

Keywords

Speech Intelligibility
Speech Perception
Auditory Perception
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ABSTRACT

Purpose: To establish the relationship between the performance on word recognition tasks, using words with and without sense and degree, and the configuration of hearing loss, by using Speech Inteligibility Index (SII) values as indicators, in children with hearing loss. **Methods:** SII were established for 55 and 65 Decibel of Sound Pressure Level (dB SPL) input sounds of ten children presenting bilateral sensorineural hearing loss (SNHL), adapted with bilateral hearing aids, and who have oral language as the main mode of communication. The children were submitted to a word and nonsense-word repetition task of two or three intensity degrees. Their productions were analyzed according to the Word Association for Syllable Perception (WASP) Protocol. In the data analysis, the values of SII were compared with the results obtained in each analysis criterion. **Results:** Pertaining to the words, there was statistically significant difference between the two types of stimuli in 55 dBSPL. As for the performance of consonants and point of articulation, there was a statistically significant difference between stimuli types in 65 and 55 dB SPL, and between intensities 65 and 55 dB SPL in nonsense words. **Conclusion:** Overall, there was no regularity in the relationship between hearing ability and performance in speech perception tasks. The results suggest that performance in the nonsense words recognition tasks was more related to intelligibility index than to words with meaning, possibly because it limits semantic closure strategies by the subject.

Descritores

Inteligibilidade de Fala
Percepção da Fala
Percepção Auditiva
Criança
Perda Auditiva
Auxiliares de Audição

RESUMO

Objetivo: Estabelecer relações entre o desempenho em tarefa de reconhecimento de palavras com e sem sentido e grau e configuração da perda auditiva, utilizando valores de Índices de Inteligibilidade de Fala (SII) como indicadores, em crianças com deficiência auditiva. **Método:** Foram estabelecidos os SII para sons de entradas de 55 e 65 Decibéis Nível de Pressão Sonora (dBNPS) de dez crianças com perda auditiva neurossensorial usuárias de aparelho de amplificação sonora individual bilateralmente que têm a linguagem oral como principal modalidade de comunicação. As crianças foram submetidas à tarefa de repetição de palavras com e sem sentido em duas ou três diferentes intensidades. As emissões foram analisadas de acordo com o Protocolo Word Association for Syllable Perception (WASP). Na análise dos dados, o SII foi comparado com os resultados obtidos em cada critério de análise. **Resultados:** Para o desempenho em palavras, houve diferença estatisticamente significante entre os dois tipos de estímulo em 55dBNPS. Para o desempenho em consoantes e ponto de articulação, houve diferença estatisticamente significante entre os tipos de estímulos em 65 e 55dBNPS e também entre as intensidades de 65 e 55 dBNPS nas palavras sem sentido. **Conclusão:** De modo geral, não houve regularidade na relação entre capacidade auditiva e desempenho em tarefas de percepção da fala. Os resultados sugerem que o desempenho nas tarefas de reconhecimento de palavras sem sentido tem maior relação com o índice de inteligibilidade do que as palavras com sentido, possivelmente por limitar as estratégias de fechamento semântico pelo sujeito.

Correspondence address:
Natália de Camargo
Pontifícia Universidade Católica de São Paulo – PUC-SP
Rua Profª Drª Neyde Apparecida Sollitto, 435, Vila Clementino, São Paulo (SP), Brasil, CEP: 04022-040.
E-mail: natalia.camargo@ymail.com

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[1] Pontifícia Universidade Católica de São Paulo – PUC-SP - São Paulo (SP), Brasil.

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INTRODUCTION

The process of selection of hearing aids (HA) in infants and young children is composed of sequential and integrated steps, namely: definition of hearing thresholds, selection of electroacoustic characteristics of amplification, verification of amplification and validation[1].

The main objective of the selection process of HA in infants and young children with hearing impairment is to ensure access to quality speech sounds without discomfort[2]. Adequacy of amplification and care with audibility are of fundamental importance[3], since language delay can occur in any degree of hearing loss[4].

The verification step is indispensable to adjust the amplification characteristics, right after the programming of the HA through the manufacturers' software. Failure to check devices according to prescriptive evidence-based rules neglects the importance of speech sound audibility[5]. The Desired Sensation Level (DSL) prescriptive rule was designed to meet the acoustic needs of the pediatric population, assuming that speech sounds are the most important. The current version of the rule is DSL m [i/o] v5, available on proprietary software of some brands of HA and on some verification equipment.

