Speech recognition in children with cochlear implants using two different speech processors

Reconhecimento de fala em crianças usuárias de implante coclear utilizando dois diferentes processadores de fala

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ABSTRACT

Purpose: To study comparatively the speech recognition skills in quiet and noise background situation in children with cochlear implants using two different speech processors. **Methods:** It was evaluated 26 children with cochlear implant device *Nucleus 24M* or *24K, Cochlear Corporation,* divided in two groups according to the speech processor used. The Group 1 consisted of 16 children who used the *Sprint* processor and the Group 2 consisted of 10 children who used the *Freedom* processor. The Hearing in Noise Test – Portuguese version of Brazil was applied in the sound field in silence and in the presence of noise background situation. **Results:** The speech recognition performance of Group 2 (*Freedom*) was higher than Group 1 (*Sprint*) in all evaluation situations, with significant difference between groups only on quiet situation. **Conclusion:** The speech processor showed significant influence on speech perception in children users of Nucleus 24K and 24M cochlear implants. The components of the signal processing available on the Nucleus Freedom processor may have contributed to the better speech recognition performance of Group 2. Further research is needed to complement these findings.

Keywords: Cochlear implantation; Child; Hearing; Noise; Hearing loss

RESUMO

Objetivo: Estudar comparativamente a habilidade de reconhecimento de fala no silêncio e na presença de ruído competitivo em crianças usuárias de implante coclear utilizando dois diferentes processadores de fala. **Métodos:** Foram avaliadas 26 crianças usuárias do implante coclear *Nucleus* 24M/24K, da Cochlear Corporation®, divididas em dois grupos de acordo com o processador de fala utilizado. O Grupo 1 foi composto por 16 crianças que faziam uso do processador de fala *Sprint* e o Grupo 2 foi composto por 10 crianças que faziam uso do processador de fala *Freedom*. Foi aplicado o *Hearing in Noise Test* – versão em Português/Brasil, em campo livre, na condição de silêncio e na presença de ruído competitivo. **Resultados:** O desempenho do Grupo 2 (*Freedom*) foi superior ao desempenho do Grupo 1 (*Sprint*) em todas as condições de avaliação, sendo evidenciada diferença entre eles na condição de silêncio. **Conclusão:** O processador de fala apresentou influência significativa na percepção de fala de crianças usuárias dos implantes cocleares *Nucleus* 24K e 24M. As características de pré-processamento do som presentes no processador de fala *Freedom* podem ter contribuído para o melhor desempenho do Grupo 2 nos testes de percepção de fala realizados. Novos estudos são necessários para complementação destes achados.

Descritores: Implante coclear; Criança; Audição; Ruído; Perda auditiva

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INTRODUCTION

The use of cochlear implants (CIs) in children with severe or profound hearing loss has increased dramatically worldwide. Increased CI use has driven the continued development of new technologies to improve the performance of CI users, especially in difficult speech perception situations, such as in the presence of background noise.

Speech perception under difficult conditions, such as in the presence of background noise and competitive reverberation[(1)], is one of the most significant issues for CI users. One study demonstrated a significant decrease in the performance of deployed speech perception in the presence of background noise[(2)], and background noise is the most frequent complaint among CI users[(3)]. According to another study[(4)], the integrity of the speech processor and its algorithms is a determining factor in the CI user's ability to understand speech and to separate the desired signal from all other signals, including background noise. Recent studies have shown benefits in speech perception for CI users who use devices with technological improvements, including improvements in the speech processor and other components that are responsible for sound processing algorithms[(1,5,6)].

A speech processor is present in all CI devices and is analogous to the main component of an external hearing device. The speech processor contains all selected parameters that are responsible for determining the manner in which the CI system transforms the acoustic signal of speech into electrical pulses, which are responsible for stimulating the remaining nerve fibers in the cochlea. These parameters include characteristics from the microphone and pre-processing strategies, plus the speech coding strategies, which represent a major fitting parameter in software programming. The coding strategies define how the processor will analyze and encode the information that is important for speech, transform the encoded information into electrical pulses and determine how they will be delivered to electrodes that are inserted into the cochlea.

