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Original Research

Speech Understanding in Noise in Children with a Cochlear Implant

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Abstract

Objectives: The aim of the study is to determine the effect of a cochlear implant on the ability to understand speech in a noisy environment.
Materials and Methods: Turkish HINT was applied to the experimental group consisting of 15 children with a unilateral Cochlear Implant (CI) aged between 7;9, and 13;9 (year; month) and the control group consisting of 15 children aged between 8;10 and 13;0 with normal hearing. Speech Reception Thresholds (SRTs) of the groups were obtained in quiet and noise in front conditions. The data obtained from the groups were compared.
Results: The mean Speech Reception Threshold (SRT) in the quiet was found to be 65.4 dB in children with CI and 21.6 dB in normal-hearing children. The mean SRT in noise was found to be +6.0 dB Signal to Noise Ratio (SNR) in children with CI and -1.6 dB SNR in normal-hearing children. A significant difference was found between the mean SRT values of the groups in quiet and noise conditions (p<0,01).
Conclusion: Children with CI need a higher SNR than children with normal hearing to understand speech in noise. In addition, the age of children with normal hearing had a significant effect on speech understanding skills in noisy conditions but not in quiet.

Keywords: *Cochlear Implant; Hearing Loss; Speech Understanding*

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Introduction

Cochlear Implants (CIs) play the role of damaged or lost hair cells in severe to profound hearing loss and directly stimulates the auditory nerve by converting sound into electrical energy. One of the best ways to determine the benefits of a Cochlear Implant (CI) is to evaluate the speech understanding skills of CI users. Speech understanding refers to auditory, cognitive, and linguistic processing involving acoustic-phonetic discrimination and long-term memory of words. Speech understanding is a skill that develops depending on age and is limited by vocabulary, phonemic classification, and linguistic competency (Eisenberg et al., 2006). Studies on speech understanding show that adults can deduce the meaning of sentences by guessing words they have not heard. Since children have a limited vocabulary, they cannot guess the words they have not heard, so they have more difficulty in understanding sentences. While this is important even in children with normal hearing in the learning process, it causes more problems in hearing impaired children. Learning disadvantage increases with the noisy environment and reverberation, vocabulary development is slower and academic achievement is affected in children with hearing loss (Gheller et al., 2020). In a study conducted with children under 5 years of age with CI, it was stated that children with CI performed closely with their normal hearing peers, only 7% of children with CI could distinguish sentences in difficult listening situations (Eisenberg et al., 2006). Children using hearing aids or cochlear implants need more SNR in order to perform the same as their normal hearing peers (Ching et al., 2018).

It is known that traditional pure tone hearing assessments are insufficient to accurately assess speech understanding in noise. It is seen as a much more effective way to use sentences used in daily conversations to evaluate speech intelligibility (Nilsson et al., 1994). Examples of sentence tests developed for this purpose are Hearing in Noise Test (HINT), AzBio Sentence Test, Connected Speech Test (CST), Speech Perception in Noise Test (SPIN), Speech in Noise (SIN) Test, and Matrix Test can be given (Cox et al., 1987; Kalikow et al., 1977; Killion et al., 2004; Kollmeier et al., 2015; Nilsson et al., 1994; Spahr et al., 2012).

The Turkish version of HINT was prepared by Çekiç in 2006 and applied to adults with normal hearing for the first time, and speech reception thresholds were determined, and it's Turkish validity and reliability were established (Cekic & Sennaroglu, 2008). There are two versions of American English HINT, adult and children. HINT in Children (HINT-C) can be applied to the age range of 6 -16 years. The sentences chosen in the adaptation of Turkish HINT are taken from primary school first-grade books, which have simple and easy-to-understand structures that can be understood by children (Cekic & Sennaroglu, 2008). Since speech

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intelligibility measured via HINT is determined as Speech Reception Threshold (SRT) (dB), it is thought that it does not cause a "ceiling" or "floor" effect (Plomp, 1977).

It can be stated that the clinical importance and value of HINT have been clearly demonstrated by many studies. HINT can be used to evaluate and compare hearing aid users, CI users and people with normal hearing. In this study, it is aimed to measure speech reception thresholds of children with unilateral CI and children with normal hearing and make a comparison between groups in order to determine the effect of CI on speech understanding.

Materials and Methods

Ethical approval was obtained from Hacettepe University Ethics Committee on 16.04.2009 with the number LUT 09/32-3. Parental consent was obtained for all pediatric subjects.