To measure the proportion of information of audible speech sounds to the child and the consequent impairment in intelligibility, there is the Speech Intelligibility Index (SII), which was proposed by the American National Standards Institute (ANSI) in 1997[6] after the revision of ANSI S3.5-1969[7]. The SII is a measure that evaluates speech signal audibility, since it determines the proportion of audible and useful speech information for the listener and has a high correlation with speech intelligibility[6]. The calculation of the SII considers the intensity of the speech signal, the hearing thresholds and the background noise level. Scientific and technological advances have made clinical use feasible and have enabled SII to be obtained by means of some equipment for checking the electroacoustic characteristics of HA (Verifit®Audiosacan and Interacoustics Affinity), which have automatic calculation[8]. The SII values are correlated with the hearing threshold averages, so that the SII value decreases as the mean threshold increases and vice versa[9-12]. SII has a stronger relationship with the association of the variables degree and audiometric configuration, when compared with its relation with the degree of hearing loss alone[13].

Reference curves with amplified SII values for the input signal presentation levels of 65 and 55 dB SPL should be included in the selection and indication protocols for HA and audiological monitoring to contribute to the assessment of adequacy of amplification according to the prescriptive rule DSLm[i/o] v5[14].

This index, which represents capacity, enables, under ideal conditions, a relative anticipation of performance in speech perception tasks in children who use amplification devices. Capacity is an abstract concept of the anatomofunctional potential of a subject from examinations that assess the integrity and/or functioning of organs. Performance is subject to the interference of numerous factors and the interaction between them, since they involve behaviors of various natures that imply listening and having the cognitive and affective possibility to demonstrate it[15].

The use of SII as an indicator in the prescription of acoustic characteristics has been cited in the literature, as well as the need for research to determine relationships between the availability of information in the auditory dynamic field and speech perception tasks involving detection, discrimination and word recognition. The SII values can be taken as the conversational distance audibility (SII 65) and longer distances when the speaker is one meter or more from the amplifier user (SII 55 and SII 52).

With the increase in the number of children treated at the Hearing Health Network (Rede de Saúde Auditiva) of the city of São Paulo, and given the heterogeneity in the training of speech-language therapists in the network, the speech perception skills assessment process contributes to the establishment of expectations, which are based on their ability hearing loss, can be of great value in monitoring children throughout the therapeutic process. Establishing relationships between hearing ability and performance in speech perception tasks in children with hearing impairment is imperative in order to seek strategies that identify and guide the effective use of residual hearing in the language development process. The difference in performance in the perception of meaningless and meaningful words may be an indicator of how much the child uses acoustic information and/or semantic closures that depend on prior knowledge of the word. Our hypothesis is that the decrease in audibility (which simulates the effect of distance) has an impact on word and phoneme recognition depending on the degree and configuration of the loss.

In this sense, the aim of this study was to establish relationships between the performance of meaningful and meaningless word recognition task and the degree and configuration of hearing loss, using SII values as indicators, in children with hearing impairment.

METHODS

The research was conducted with hearing impaired children attended at the "Centro Audição na Criança" (CeAC). This study was approved by the "Comitê de Ética em Pesquisa" da "Pontifícia Universidade Católica de São Paulo" (PUC-SP), according to research protocol No. 204/2011.

Children whose language category was 4 or 5[16] were invited to participate in the research, aiming at the participation of children considered oralized deaf children. For the sentence comprehension test[17], the child would have to perform above 70%. The study included 10 children with quadritonal mean value of both ears ranging from 41.25 to 96.25 dBHL. For the performance analysis, the best ear SII was used.

Ten children participated in this study and the demographic and audiological characteristics are listed below. Table 1 describes the subjects according to Age, Age at diagnosis, Age at first HA fitting, Age at current HA fitting and Hearing age (Table 1).

In the distribution of frequencies regarding the acquisition and occurrence of hearing loss progression, there is one acquired (at 8 months) and stable, eight congenital and stable and one congenital and progressive. Frequency distribution regarding the etiology of hearing loss shows 35 DelG Conexin 26, one with perinatal complications and mechanical ventilation, one with

Table 1. Descriptive statistics for Age, Age at diagnosis, Age at first HA fitting, Age at current HA fitting and Hearing age in months (n=10)

Variable (in months)	n	Mean	Standard deviation	Minimum	Median	Maximum
Age	10	93.8	17,5	60	93.5	124
Age at diagnosis	10	27.5	17,9	4	26.5	63
Age at first HA fitting	10	29.5	18,2	4	29	66
Age at current HA fitting	10	81.8	22,3	34	85	121
Hearing age	10	64.3	28,5	10	75	95

meningitis and seven unknown. In the distribution of frequencies in terms of educational level, there is one child in kindergarten and nine in elementary school. Regarding the educational level of parents, one with incomplete elementary school, three with complete elementary school, one with incomplete high school, three with complete high school and two with complete higher education. The average daily use of HA was 11 hours, thus, all subjects can be considered consistent users of HA. Sixty percent of the children had frequency-compressed HA. For these, the compression remained activated during all stages of this work, as they used in everyday life. Eight children (80%) do therapy once a week and two (20%) do it twice a week.

