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Audibility and oral language development in children with hearing loss

Audibilidade e desenvolvimento de linguagem oral em crianças com deficiência de audição

Audibilidad y desarrollo del lenguaje oral en niños con discapacidad auditiva

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Abstract

Introduction: Audibility, measured by SII, has been shown to be a necessary condition for language development, since it allows access to the linguistic input. Likewise, vocabulary development has been shown to be a good indicator of language development. **Objective:** To investigate the audiological characteristics and the development of oral language characteristics in hearing impaired children who are hearing aid users. **Methods**: Sixty-five children aged 6 to 17 years old, hearing aid users, and based

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Authors' contributions:
TMD: Designed the scientific project, was also responsible for the direct intervention with the participants, collected and participated in the data tabulation and participated in writing.
RSLF and BCAM: Participated in data collection, tabulation and interpretation, bibliographical survey, reading and interpretation of scientific texts, in addition to text revision and writing.
CFL: Assisted in the design of the scientific project, literature review, reading and interpretation of literary texts and data interpretation.
BCACN: Guided the members of the group, defined the processes in order to conduct the work, and also monitored, organized and guided all the procedures carried out from the elaboration of the project until the completion of the study.

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in the state of São Paulo, were evaluated for their receptive vocabulary performance (Peabody Picture Vocabulary Test – 4) and their relation to audibility (SII 65). **Results**: Audibility for speech sounds assessed by the SII values revealed that 9% of the subjects had SII scores lower than 37, 47% had SII scores between 38 and 57, and 43% scored greater than 58. The overall mean of the standard score values in the receptive vocabulary test was 51.8. When relating audibility (SII 65) with vocabulary, the linear tendency of (i) the increase vocabulary performance with (ii) the increase of audibility was not significant. **Conclusions**: The characteristics and heterogeneity of the studied population sample seemed to represent different conditions of the subjects attended in an auditory health service in Brazil. Within the population analyzed, audibility did not determine vocabulary performance, being a critical but not sufficient factor to ensure adequate vocabulary development and growth.

Keywords: Speech intelligibility; Hearing aids; Hearing loss; Vocabulary; Child; Audiologic rehabilitation

Resumo

Introdução: A audibilidade, medida pelo SII (Índice de Inteligibilidade de fala), tem se mostrado uma condição necessária para o desenvolvimento de linguagem, pois permite o acesso ao input linguístico. O desenvolvimento de vocabulário tem provado ser um bom indicador do desenvolvimento de linguagem. **Objetivo:** investigar as características audiológicas e de desenvolvimento de linguagem oral em crianças com deficiência auditiva usuárias de aparelho de amplificação sonora individual. **Método:** Foram avaliadas 65 crianças entre 6 e 17 anos, usuárias de aparelho de amplificação sonora individual, quanto ao desempenho de vocabulário receptivo (Peabody Picture Vocabulary Test - PPVT-4) e audibilidade (SII 65). **Resultados:** A audibilidade para sons de fala revelou que, 9% dos sujeitos tinham SII 65 menor que 37, 47% tinham SII 65 entre 38 e 57 e 43% maior que 58. A pontuação média de escore padrão no teste de vocabulário foi de 51,8 pontos. Ao relacionar a audibilidade com o vocabulário, a tendência linear de aumento no desempenho de vocabulário com o aumento da audibilidade não foi significativa. **Conclusões:** As características e heterogeneidade da população pareceram representar as diferentes condições dos sujeitos acompanhados em um serviço de saúde auditiva no Brasil. Para a população estudada, a audibilidade não determinou o desempenho do vocabulário, sendo condição necessária, mas não suficiente para o desenvolvimento e crescimento do vocabulário.

Palavras-chave: Inteligibilidade de fala; Auxiliares de audição; Perda auditiva; Vocabulário; Criança; Reabilitação da deficiência auditiva.