Subjects

Experimental and control groups were needed in the study. Children with a unilateral CI, whose average hearing thresholds were within speech banana, and whose SRT performance could be measured in the quiet condition of the HINT, were included in the experimental group. In order to determine this group, 29 children with unilateral cochlear implants were evaluated, and 14 of them were excluded from the study as they didn’t meet the criteria for participation. The experimental group consisted of 15 children with unilateral cochlear implants, 5 girls and 10 boys, aged 7;9 to 13;9 (year; month) (Mean±SD = 10;8 ± 1;10) participated. All children with CI had congenital hearing loss, and all had normal cochlear anatomy except 'Participant-3', who was being followed up with the diagnosis of Type II Cochlear Anomaly (Sennaroglu, 2009) (Table 1). Children with normal otological findings, normal middle ear pressure and bilateral Pure Tone Average (PTA) in the normal range were included in the study. Totally 20 children were evaluated for this purpose, and 5 of them were excluded from the study as they did not meet the including criteria. The control group consisted of 15 children, 5 boys and 10 girls, aged between 8;10 and 13;0 (year; month) (Mean±SD = 10;0 ± 1;8). The mother tongue of all participating children was Turkish.

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Table 1: Demographic information of children with CI.

Subject Number	Age (y;m)	Sex	Age at Implantation (y;m)	CI Experience (y;m)	Implanted Ear	CI Brand
1	12;11	F	4;5	8;5	L	Medel
2	13;4	M	8;10	4;5	R	Medel
3	8;8	F	5;11	2;8	R	Cochlear
4	10;7	M	5;8	4;10	R	Cochlear
5	12;3	M	2;11	9;3	R	Cochlear
6	8;6	M	2;2	6;3	R	Medel
7	11;6	M	8;3	3;2	R	Advanced Bionics
8	9;10	M	2;8	7;1	R	Cochlear
9	10;2	M	4;7	5;6	R	Cochlear
10	11;1	F	3;8	7;4	R	Medel
11	13;9	F	4;3	9;5	R	Cochlear
12	7;9	M	3;11	3;9	R	Advanced Bionics
13	8;9	M	3;8	5;0	R	Advanced Bionics
14	9;11	M	2;2	7;8	R	Cochlear
15	11;3	F	2;9	8;5	R	Cochlear

(M: Male, F: Female, L: Left, R: Right)

The study was conducted in the quiet rooms of the IAC (Industrial Acoustics Company) in the university hospital. In order to evaluate the speech reception skills of the participants, a computer with the "HINT for Windows" software program, a device called "HINT BOX" connected to the computer, and a speaker was used to send speech signals.

Procedure

Children with CI who are followed in the audiology department of the university hospital and are diagnosed with bilaterally normal hearing were included in the study. Consent was obtained from the parents of all children. All tests for experimental group were performed in the monaural listening condition (with CI only).

HINT in quiet and noise front conditions were applied to both experimental and control groups in a free field. In these conditions, the loudspeaker is positioned at 0° azimuth, 1 m distance from the participant. To determine the SRT in quiet condition, the initial intensity of the signal was set as 70 dB for the cochlear implanted group and 20 dB for the normal-hearing group. Children with CI who could not achieve SRT in quiet were excluded from the study. All normal-hearing children who met the inclusion criteria achieved SRT in the quiet condition. HINT in noise front condition was applied to all participating children who had SRT in quiet. In the noise front condition, speech and the noise signals were given from the loudspeaker at 0 degrees azimuth. The speech signal was set to be sent 2 seconds after noise. The intensity of

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the speech and noise signal was adjusted at the same level for the experimental and control groups. The noise signal was fixed at 65 dBA, while the intensity of the speech signal was initiated at 0 dB SNR. As a result of HINT noise in front condition, which progressed adaptively depending on whether the participant repeated the sentences correctly or not, the SRT was determined as dB Signal to Noise Ratio (SNR).

Statistical Analysis

The collected data were analyzed using the SPSS software statistical computer package version 15.0. Statistical significance was defined as $p<0.05$. In order to see whether some values in the data were outliers or not, the Dixon Test was applied first. The Mann-Whitney U Test was used to compare the SRTs obtained by the experimental and control groups. Linear Regression analysis was performed in order to determine to what extent the SRTs of the experimental group were affected by the age of implantation and duration of implant experience. Linear Regression analysis was performed to determine to what extent the SRTs of the control group were affected by age.

Results

As a result of the Dixon Test, no outliers were found. Therefore, all data obtained were used in statistical analysis.

A significant difference was found as a result of the Mann Whitney U Test, which was conducted to see the difference between the SRTs of the experimental and control groups in quiet and noise conditions (SRT in quite z = -4,666 and p = 0,000, SRT in noise front z = -4,652 and p = 0,000) (Table 2).

Linear Regression analysis has shown that there is no statistically significant relationship between SRTs in quiet and age at implantation, duration of implant experience of children with CI (Adjusted R^2=-,060, Durbin Watson=2,102). Similarly, it was found that there was no statistically significant relationship between the SRTs in noise front and the age of implantation, and duration of implant experience in children with CI (Adjusted R^2=-,094, Durbin Watson=1,494).