Procedures

HA verification and SII determination

The SII can be automatically calculated by the Verifit® Audioscan device for the degree of hearing loss without amplification and amplification for different stimulus inputs, ranging from 40 to 75 dB SPL. The SII values are represented on a scale from 0% to 100%, where 0% means no audibility of speech sounds and 100% total audibility of speech sounds. For this study, the calculated SII for the input sound of 55 and 65 dB SPL served as the basis for characterizing hearing ability.

Preparation of meaningful and meaningless word lists

The preparation of the material involved the recording of the children's vocabulary word lists and the speech stimulus calibration, which took place in two moments: 1- Calibration of the meaningful syllable and trisyllabic word lists[18] and 2-calibration of meaningless syllable word lists[19].

Application of word repetition task

Preparation

The lists were placed in an acoustic booth, with the light off and the child positioned at zero azimuth of the speaker.

Before starting the task, the following procedures were performed: the HA were checked, new batteries were inserted and a hands-free training was performed. Then, with the orofacial reading support, the children received the following guidance: pay close attention to the words and repeat as you see fit. The application of the word repetition task was divided into two different encounters, for two reasons: 1) avoid tiredness and/or demotivation by the child, since there are several procedures that require their participation and/or collaboration; and 2) because the same word list is applied in both encounters, varying only the distance between the child and the speaker in each one of them.

Aplication

First session

List 1 of meaningful syllable words, and List 1 of meaningful trisyllable words – intensity: 65 dB SPL - 60 cm from speaker.

List 2 of meaningful syllable words, and List 2 of meaningful trisyllable words – intensity: 55 dB SPL - 60 cm from speaker.

The lists and intensities were combined in the same way for all children. The order of application was decided at each start of the test by a draw, however the first list was always the trisyllable at 65 dB SPL (considered the easiest), aiming to facilitate the understanding of the task by the children.

Second session

List 1 or List 2 of meaningful syllables used in the first meeting were drawn. The same List was maintained for all children and was applied at a distance of 90 cm.

List 1 of nonsense syllable words – intensity: 65 dB SPL - 60 cm from speaker.

List 2 of nonsense syllable words – intensity: 55 dB SPL - 60 cm from speaker.

If, in the latter (55 dBSPL at 60 cm), the child presented word accuracy higher than 40%, and aiming at sensitizing the performance in relation to the intensity, the List 3 of nonsense syllable words was also applied keeping the adjustment in the computer, just increasing the distance to 90 cm. Based on the "6 dB rule"[20], which states that when the distance between speaker and listener is doubled, the intensity decreases by approximately 6 dB SPL, it is estimated that in tests performed at 90 cm from the speaker sound, the sound averages 52 dB SPL for the assessed child.

The words were repeated only once when the child did not respond or when he/she answered something unintelligible. The children's emissions were recorded and orthographically transcribed by two hearing judges. In case of doubt, a third judge, also a listener, could assess the child's emission. They were all experts in the field and there was no need for consensus.

Data analysis

The Word Association for Syllable Perception (WASP) was used[21,22]. This protocol allows to analyze, in addition to the percentage of word accuracy, the consonant phoneme emissions according to the linguistic traits: place of articulation, articulation mode and voice.

To verify how stimulus presentation intensity (65, 55 and 52 dB SPL) and stimulus type (meaning words and meaningless words) affect the performance in the different evaluation modalities, the Variance Analysis technique with repeatedly measurements was used[23]. The model considered was 1 factor with 5 levels: words with meaning at intensities of 65, 55 and 52 dB SPL and meaningless words at intensities of 65 and 55 dB SPL. The adequacy of the assumption of normality was assessed by residual analysis. The stimulus type "meaningless words" at the intensity of 52 dB SPL was analyzed only descriptively because there were only three children who responded in this condition. Pearson's correlation coefficient[24] was used as a correlation measure of SII 65 and the different error analysis criteria. In the hypothesis tests, a significance level of 0.05 was set. The analysis was performed with the aid of Minitab (version 16) and SPSS (version 18) programs.

RESULTS

For the present study, the SII were obtained for a weak (55 dB SPL) and medium (65 dB SPL) input sound. Figure 1 shows the hearing thresholds of the 10 children and the corresponding SII in descending order according to SII 65.

The differences in SII between the two inputs (55 and 65) can be seen in Figure 2 and represent the influence of the configuration on the difference between SII 65 and SII 55.

The evaluation of the effect of intensity (65, 55 and 52 dB SPL) and type of stimulus (words with and without meaning) on the performance in the different evaluation criteria is organized by word hit, consonant hit and place of articulation hit.