Rapid technological advancements have promoted the development of increasingly sophisticated speech processors that are associated with new sound processing strategies and more complete fitting software to further improve the quality of speech sounds and eliminate background noise. However, the question remains regarding whether these new processors could also promote better performance for users of previous generations of CIs.

Thus, the present study aimed to perform a comparative study of the ability to recognize speech in the presence and absence of background noise in children who use CIs with two different speech processors.

METHODS

The present study was conducted in the Cochlear Implant Program at the Hospital for the Rehabilitation of Craniofacial Anomalies, Universidade de São Paulo (HRAC/USP - Bauru). The study was approved by the Ethics Committee of the Bauru School of Dentistry, Universidade de São Paulo (FOB/USP), under the number 093/2009. The study included 26 children of both genders who used the CI system Nucleus® 24 (Cochlear Corporation®).

The children were divided into two groups according to the speech processor present in their CI systems. Group 1 was composed of 16 children who were users of the Nucleus CI24M or CI24R(ST) and the Sprint speech processor. Group 2 was composed of 10 children who were users of the Nucleus CI24M or CI24R(ST) and the Freedom speech processor.

Data were collected regarding the distribution of groups in terms of age at the time of trial (IDD), duration of auditory sensory deprivation (TPRI) and time of CI use (TUSO) (Table 1).

All children studied had severe, severe/profound or profound sensorineural hearing loss, bilateral and of a prelingual source, with surgery performed at HRAC/USP at the age up to

Table 1. Group distributions with respect to age of the children when the research was carried out, duration of auditory sensory deprivation and time of cochlear implant use

	Subjects (n)		AGE (month)	DASD (month)	TUSE (month)
Group 1 (Sprint)	16	Average	98.19	25.23	71.88
		SD	26.48	10.28	18.15
		Median	92.50	23.00	67.00
		Minimum	62.00	13.00	46.00
		Maximum	144.00	47.00	98.00
Group 2 (Freedom)	10	Average	118.30	27.90	87.80
		SD	33.70	11.00	26.45
		Median	118.50	23.50	91.50
		Minimum	74.00	17.00	52.00
		Maximum	186.00	50.00	137.00

Note: AGE = age of the children when the research was carried out; DASD = duration of auditory sensory deprivation; TUSE = time of cochlear implant use; SD = standard deviation

4 years. The time of CI use that was considered for the study selection was at least 3 year and the time of speech processor use that was considered for study selection was at least 5 months. The length of experience with the Freedom speech processor (Group 2) ranged from 5 months to 3 years. All children had a full insertion of electrodes into the cochlea.

All children studied presented auditory skills of speech recognition in an open set ("open-set") situation, according to the categories of hearing[7] and fluent oral language, according to the categories of speech[8]. All children had similar characteristics and socioeconomic status and were regularly enrolled in and followed by the Cochlear Implant Program at the HRAC/USP. It was performed a distribution of groups with respect to the etiology of hearing loss (Table 2).

Table 2. Distribution of the groups according to the etiology of the hearing loss

Etiology	Frequences (n) and percentages (%)				Total	
	Group 1		Group 2			
Genetics	0	0	3	18.75	3	11.54
Idiopathic	6	60.00	12	75.00	18	69.23
Meningitis	1	10.00	0	0	1	3.85
Rubella	3	30.00	1	6.25	4	15.38
Total	10	100.00	16	100.00	26	100.00

The main fitting parameters that were selected for Groups 1 and 2 were also obtained (Table 3).

Table 3. Main fitting parameters selected in the groups

Parameter	Group 1	Group 2
Active electrodes	22	22
Mode of stimulation	MP1+2	MP1+2
Speech coding strategy	ACE	ACE
Number of Maximas	12	12
Stimulation rate/channel	1200 PPS	1200 PPS
Frequency distribution	188 – 7938 Hz	188 – 7938 Hz

All subjects in Group 2, who were users of the Freedom speech processor, were using Adaptive Dynamic Range Optimization (ADRO) and an Instantaneous Input Dynamic Range (IIDR) of wider than 40 dB.