Resumen

Introducción: La audibilidad, medida por SII(Índice de Inteligibilidad del Habla), ha demostrado ser una condición necesaria para el desarrollo del lenguaje, ya que permite el acceso al *input* lingüístico. El desarrollo del vocabulario ha demostrado ser un buen indicador del desarrollo del lenguaje. **Objetivo**: investigar las característicasaudiológicasy del desarrollo del lenguaje oral en niños con discapacidad auditiva,usuarios de audífonos. **Método:** Sesenta y cinco niños entre 6 y 17 años, usuarios de audífonos fueron evaluados por su desempeño en vocabulario receptivo (*Peabody Picture VocabularyTest*-PPV- 4) y su audibilidad (SII 65) . **Resultados:** La audibilidad para los sonidos del habla reveló que el 9% de los sujetos tenían SII65 inferiores a 37, el 47% tenían SII65 entre 38 y 57, y el 43% mayor de 58. El promedio de la puntuación estándar en la prueba de vocabulario fue de 51.8. Al relacionar la audibilidad con el vocabulario, la tendencia lineal de aumento en el rendimiento del vocabulario con el aumento de la audibilidad no fue significativa. **Conclusión:** las características y la heterogeneidad de la población estudiada parecieron representar las diferentes condiciones de los sujetos atendidos en un servicio de salud auditiva en Brasil. En la población analizada, la audibilidad no determinó el rendimiento del vocabulario, siendo condición necesaria pero no suficiente para el desarrollo y crecimiento del vocabulario.

Palabras claves: Inteligibilidad del habla; Audífonos; Pérdida Auditiva; Vocabulario; Niño; Rehabilitación de la Discapacidad Auditiva.

Introduction

Hearing loss in children is a silent and hidden disability that severely affects their development. When not detected and treated early, this serious problem can lead to delays in language development, social and emotional problems, academic failures and later in adult life in terms of labor market, employment and personal relationships. However, early detection and intervention through the use of electronic devices and proper rehabilitation can minimize the consequences of hearing impairment and thus promote better quality of life for these individuals[1].

As a result of the newborn hearing screening that was implemented in 1994 to 1998 in developed countries, and in 2000 in Brazil[2,3], children with different degrees of hearing loss are having an earlier access to early intervention to address hearing impairment. The early diagnosis of hearing impairment in children leads to an early adaptation of an Individual Sound Amplification Device (ISAD), and the age at the first adaptation of the ISAD is a predictive factor for speech perception, speech production and oral language. In addition, early identification and intervention have a positive impact on speech and language development of children with hearing impairment[4,5]. However, even with all this progress, hearing loss in children fundamentally changes the listening experience, thereby changing the opportunities for development. The listening experiences during early childhood of these children vary widely and are influenced by the audibility of speech sounds[6,7].

The ISAD is regarded as the main component of early intervention for children with hearing loss and the device is adjusted with the aim of providing access to acoustic components of speech and language. The audibility provided by the ISAD can be distinguished between different children, or even in the same child over time, based on the degree of hearing loss or in the proximity of the ISAD programming to prescriptive rules. Children with more pronounced hearing loss and prescriptive rules below target have audibility levels above the expected[6].

The Speech Intelligibility Index (SII) is a measure that may influence the amplification characteristics of the hearing aid, and which proved to be more consistent in the prediction of language development in children with hearing loss. This tool provides the amount of audible speech information to individuals with and without the use of amplification, thus being a way to quantify the relationship between the speech signal and the speech recognition scores. The SII is an objective measure performed during the verification process of the ISAD, and has been used as a tool to determine if the patient is a potential candidate for the use of the amplification[8]. The access for professionals to SII values is feasible in Brazil, since the achievement of these values is accomplished through a device to obtain insertion, which is mandatory in Specialized Rehabilitation Centers - CER and have been gradually implemented in different regions of the country.