Word hit

Regarding the descriptive statistics for the Percentage of words that are correct, the following means were obtained: 52.93 at 65 dB SPL (n=10), 58.97 at 55 dB SPL (n=10) and 59.17 at 52 dB SPL (n=10). In the meaningless words, the following means were obtained: 42.63 at 65 dB SPL (n=10), 32.62 at 55 dB SPL (n=10) and 59.63 at 52 dB SPL (n=3). Given the heterogeneity in group performance, an intrasubject analysis was chosen.

Figure 3 shows the graph of individual word hit percentage profiles. In this graph, it is possible to analyze the behavior of each subject in the different types and intensities of the stimulus.

The analysis of variance with repeated measures indicated that the averages of the word hit percentage in the five combinations of intensity and stimulus type are not all equal (p<0.001). In the continuation of the analysis, the averages in the intensities were compared two by two in each type of stimulus, and the averages in the two stimuli were compared in each intensity. The results obtained are presented in Table 2.

There was no statistical significance for the difference between the mean percentages of correct and meaningless words at 65 dB SPL intensity. Only when the intensity was decreased to 55 dB SPL, this intensity did the difference between the

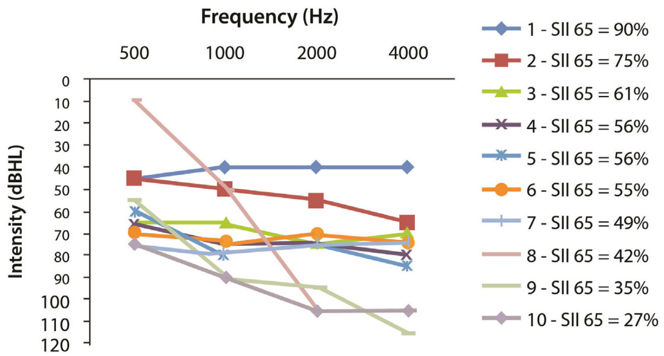

Figure 1. Auditory thresholds and SII 65 of the best ear of each child (n=10)

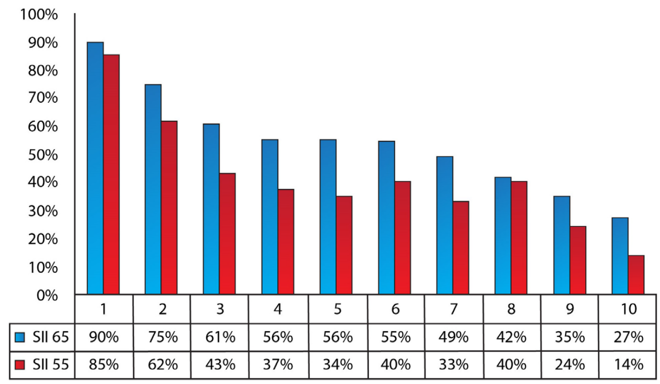

Figure 2. SII 65 and 55 of each subject (n=10)

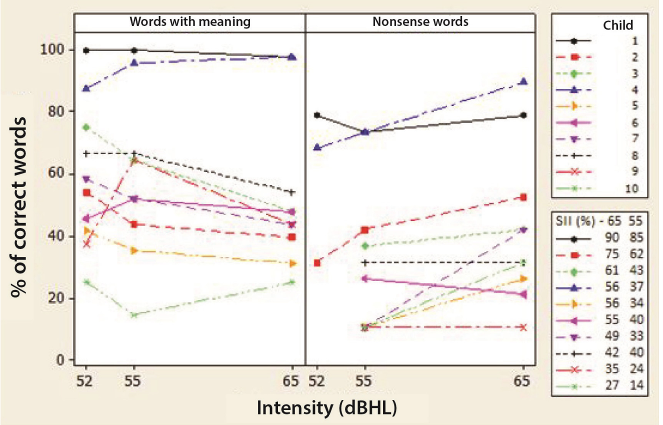

Figure 3. Individual Profiles of Percentage of Word Meaning with and without meaning at intensities of 65, 55 and 52 dB SPL

mean percentage of guess and miss meaning words and could be statistically significant, i.e. the type of stimulus only made a difference for the weaker sounds or, by inference, more distant.