The assessments of the external component (speech processor, transmitter antenna, microphone and cables) were performed through manual inspections. The assessments of the internal components were performed through telemetry systems, including impedance telemetry, compliance telemetry and neural response telemetry (NRT). These assessments were performed to rule out problems with the devices.

Participants were evaluated during visits to the Audiological Research Center for follow-up evaluations (post-surgical stage). The evaluation of speech perception was performed with the "map" or program that was most often used by the patient since the last visit.

The follow-up evaluations in the post-surgical period were performed every three months in the first year of device use, every six months in the second year and were more widely spaced with increased experience with the CI. This change in frequency occurs partly because the thresholds and comfort levels for electrical stimulation vary over time, especially during the initial programming sessions, but tend to stabilize as the individual gains experience with the device. Thus, maps containing electrical stimulation thresholds and comfort levels, created in the speech processor, are adjusted through a process of gradual fine adjustments over time.

To assess speech perception, the children were instructed to use only the CI system, disregarding the use of the contralateral hearing aid (HA). The evaluation protocol of speech perception was a version of the Hearing in Noise Test (HINT) that was adapted for Portuguese/Brazil[9]. The HINT corresponds to a test of speech recognition in the presence and absence of background noise. It is an adaptive test, where the intensity of projected sentences varies with the subject's response. It comprises 240 sentences that are distributed into 12 lists of 20 phonetically balanced sentences each that can be projected through headphones or in an open field. The results are expressed as Speech Reception Threshold (SRT), and a lower value indicates a subject's better performance.

The HINT was developed to improve the quality of the technology of assistive listening devices such as hearing aids and CIs[10]. Its application to evaluating the performance of CI users has grown in popularity because the test is efficient, fast, easy to use and provides reliable measurements and results that can be replicated. Additionally, the test allows a reliable comparison of the results obtained in several other countries because it has been adapted for different languages.

The HINT allows the evaluation of functional capacity impairment, i.e., determining how skilled a person is at hearing and understanding speech, especially in noisy environments. Given the negative impact of background noise on communication, speech perception tests in the presence of background noise more effectively reflect normal listening conditions, enabling a detailed assessment of communication skills[11].

The present study projected a list of 20 sentences for each test condition, randomly chosen by the HINT software in an open field. The test was performed under conditions of silence (S) and in the presence of background noise (S/N 180º). The sentences were projected under a condition of silence in a front position (0° azimuth) through a loudspeaker that was positioned one meter away from the child (Figure 1A). In the presence of background noise, the sentences were projected in a front position (0° azimuth), and the background noise was projected behind the patient (180° azimuth). The sentences and the background noise were projected through loudspeakers that were located one meter from the child, at the 0º and 180º azimuth positions (Figure 1B).

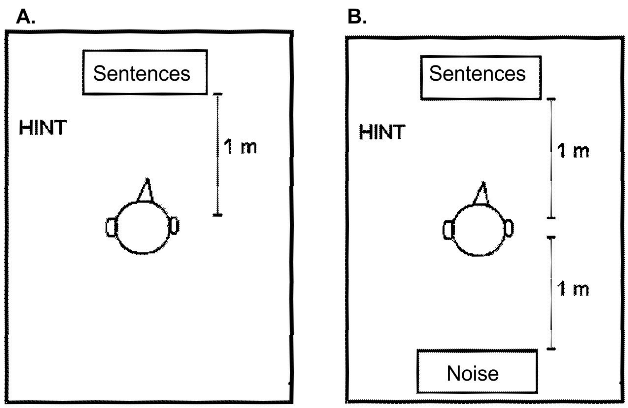
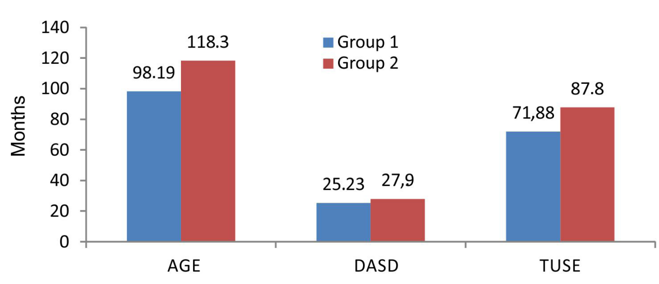