Since low SII indexes with the use of ISAD indicate limited access to speech sounds, and in order to determine from what degree oral language is vulnerable to the effects of hearing loss, surveys have suggested that children with SII amplified in the best ear below 0.65 may be at risk for delays in vocabulary development[8-10]the aided Speech Intelligibility Index (SII; American National Standards Institute, 2007. This means that if the audibility is 0.65 or worse for conversational situations in quiet environments, it is likely to be even lower in real situations where the speaker is over a meter away, and/or in an environment with background noise and reverberation, not to mention the auditory effort and fatigue.

In addition to the establishment of the hearing, through the ISAD and/or Cochlear Implant (CI), the main goal of the early intervention on hearing impairment is the oral language acquisition. Therefore, audibility has proven to be a necessary condition for the language development as it will allow access to the linguistic input, and there are several variables that may influence on the response of these children. In this sense, it is understood that there is a positive relationship between audibility with electronic devices and language development[11].

As one of the indicators of language development, vocabulary development has been widely used in research with children with hearing impairment. According to Yoshinaga-Itano, Baca, and Sedey[12] the use of a standardized metric provides benefits, as it allows the comparison of results of children with hearing loss with their hearing peers, as well as being essentially very simple to understand and interpret. With respect to the Peabody

Picture Vocabulary Test (PPVT), the growth curve is related to the auditory receptive vocabulary.

Literature on the relationship between the vocabulary development in ISAD users is still scarce, since most studies in this area address the performance post cochlear implant.

Therefore, this study aims to investigate the relationship between the audibility and oral language development in hearing impaired children who are hearing aid users, analyzing the relationship between audibility for speech sounds and receptive vocabulary.

Methods

Research Location and Ethical Precepts

This study was conducted in the CeAC linked to (i) the Division for Education and Rehabilitation for Communication Disorders of DERDIC/PUCSP; and (ii) the Graduate Program in Speech-Language Pathology and Hearing Sciences/Children's Hearing Research Line of the Faculty of Humanities and Health of the Pontifícia Universidade Católica de São Paulo - PUCSP. It is a Specialized Rehabilitation Center - CER II accredited by the Brazilian Unified Health System (SUS), which provides medical care to hearing impaired (or suspected) children from 0 to 18 years of age. This work integrates a more comprehensive study project on the selection process of sound amplification devices for infants in the first years of life, and it followed the precepts laid down in the Code of Ethics for Research with Human Beings, having been approved by the Ethics Committee of the PUCSP under the Research Protocol no.337/2010.

Research Subjects

The study consisted of 65 subjects, aged between 6 and 17 years old, being 24 male and 41 female, and diagnosed moderate to severe bilateral sensorineural hearing loss, hearing aid users, and who attended the ambulatory of the CeAC from 2016 to 2017.

The subjects were selected by convenience sample, when they attended the ISAD outpatient clinic to: audiological follow-up, ISAD replacement, mold replacement, consultation with an otolaryngologist, social worker or any other service. If they fit the selection criteria of the study (SII 65 between 30 and 70 in the better ear, between 6 and 17 years old and with oral communication) they were invited to voluntarily participate. After the explanation of the procedures to be performed, the parents or guardians decided whether or not they agreed to participate in the research, and those who agreed, signed a Free and Informed Consent Form.

Procedures

In order to characterize the sample and thematic axes, an interview was conducted with parents or guardians; moreover, data were also collected from the medical records of the subject.

The following actions were performed in order to obtain the updated auditory thresholds of subjects:

- Inspection of external ear or otoscopy;
- Tonal audiometry threshold by air in the frequencies from 250 to 8000 Hz and by bone in the frequencies from 500 to 4000 Hz.

From the thresholds established in the audiological assessment, the ISADs were checked according to the DSLm [i/o]v5 prescriptive rule. SII values were obtained using the Verifit model of the Audioscan® brand. A Verifit Audioscan® device was used to perform verification measures for speech sounds of 55, 65 and 75 dBNPS and a maximum MPO output (90 dBNPS). The positive or negative 3 dB difference was accepted to determine similar values between the gain and output electroacoustic characteristics prescribed in the DSLm [i/o] v5 software and the values found in the ISAD. Features like compression or frequency transposition were disabled, when available for the ISAD model. The SII values at the intensities of 55, 65 and 75 dB for each ear were obtained and analyzed in the verification process of the ISADs.