There was also no statistical significance for the difference between the mean percentages of word accuracy at 65 and 55 dB SPL in both stimulus types. In meaningful words, probably due to the fact that children with intermediate SII, except for child 4, had underperformed already at the intensity of 65 dB SPL, because, considering the percentage of hearing speech sounds, these subjects would have conditions word recognition. This may

Table 2. P-values obtained by Tukey's method in the comparison between the averages of the Word Hit Percentage in the different intensities in each type of stimulus, and between the two types of stimulus at each intensity

Comparison between intensities			Comparison between types		
Type	Comparison	p	Intensity	Comparison	p
With meaning	65 × 55	0.629	65	With x Without	0.140
	65 × 52	0.600	55	With x Without	<0.001*
	55 × 52	>0.999			
Without meaning	65 × 55	0.160			

*significant
Caption: p = probability value

have been due to the fact that many children do word closures with orofacial reading support. Also noteworthy is the fact that the percentage of correctness of meaningful words was lower at the intensity of 65 dB SPL than the others, a fact that may be related to the practice of the task, since the weaker intensities were presented later. However, if there was an order effect, it was the same for all children, since the order of stimulus presentation was the same for all children. Regarding the meaningless words, it could be observed a variable decrease in performance in the intensity to 55 dB SPL, possibly due to the fact that the children had different impacts with this decrease. The number of subjects and their characteristics regarding the degree of hearing loss, use of residual hearing, language development, language repertoire, among others, probably influenced performance. Increased attention to lower intensity words can also influence word repetition tasks.

In Figure 3, it is possible to appreciate individual performances in the meaningless words, it is noted that children 3 and 7 had the same percentage of success in 65 dB SPL. However, the impact of decreased intensity resulted in a worsening of 31.6% for the child 7 and only 5.3% for the child 3.

The same was true for children 8 and 10 who had the same meaningful hit percentage at 65 dB SPL in the meaningless words. However, as the intensity decreased, child 10 decreased by 21.1% while child 8 did not change its performance. Child 8 has SII 65 equal to 42% and, with decreasing intensity to 55 dB SPL, drops to 40%, while child 10 has SII 65 equal to 27% and, with decreasing intensity, falls to 14%.

Children 8 and 9 performed the same on meaningless words at both stimulus presentation intensities. These are the two children with descending hearing loss who have an SII change of 2% (from 42% to 40%) and 11% (from 35% to 24%), respectively, with a decrease in intensity of 65% to 55 dB SPL.

Child 4 has the fourth best SII (56% to 65 and 37% to 55) and yet similar performance to child 1 who has the best SII (90% to 65 and 85% to 55). Child 4 was diagnosed and intervened at 4 months of age, always had speech-language therapy sessions and consistent use of HA, made use of the Frequency Modulation System (FM system) and, in addition, her hearing loss was progressive.

A greater familiarity with the vocabulary of lists presented at weaker intensities or task learning (since 55 dB SPL was the second stimulus presentation intensity) may justify the fact that child 3, the youngest of the group, have tended to improve with decreasing intensity of meaningful words.

It is also possible to observe that children 1 and 4 perform better than 70% in the four stimulus presentation combinations. However, given the group's SII, good performance was expected. It is children 2, 3, 5, 6 and 7 who perform below expectations. These, with the exception of child 6, were little affected by the introduction of meaningless words, since their performance suffered little change, which demonstrates that they are not using hearing closure to recognize meaningful words.

Consonant hit

As for the descriptive statistics for Consonant Hit Percentage, the following averages were obtained: 77.01 at 65 dB SPL (n=10), 75.68 at 55 dB SPL (n=10) and 71.89 at 52 dB SPL (n=10) in meaningful words and 53.16 in 65 dB SPL (n=10), 37.88 in 55 dB SPL (n=10) and 59.63 in 52 dB SPL (n=3) in meaningless words.

Figure 4 presents the graph of individual profiles of the consonant hit percentage, in which it is possible to analyze the behavior of each subject in the different types and intensities of stimulus presentation.

The means of Consonant Hit Percentage are not all equal in the 5 Intensity and Stimulus Type combinations (p<0.001), as shown in Table 3.

There was statistical significance for the difference between the mean percentages of consonant hit percentages in words with and without meaning at intensities of 65 and 55 dB SPL. At 65 dB SPL, children performed at least 5.7% and at most 44.6% better on meaningful words compared to meaningless words. At 55 dB SPL, the performance was at least 18.6% and at most 63.4% better in words with meaning.

There was statistical significance for the difference in mean consonant hit percentage at intensities of 65 and 55 dB SPL only in meaningless words. In this, with the decrease of 10 dB SPL, seven children (2, 4, 5, 6, 7, 9 and 10) significantly worsened their performance and three (1, 3 and 8) remained with the hit percentage equal to 65 dB SPL. .

For children 1 and 8, this can be explained by the fact that the SII predicts for them the smallest differences between the 55 and 65 dB SPL values of the group. In child 1, SII drops from 90% to 85% and in child 8 from 42% to 40%. Child 3, on the other hand, probably did not have its performance impaired with the decrease in intensity because it had already underperformed at 65 dB SPL, which may be due to the fact that it is the youngest in the group. It is worth mentioning that children 1, 3 and 8, together with child 2, have the best hearing thresholds at 1 kHz.