Figure 1. A. Positioning of the patient's head and loudspeaker during the HINT test (silence Condition - S). **B.** Positioning of the patient's head and loudspeakers during the HINT test (presence of background noise – S/N 180º)

In the present study, we used methods of descriptive analysis because of the nature of the study as an exploratory study and aimed for data completeness and consistency. Therefore, we conducted a comparison of experimental groups with respect to the dependent variables (S and S/R180º) using a t-test. The significance level for all statistical tests was set at 5%.

RESULTS

Comparisons were made between Groups 1 and 2 with respect to age (AGE), duration of auditory sensory deprivation (DASD) and time of CI use (TUSE) (Figure 2). The group distributions were similar for all three variables, with slightly higher mean values for Group 2.



Note: AGE = age of the children when the research was carried out; DASD = duration of auditory sensory deprivation; TUSE = time of cochlear implant use

Figure 2. Comparison of age, duration of auditory sensory deprivation and time of cochlear implant use between the groups

Several studies have demonstrated a significant influence of these variables on the performance of speech perception in children with CIs[12,13]. Thus, there was a need to control for these variables during the evaluations of the two study groups. Group 2 had higher average and median ages compared to Group 1, as well as greater age variability (SD=33.70 months) (Figure 1). However, a comparison of the mean age in both groups by a t-test indicated no significant difference in age between the two groups (p>0.05).

For both groups 1 and 2, the duration of auditory sensory deprivation were approximately equal. The results of a t-test indicated no significant differences between groups for the duration of auditory sensory deprivation (p>0.05).

Regarding the time of CI device use, Group 2 had higher average and median times and higher variability of usage time compared to Group 1. These results were most likely due to the wider distribution of children in this age group. Group 2 had higher average and median ages, and greater age variability compared to Group 1. A comparison of the mean time of CI use using a bilateral t-test showed no significant differences between the two groups (p>0.05). The HINT performances of the two groups for the condition with no background noise (S) was compared (Figure 3). Group 2 had a lower average SRT value than Group 1, indicating a better performance in this test condition. A t-test revealed that this difference was significant (p>0.05), although the p-value was very close to the 5% significance level.

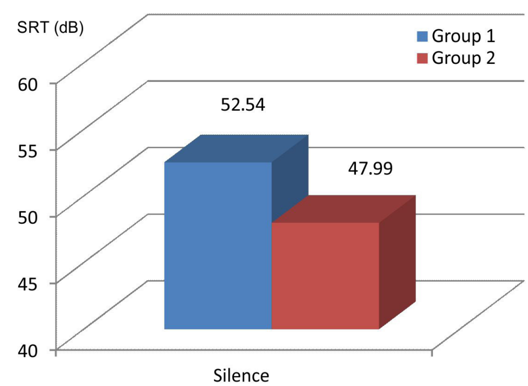


Figure 3. Mean values for the Speech Reception Threshold (SRT) obtained by the Groups 1 and 2 for the HINT test (Condition of Silence)

The HINT performances of the two groups in the condition with background noise (S/N 180º) were also compared (Figure 4). Group 2 had a lower average SRT value than Group 1, indicating a better average performance in the presence of background noise. However, while Group 2 had a better average performance when background noise was present, a t-test showed no significant difference between the performance levels of the two groups (p<0.05).

It was created a distribution of the results for Groups 1 and 2 in the condition of competing background noise (S/N 180º) (Figure 5). A point was observed in an atypical distribution of responses from Group 2, leading to disparate average and median results for this group.