Based on what was proposed by Figueiredo(13) the following auditory criterion (SII 65) was used for this study:

- SII 65 lower than 37: little audibility
- SII 65 between 38 and 57: intermediate audibility
- SII 65 higher than 58: good audibility

Consistency Assessment of Amplification Use (Data logging): Along with the ISAD programming and verification, the measurement of the use of the ISAD (average hours per day) was performed through the "data logging" feature, which is available on all ISAD models of the participants of this survey. This measurement was performed by connecting the ISADs to the HiPro programming interface and using the appropriate software for the ISAD brand. In addition to the measurement

performed on the day of collection, an average of "data logging" records of last year was performed, by collecting the values contained in the records of each participant. When values were different between the ears, the value of the best ear was included in the data analysis in order to calculate the average use of the devices.

As all participants were older than 6 years in this study, the use of the device classified as effective was considered in cases where the ISAD was used on average for more than 10 .1 h/day, based on Manane and Ching, and Hirshkowitz et al[14,15] infants have access to universal newborn hearing screening (UNHS.

The Peabody Picture Vocabulary Test 4th edition - PPVT-4[16], which consists of the assessment of the receptive vocabulary of adults and children from 2 years and 6 months, was used to evaluate the receptive vocabulary. Each form contains four training boards followed by 228 test boards, and each board consists of 4 colored figures arranged on white background. The subject to be examined must select the figure that best illustrates the meaning of the word spoken by the examiner. The 228 boards are grouped into 19 sets of 12 items each. The sets are organized by difficulty, so the examiner can manage only sets that are appropriate to the vocabulary level of the subject.

The 4th edition of the PPVT Test in English was released in the United States in 2007. Some changes were made in this new edition, such as: bigger and more colorful illustrations, new words that have replaced old items that are no longer used in the current language, easier items added to improve the base score, simplified procedures to manage the training boards, expanded interpretation options consisting of item content analysis on the part of speech (noun, verb, and attribute or descriptor). Until the data collection of this study, the 4th edition of the PPVT Test did not have translation and validation for the Portuguese language. Since the purpose of using this test was to use the results as an estimate of how these individuals work in relation to the receptive vocabulary skill, and as the purpose was not to standardize the subject in relation to age, but establish a uniform criterion that allows the analysis of the variables chosen, the authors of this research conducted a free translation from English to Brazilian Portuguese in order to enable the use of the 4th edition of the PPVT test with the subjects of this research.

Form A of the PPVT-4 with free translation into Portuguese was applied to all subjects of the research. The test was performed as instructed by the application manual proposed by authors. First, the test was presented and instructions were provided, then the two test boards were presented to familiarize the individual with the test and to verify if the subject was able to respond. Later, the examiner began the test with the board corresponding to the age of the subject, continuing the test with the remaining sets until the subject obtained eight or more errors in a set. In cases where the subject had two or more errors on the set 1, it was not possible to continue the test and the score was computed as zero for data analysis. The answers were noted on the response form for further analysis.

The test score was also calculated as instructed by the application manual proposed by authors. For a quantitative analysis of the results of this test, the following variables were used: standard score (ranging from 20 to 160) and equivalent age (ranging from 2 years and 6 months to 90 years).

Since there was no validation of the test version translated into Portuguese and as the test was developed and standardized for North American children, the scores obtained by the subjects of this study were not compared to the normal values proposed by the test. Instead, the study defined cohorts based on the standard deviations that the subjects were included in the normal curve. Scores above -2 SP were considered a good perform in the test.

Data analysis

Descriptive analysis of age, SII of the best ear and receptive vocabulary (PPVT): The study also designed receptive vocabulary and SII diagrams. The Pearson correlation coefficient (r) was used as a measure of the correlation between the receptive vocabulary and the SII. The significance level of (0.05) was set in the significance test of this coefficient in order to evaluate the association of the receptive vocabulary (standard score) with the SII of the best ear.