Table 3. P-values obtained by the Tukey method in comparing the mean Consonant Hit Percentage at different intensities in each stimulus type, and between the two stimulus types at each intensity

Comparison between intensities			Comparison between types		
Type	Comparison	p	Intensity	Comparison	p
With meaning	65 × 55	0.997	65	With × Without	<0001*
	65 × 52	0.676	55	With × Without	<0.001*
	55 × 52	0.861			
Without meaning	65 × 55	0.003*			

*significant
Caption: p = probability value

Place of articulation hit

For descriptive statistics for Place of Articulation Hit Percentage, the following averages were obtained: 79.33 at 65 dB SPL (n=10), 77.92 at 55 dB SPL (n=10) and 75.01 at 52 dB SPL (n=10) in meaningful words and 58.43 in 65 dB SPL (n=10), 45.79 in 55 dB SPL (n=10) and 63.17 in 52 dB SPL (n=3) in meaningless words.

Figure 5 presents the graph of individual profiles of the percentage of place of articulation hit, in which it is possible to analyze the behavior of each subject in the different types and intensities of stimulus presentation.

Table 4 presents the *p*-values obtained by the Tukey method in comparing the means of Place of Articulation Hit Percentage at the different intensities in each stimulus type, and between the two stimulus types at each intensity.

There was statistical significance for the difference between the mean percentages of place of articulation hit in meaningful and meaningless words for the 65 and 55 dB SPL intensities. At 65 dB SPL, children performed at least 8.8% and at most 44.9% better on meaningful words when compared to nonsense, except child 7. At 55 dB SPL intensity, in turn, the performance was at least 5.3% and at most 64.2% better in words with meaning.

There was statistical significance for the difference in mean percentage of place of articulation hit at 65 and 55 dB SPL only in meaningless words, as six children (2, 4, 5, 7, 9, and 10) significantly worsened their performance, three (3, 6, and 8) remained with the hit percentage equal to 65 dB SPL and only the child 1 improved. Children 7, 9 and 10 were the most affected with a 10 dB SPL decrease in meaningless word intensity. They are children with some of the lowest SII in the group (49% and 33% - 35% and 24% - 27% and 14%, respectively).

The SII may also explain the fact that children 3, 6, and 8 had, in the meaningless words, the same percentage of place of articulation hit at both stimulus presentation intensities. In the case of child 8, the SII predicts a difference of only 2% in speech intelligibility (from 42% to 40%,) with decreasing input sound intensity. On the other hand, for children 3 and 6, this decrease was not enough to negatively impact performance, as the former has SII 65 equal to 61% and SII 55 equal to 43% and the second has SII 65 equal to 55% and SII 55 equals 40%.

By comparing word performance with consonant and place of articulation performance, it can be seen that the word hit percentages were lower than the consonant hit and place of articulation percentages.

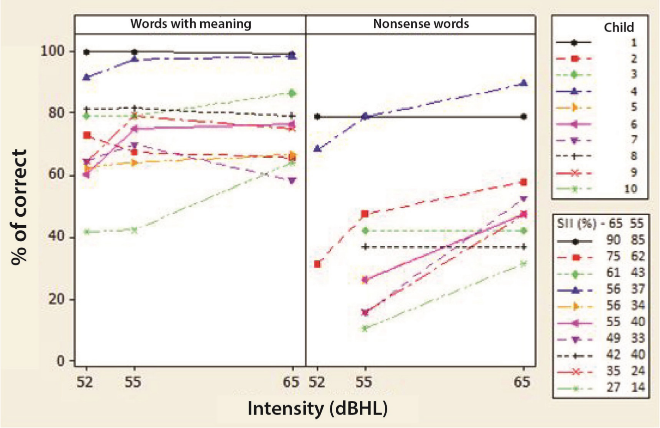

Figure 4. Individual Consonant Hit Percentage Profiles in meaningful and meaningless words at intensities of 65, 55, and 52 dB SPL

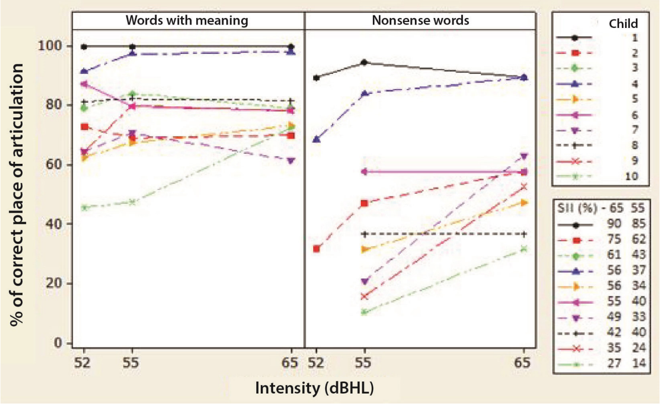

Figure 5. Individual Profiles of Place of Articulation Hit Percentage in words with and without meaning at intensities of 65, 55, and 52 dB SPL

The performance in words was, except in the case of children 1 and 4, below the hearing potential, since the predicted audibility of the SII seems to be better represented by the correctness trends in the consonant and place of articulation adjustment criteria. In the case of meaningful words, they are not making the necessary auditory closures and thus make the words err by a consonant or even by a single linguistic feature.