Subject 7, who generated the atypical point in Group 2, had a relatively high score compared to the other scores in this group (12.4 dB SNR compared to the average of approximately 1.30 dB SNR for the group). This difference did not occur in the

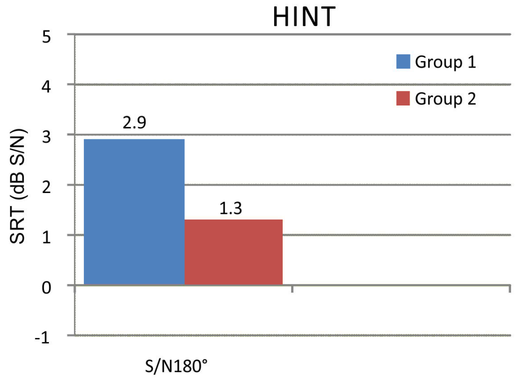


Figure 4. Comparison of the results obtained by the Groups 1 and 2 for the HINT test in the presence of background noise (S/N180º)

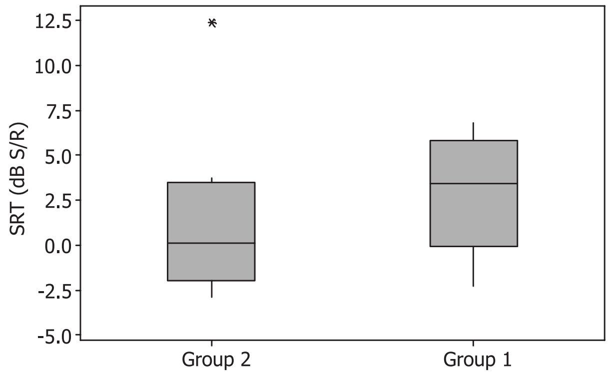


Figure 5. Results obtained for the Groups 1 and 2 to the HINT test in the presence of background noise (S/N 180º)

absence of background noise (S), in which the subject had the SRT for HINT sentences at 55.5 dB, leading to a symmetrical distribution of results among the group subjects.

For the HINT in the presence of background noise (S/N 180º), it was noted that regardless of the inclusion of the atypical point in Group 2, this group had a better average performance compared to Group 1. However, these results showed significant differences between groups only when the atypical point was excluded. After excluding the atypical point of Group 2, the values for the S/N180º condition had higher average and median values for Group 1 (2.975 dB Signal/Noise and 3.45 dB Signal/Noise, respectively, for Group 1 compared to 0.067 dB Signal/Noise and -0.30 dB Signal/Noise, respectively, for Group 2), indicating a better average performance for Group 2.

The differences in obtained values for the groups were more discrepant when the atypical point was removed from Group 2. The mean values were statistically significantly different according to a bilateral t-test, which rejected the equality between them ($p<0.05$).

DISCUSSION

The present study aimed to investigate the ability of speech recognition in the presence and absence of background noise in children with CIs and two different types of speech processors. Thus, the objective was to determine whether different processors could influence the ability of speech recognition in the presence and absence of background noise. It was found that the children who used the Freedom speech processor outperformed the children who used the Sprint speech processor for all evaluation conditions. However, significant differences were observed between the groups for speech perception just in absence of background noise.

The superior performance of the Freedom speech processor on the speech perception tests compared to other processors (Sprint, Esprit and Esprit 3G) for users of the Nucleus 24M or 24K has been reported previously[14-16].

The study subjects had a better average performance with the Freedom speech processor for speech recognition in the presence of background noise (a difference of 1.68 dB SNR) compared to the Sprint processor. This result is in agreement with a previous study[14] that showed an average improvement in the performance of subjects with respect to speech recognition in the presence of background noise with the Freedom speech processor (an improvement of approximately 1.8 dB SNR) compared to the Sprint, Esprit 3G or Esprit processors. These findings indicate the importance of studies that investigate the results of different models of speech processors.

It is known that other variables significantly influence the results of speech perception of CI users, including auditory sensory deprivation, time of CI use and age[12,13,17]. The results of the present study showed that these variables were controlled between the study groups, eliminating the possible influence of these factors on performance.