The association of the receptive vocabulary with the quantitative variable SII 65 was evaluated.

Results and Discussion

The study population in this study represents the flow of patients from a hearing health care service in São Paulo state, and the subjects who

attended the audiological or ISAD follow-up were included, including those who returned to check the use of the FM System in the school, aged over 6 years and with enough oral communication to perform speech perception tests. We sought to include subjects that represent a variety of audibility standards, prioritizing the intermediate audibility, with a SII 65, between 30 and 70%, subjects in which there is a greater performance variation[13]. Several authors[8,17,18] report that the SII was a better indicator of receptive vocabulary and speech perception than the average of pure tone thresholds in the frequencies of 0.5, 1, 2 and 4 kHz. In this sense, the use of the SII and the diversity of characteristics of the study population have enabled the analysis of audiological variables that affect the positive relationship between audibility for speech sounds and vocabulary.

The study population consisted of 65 individuals, mostly female **gender** (63%), with **age group** ranging from 6 to 17 years, with an average of 10 years and median of 10 years. All individuals attended **school**, of which 86% attended regular schools and 72% public schools. These data are in line with the school census of 2016, which indicated that 78% of students in Brazil are enrolled in public education network (federal, state or municipal schools) and that 57.8% of Brazilian schools have disabled students included in inclusive regular classes.

With respect to the **education level,** most of those responsible for the subject had incomplete high school or higher education (44%), while 13% were illiterate or had incomplete elementary school, which is in line with data reported in national studies[19], showing that 41 .1% of mothers have completed elementary school, in a study with a population that also attended the Brazilian Unified Health System. Almost half of the families (47%) of this study belonged to **socioeconomic class C**, according to its definition in Brazilian, and according to data from the last census of 2010[20], which reports that the majority of the population in the São Paulo State belongs to class C.

More than half of the population of the study attend or attended **speech-language pathology and audiology therapy** (55%). Most of the individuals had idiopathic **etiology** (47%); but as many study subjects have not undergone genetic studies, it is possible that part of the hearing loss with unknown etiology may be related to genetic factors, which according to Smith[21] may be responsible for up to 30% of the pre-lingual hearing losses. The data from this study are in line with Pinto, et al.2[2], who reported a 42% of idiopathic etiology in his study in Brazil in 2012. Ten individuals (15%) had confirmed etiology (genetic - 4, meningitis - 3, malformation - 2, ototoxicity - 1), 31 individuals (47%) had unknown etiology (idiopathic); and 23 (35%) had suspected etiology due to risk factors for hearing disabilities (namely: suspected genetic changes, prematurity, neonatal ICU, low weight, use of ototoxic drugs, malformation, suspected syndrome, jaundice, consanguinity).

The average age at the **diagnosis** of hearing impairment among participants was 38 months, with great variability (standard deviation of 33.4 months). Other national studies[22-24] also reported the age at diagnostic between 2 and 3 years of age in large part of the study population. The average age at **adaptation** to the 1st ISAD in this study was 51 months with a standard deviation of 33.9 months. National studies[22-24] also reported an advanced age at the beginning of the intervention. The age at diagnosis and intervention commonly occur mostly after 2 years of age in developing countries, such as Brazil, according to a study[25] conducted for WHO. Although the data found in this study are in line with several findings in the literature from developing countries, which show age at intervention and late diagnosis, the data suggest that there is still much to do whereas this late intervention are out of step with the recommendation by the *Joint Committee of Infant Hearing*[2] and the Hearing Health Multidisciplinary Committee - COMUSA [3] that advocate that the diagnosis should be completed until the third month of life and that the access to an early intervention program must be provided until the sixth month of life.