Children 1 and 4 have the highest hit percentages in all categories. The first one for having SII 65 equal to 90%, and the second for making better hearing closures since it has greater knowledge and mastery of the language.

Table 4. P-values obtained by the Tukey method in comparing the means of Articulation Point Hit Percentage Percentage at different intensities in each stimulus type, and between the two stimulus type at each intensity

Comparison between intensities			Comparison between types		
Type	Comparison	p	Intensity	Comparison	p
With meaning	65 × 55	0.998	65	With × Without	<0.001
	65 × 52	0.862	55	With × Without	<0.001
	55 × 52	0.963			
Without meaning	65 × 55	0.049			

Caption: p = probability value

Table 5. Pearson correlation coefficients values (r) for SII 65 and error analysis criteria (n=10)

Criteria	Stimulus type			
	Words with meaning		Words without meaning	
	r	p	r	p
Word Accuracy %	0.55	0.097	0.63	0.053*
Vowel Hit %	0.53	0.111	0.52	0.128
Consonant Hit %	0.47	0.168	0.63	0.051*
Place of Articulation Hit %	0.42	0.222	070	0.025*
Articulation Mode Hit %	0.41	0.240	0.59	0.076
Voicing Hit %	0.38	0.285	0.57	0.086
Consonant omission %	-0.24	0.501	-0.54	0.105
Consonant substitution %	-0.53	0.118	-0.45	0.188

*significant
Caption: p = probability value

SII 65 correlation and error analysis criteria

Table 5 shows the observed values of Pearson's color correlation coefficient of SII 65 and the error analysis criteria for both types of stimuli and the *p*-values obtained in the coefficient significance test. These *p*-values are illustrative only because, due to the small sample size, only high coefficient values are considered significant. It can be observed that, in general, the absolute values of the coefficients are higher in the meaningless words, indicating a stronger correlation of the criteria with SII 65 in this type of stimulus.

In the words with meaning, the highest absolute values of the coefficient were obtained in the Word Hit Percentage, Vowel Hit Percentage, and Consonant Substitution Percentage, and in this last criterion, the correlation is negative. In the nonsense words, the highest absolute values of the co-efficient were observed in Word Hit Percentage, Consonant Hit Percentage, and Place of Articulation Hit Percentage, p<= 0.5.

DISCUSSION

There was no statistical significance for the difference between the mean percentages of correct and meaningless words in the 65 dB SPL intensity. Only when the intensity was decreased to 55 dB SPL did the difference between the mean percentage of meaningful and meaningless words hit be statistically significant, i.e. the type of stimulus only made a difference in word recognition at intensity below 65 dB SPL, considered the mean of the conversational intensity. Some researchers, when studying the influence of predictive factors on the audiological results of children with bilateral sensorineural hearing loss, found that the degree of hearing loss in the best ear was a good predictor of performance in speech and oral language production, but was not an important factor to predict speech perception performance[11]. Also in the present study, children with SII 65 that represent good audibility for speech sounds, did not perform audibly compatible as observed in children 2 and 3[11]. Other factors such as family involvement and the consistency of use of HA throughout language development may have been determinants of better or worse performance in speech perception tasks[14,25]. This fact may explain the word accuracy percentages below 70% for subjects with SII 65 around 50%, except for child 4, with SII 65 = 56%, with excellent performance in meaningful words and superior performance in meaningless word tasks, when compared to children 2 and 3, who had better audibility for speech sounds.

The appreciation of the value of the SII 65 obtained in the verification process and its use leads to the expectations of parents and speech-language therapists involved in rehabilitation[12]. However, if auditory behaviors are not consistent with the audibility indicators for speech sounds during the validation process, other variables should be considered.

In this sense, the relationship between SII and speech recognition should not be straightforward, as SII is an objective measure related exclusively to hearing, whereas speech recognition tests involve other variables related to the individual characteristics of each child, as well as the characteristics of the speech material used [12,26].

As can be observed in this study, in the case of meaningful words, children who have knowledge of the language, with guaranteed semantics and coarticulation, use hearing closure to make the recognition. Auditory closure has been described as the ability to use intrinsic or extrinsic redundancies to fill in missing or distorted parts of the auditory signal and recognize the full message. Knowledge of the subject, familiarity with vocabulary, knowledge of phonemic aspects of speech, and familiarity with language rules are some of the factors that help auditory closure[27].