Regarding the comparison of age at the time of the experiment, we observed a slight asymmetry toward higher ages in the distributions of both groups. This variability was most likely due to the wide distribution of ages evaluated, which ranged from 5 years to 15 years. Atypical points were not observed, namely, children with ages that were very different from the average subject age.

Whereas the time of auditory sensory deprivation appeared to be symmetrical and approximately equal between the two groups, it is expected that the time of CI use is longer and the variability is greater for the subjects of Group 2.

The remarkably high score of Subject 7, demonstrated by the presence of the atypical point in the distribution of results of Group 2 to the S/N 180º condition, indicated a worse performance for this individual in the perception of speech in the presence of background noise. This irregularity was considered to be an isolated incident and should be carefully investigated if it occurs in a clinical setting. Because there were strong efforts to control for other variables that could affect the results of the study, this fact could be attributed to the auditory processing ability of this subject.

Regarding the technological characteristics and processing of sound in the studied speech processors, the same main fitting parameters were selected for both groups, as shown in Table 3.

Although the same sound processing strategy was used for the two groups, the processors have characteristics that differ in terms of pre-processing of the sound. Thus, these algorithms seem to significantly influence the superior performance of children using the Freedom speech processor, as demonstrated in the present study.

A previous study[14] showed better performances for speech recognition in quiet conditions with subjects who used the Freedom speech processor with ADRO activated compared to those using the Freedom processor without ADRO activation or those using other processors, including Esprit, Sprit 3G and Sprint. ADRO dynamically adjusts the gain of each stimulation channel according to the level of the input signal of this channel. The algorithm optimizes the gain for each channel and the output maintained within a dynamic range that is comfortable for the patient. The channels that represent low-intensity sounds are enhanced, while high-intensity sounds are attenuated. All children who used the Freedom speech processor had ADRO activated, which leads us to propose that this algorithm might have a significant influence on the superior performance of Group 2 in the present study.

There seems to be a consensus regarding the best results for speech perception in quiet conditions using ADRO. However, in the presence of background noise, such a consensus is lacking. One study reported a significant influence of ADRO in speech perception in the presence of background noise[15]. In contrast, another study reported that this algorithm has no effect when speech competes with background noise[18].

The same arguments have been made for IIDR. One study[19] showed that users of the Freedom speech processor who used a broader IIDR (40 dB) had better results for speech perception in quiet conditions, especially at lower intensities compared to those who used the Freedom speech processor with IIDR at 30 dB or other processors, such as Sprint or Esprit, with IIDR at 30 dB. IIDR corresponds to the range of acoustic intensities selected to map the dynamic area of electrical stimulation of the CI user. All children who used the Freedom speech processor made use of a broader IIDR (40 dB) compared to children who used the Sprint speech processor (30 dB). However, further studies are needed to investigate the influence of each component of sound pre-processing in the speech perception skills of the user.

Studies related to sound processing algorithms make important contributions to the selection of fitting parameters to optimize the speech perception of the user. Furthermore, with the rapid advancement of technology and the development of increasingly sophisticated new speech processors, the question arises regarding whether these new processors could also promote better performance for users of previous generations of CIs. This information can assist in selecting a new speech processor, with respect to its useful life and other problems that result in the need for replacement, and guide public and private policy related to the exchange of speech processors.

The present study also provides important contributions to improvements in the outcome measures of speech perception in children with CIs in Brazil. The use of HINT makes it possible to compare the results of the present study with those from several other countries because it allows a comparison of the results of functional hearing in different languages.

CONCLUSION

Different speech processors have significant influences on speech perception in childhood users of Nucleus 24M and 24K CIs. The algorithms for the pre-processing of sound that are present in the Freedom speech processor might contribute to the better performance of the subjects of Group 2 in the present study. Further studies are needed to accurately investigate the influence of the components of the speech processor, including the algorithms for pre-processing and processing of sound, in the speech perception skill of the user.

The HINT is an effective tool in the evaluation of speech recognition in the presence and absence of background noise in children with CIs. Thus, the results of the present study can be compared to studies performed in other countries and future hearing research in Brazil.

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