The average **use of the device** was 9.5 hours/day, which is close to the value stipulated as optimal use of 10 hour/day (75% of the time awake). This result is also in line with Walker et al,[26] in which the study population used the device on average 10.63 hours per day. Eighty-seven percent (87%) of the subjects used the **FM system**.

With respect to the **audibility** for speech sounds assessed by the SII values, 9% of the subjects had SII scores lower than 37, 47% had SII scores between 38 and 57, and 43% scored greater than 58 (Figure 1).

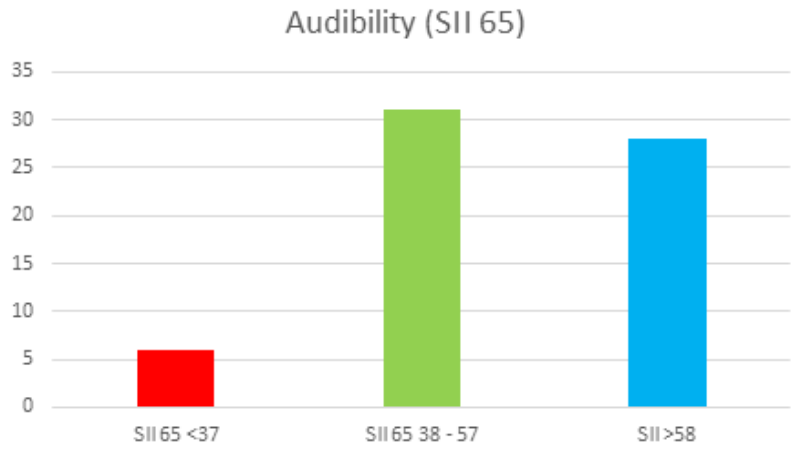

Figure 1. Distribution of subjects in the three audibility groups (SII 65) of the best ear.

The characteristics and heterogeneity of the study population seemed to represent the different conditions of the subjects monitored by the service, thus enabling comparative analysis from the relationship between audibility and receptive vocabulary.

Our first assumption was that there would be positive relationship between audibility (SII 65) and performance on the vocabulary test (PPVT). However, this hypothesis was not confirmed in this population, probably due to the heterogeneity of demographic characteristics and to the daily life of the subjects analyzed. The average standard score in the **receptive vocabulary test** was 51.8 points, which is less than -3DP, in line with the standard set by the PPVT test-4.

With respect to studies conducted in Brazil, Penna et al[24], reported that 65% of children had vocabulary changes, as found in this study; however, the authors used an expressive vocabulary test as instrument for measuring the vocabulary. Another study[27] that used the same instrument of this study, but with CI users, found a slightly higher average of receptive vocabulary performance (64.9 in standard score) when compared to those in this study. Armonia et al[28] also used the same instrument, but with a population of children with Specific Speech and Language Developmental Disorder and they described that 52.4% of the subjects had a performance compatible with the age group on the assessment of the receptive vocabulary.

When associating audibility (SII 65) with the vocabulary (PPVT test-4), it was suggested that there was a tendency to increase in vocabulary performance with increasing audibility, however, this linear tendency was not significant. In this way, the hypothesis was not confirmed (as shown in Figure 2). In addition, it was observed in this sample that 30% of the subjects with good audibility (SII 65>58) had poor performance on the vocabulary test (<-2DP). That is, no subject with low audibility (SII 65<37) in this sample achieved a performance above -2DP in the vocabulary test, and 71% of subjects with good audibility (SII 65>58) had low performance on the vocabulary test. The data found in this study are not in line with data reported by international studies[8,9] that found a significant correlation between receptive vocabulary and audibility scores, so that the degree of delay in language development was greater with increasing hearing loss, where a better audibility was associated with faster rates of growth of the language development, suggesting a continuous relationship between audibility and vocabulary acquisition. Similarly, a national study[19] reported that the group that showed the highest number of children with good performance on the vocabulary test was the group with mild to moderate hearing loss. The literature has shown[7,8] that the audibility of speech sounds obtained with the use of amplification favors language development, aiming to demonstrate that the cochlear implant is necessary from a certain degree and loss characteristics. However, it also points to complex variables that may interfere with this relationship.