In the case of meaningless words, which have guaranteed co-articulation, but do not have semantic information, they depend exclusively on audibility, which may interfere with the ability to decode the phonemic aspects of the speech signal. In this case, child 3 performed similarly at both intensities. Speech material that uses meaningless syllables or has few contextual clues is said to be more difficult for children[28]. It is noteworthy that polysyllable words are easier to hear and repeat, followed by monosyllable words, while meaningless words and syllables are the most difficult[19]. The stronger correlation of meaningless word error analysis criteria with SII 65 can be explained by the fact that the recognition of meaningless words depends exclusively on audibility.

There was statistical significance for the difference between the mean consonant hit percentages in words with and without meaning at the 65 and 55 dB SPL intensities and also for the difference in the mean consonant hit percentages at the 65 and 55 dB SPL intensities only in meaningless words. In this, with the decrease of 10 dB SPL, seven children (2, 4, 5, 6, 7, 9 and 10) significantly worsened their performance and three (1, 3 and 8) remained with the hit percentage equal to 65 dB SPL. For children 4, 5 and 6, this worsening may be explained by the fact that the greatest differences between SII 55 and 65 are for SII 65 values equal to 56.4%, that is, when the verification values are obtained SII 65 close to 56.4%, it is known that with the alteration of the input signal intensity there will be a greater change in the audibility of speech sounds to SII 55, generating greater difficulty in distance and noise listening[29]. Consonant audibility seems to be directly related to audibility[10], which shows that SII values below 35% do not favor the development of canonical babbling, i.e., an intelligibility below 35% is not sufficient for the development of speech production of consonants.

There was statistical significance for the difference between the mean percentages of place of articulation hit in meaningful and meaningless words for the 65 and 55 dB SPL intensities and also for the difference in the percentage of place of articulation hit percentages in 65 and 55 dB SPL only in meaningless words, since six children (2, 4, 5, 7, 9 and 10) significantly worsened their performance, three (3, 6 and 8) remained with the percentage of correct answers 65 dB SPL and only child 1 improved. Children 7, 9 and 10 were the most affected with a 10 dB SPL decrease in meaningless word intensity. They are children with some of the lowest SII in the group (49% and 33% - 35% and 24% - 27% and 14%, respectively). For children 4 and 5, this can be explained by the fact that they have SII values 65 close to 56.4%, a range in which there is a greater change in the audibility of speech sounds to 55[29].

In general, the place of articulation was the language trait that most compromised consonant recognition. This result is in agreement with the literature, in a classic consonant perception article, which reaffirms the importance of lip reading for the identification of the place of articulation, since it is the easiest trait to visualize and the most difficult to hear correctly[29]. As a result, children are losing their ability to auditory discrimination and, in the case of tests that use recorded material and do not have the support of orofacial reading, the percentage of accuracy is relatively low. In this sense, speech-language therapy seems to be extremely important for children with hearing impairment, since, as could be observed in this study, it is not enough to have audibility, it is necessary a work for the word recognition to reflect performance compatible with the ability hearing loss provided by the SII.

CONCLUSIONS

There was no statistical significance for the difference between the mean percentage of words with and without meaning in the 65 dB SPL intensity. The difference in correctness of meaningful and meaningless words was statistically significant when the intensity was decreased to 55 dB SPL. It was concluded that the type of stimulus interfered with the intelligibility of weaker or, by inference, more distant sounds.

There was statistical significance for the difference between the averages of consonant hit percentages in meaningful and meaningless words at 65 and 55 dB SPL. However, there was statistical significance for the difference in mean consonant hit percentages at intensities of 65 and 55 dB SPL only in meaningless words.

There was statistical significance for the difference between the mean percentage of Place of Articulation Hit in meaningful and meaningless words at intensities of 65 and 55 dB SPL. However, there was statistical significance for the difference in mean percentage of Place of Articulation Hit at 65 and 55 dB SPL only in meaningless words. In general, the place of articulation was the language trait that most compromised the recognition of consonants

By comparing word performance with consonant and place of articulation performance, it can be seen that the Word Hit Percentages were lower than the Consonant Hit and place of articulation percentages. Overall, there was no regularity in the relationship between auditory ability and performance in speech perception tasks. The results suggest that the performance in meaningless word recognition tasks is more related to the intelligibility index than the meaningful words, possibly limiting the semantic closure strategies by the subject.

Further studies are needed, considering the number of subjects evaluated in this research and the heterogeneity of the population of hearing impaired children who use electronic devices and communicate through oral language.

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Author contributions

NC participated as a student; BCACN participated as advisor; BCAM participated in the correction of the article.