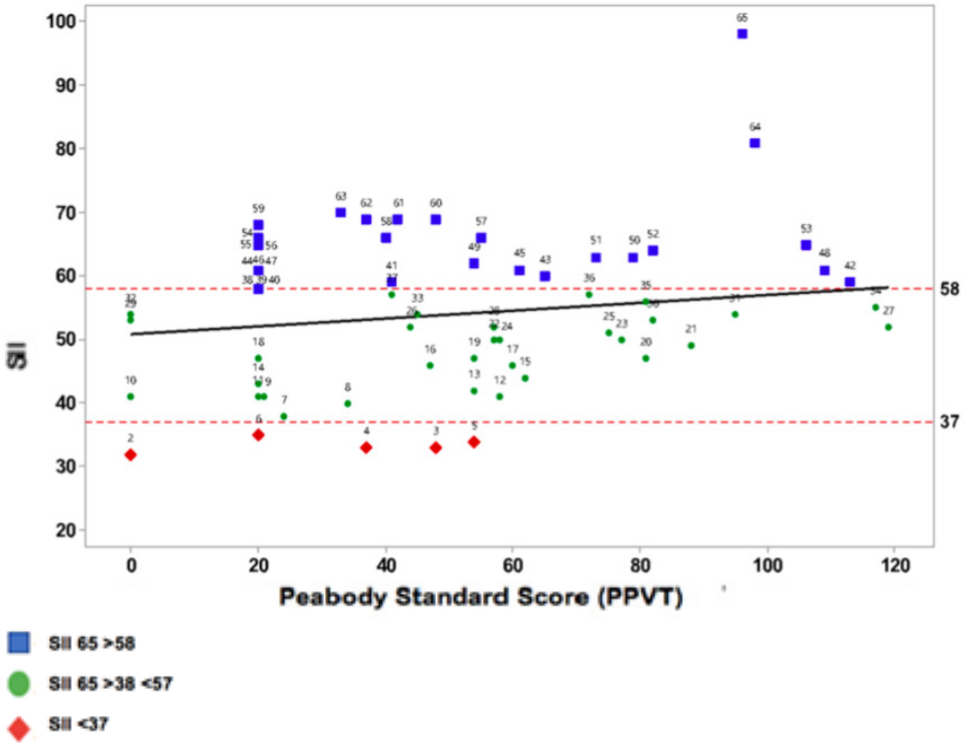

Figure 2. Auditory dispersion diagram (SII 65) in the best ear and standard score in the receptive vocabulary test (PPVT-4).

Considering the characteristics found in the group, it is of paramount importance to analyze other factors that explain the variability in the vocabulary test performance, regardless of audibility. The subjects' histories are so diverse in terms of socioeconomic group, oralization and education level that have led to an imperfect relationship between audibility and vocabulary performance. In short, the audibility did not determine vocabulary performance, being a critical but not sufficient factor to ensure adequate vocabulary development and growth.

Literature shows that audibility alone is not always enough for language and vocabulary development, since there are several factors that will influence the quality and quantity of audibility throughout the child's trajectory[29]In addition, it is quite unlikely that the audibility will operate alone to influence the results, since there is a large number of variables that have potential influence on the response of these children[30] .

Results found in this study suggest that other variables should explain these findings, considering the heterogeneity of the study population. In this sense, further studies (in preparation) investigated other factors in this population.

Conclusions

This study allowed to verify that characteristics and heterogeneity of the studied population sample seemed to represent different conditions of the subjects attended in an auditory health service in Brazil. When verifying the relationship between audibility for speech sounds and receptive vocabulary, the studied cases suggest that audibility did not determine vocabulary performance, being a necessary but not sufficient condition for the development and growth of this ability. These results suggest that other variables should explain these findings, considering the heterogeneity of the study population. In this sense, further studies (in preparation) investigated other factors in this population.

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