As a result of the Linear Regression performed to see the level of effect of age on SRTs in quite of normal hearing children, no significant relationship was observed (Adjusted R^2= .010, Durbin Watson=1,869). However, a statistically significant relationship was found as a result of the Linear Regression performed to see to what extent the SRTs in the noise of the participants were affected by age (p = .039) (Table 3)

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Table 2: Mean, Standard Deviation values of HINT scores obtained by the experimental and control groups and Mann Whitney U statistical analysis

	Experiment Group (Children with CI)	**Control Group (Normal Hearing)**	**Mann-Whitney U**	
HINT Conditions	X ± SD	X ± SD	Z	P (2 tailed)
SRT in Quite (dB)	65,4 + 4,02	21,6 + 2,76	-4,666	0,000*
SRT in Noise Front (dB SNR)	6,0 + 1.77	0,4	-4,652	0,000*

*p<0.01

Table 3: The level of effect of age on the SRTs in noise of control group.

	Standardized Beta	**t**	**p**
Constant	—	1,915	0,078
Age (month)	-0,536	-2,292	,039*

* p<0.05
Adjusted R^2= ,233
Durbin Watson= 2,196

Discussion

In the present study, a statistically significant difference was found between the SRTs of children with unilateral CI and children with normal hearing in quiet and noise front. This result showed that children with CI need higher speech intensity to understand speech in quiet and noisy situations than children with normal hearing. Accordingly, we may think that children with CI are at a disadvantage in learning and communication skills compared to children with normal hearing.

No significant correlation was found between the SRTs obtained in quiet and noisy situations in children with CI, and the age of implantation and duration of implant experience. 6% (Adjusted R^2= -.060) of the change in SRT in quite can be explained by age of implantation

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and duration of experience. Negative R^2 values are due to the low sample size. Although the result obtained was not statistically significant, it was not found in the expected direction. In the literature, it has been reported that better speech understanding performance is obtained with early age implantation (Anderson et al., 2004; Dowell et al., 2002). Cochlear implantation is recommended to be performed during the peak of neural plasticity (up to 3.5 years of age) (Sharma et al., 2002). In noise front condition, 9% of the variation in SRT (Adjusted R^2= -.094) can be explained by implantation age and experience duration. In the literature, it has been reported that speech understanding performance improves with increasing experience duration (Dowell et al., 2002; Waltzman et al., 2002). These findings were not statistically significant, but they support the literature. It is thought that a larger population should be evaluated in order to reach statistically significant results.

The effect of age on SRTs of children with normal hearing was investigated. No significant relationship was observed between SRTs obtained in quiet, but a significant relationship was found between SRTs obtained in noise front condition. 1% of the change in SRT in quiet (Adjusted R^2= .010) can be explained by age. Although our findings were not statistically significant, it has been shown that when the age is increased by one unit, the SRT in quite decreases by 29%, meaning that it improves. Similar results have been obtained in some studies in the literature. In a study which was conducted to create the children's version of the French HINT, SRTs of children aged 6-8-10-12 years with normal hearing were determined, and a significant effect of age on HINT scores was shown (Vaillancourt et al., 2008), In addition, it has been shown that as the age increases, the SRT decreases and reaches the adult level around the age of 12.

The study showed that the age of children with normal hearing had a statistically significant effect on SRT in noise front. 23% of the variation in SRT (Adjusted R^2= .233) is explained by age. When the age is increased by one unit, SRT in noise front decreases by 54%, which means it improves. In the literature, it has been stated that the maturation of speech understanding skills is completed around the age of 10, while the maturation of the ability to distinguish the source of the speech signal in noise and understand speech in noise is completed at the age of 11-12 years (Vaillancourt et al., 2008). This result obtained from our study supports the literature.

In our study, in the noise front condition, speech and noise signals were sent from the loudspeaker placed at 0° azimuth. In children and adults, one of the factors affecting the ability to understand speech in noisy environments is the spatial location of the target speech (Akeroyd,

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2006). In a study, it has been shown that the SRT obtained when the noise comes from the front is 6-10 dB better than the SRT obtained when the noise comes from the 90° azimuth. (Vaillancourt et al., 2005). In the present study, it has not been investigated how children with CI take advantage of spatial release from masking. This can be considered a limitation of the study.

In understanding the speech signal in noise, the intensity and direction of the noise, as well as its phase, are very important. Individuals with normal-hearing experience similar problems with cochlear implant users in fluctuating noise (Nelson et al., 2003). It has been reported that this situation was related to the decrease in frequency resolution. Evaluating speech understanding the performance of individuals with CI only in the case of stationary-phase noise would mean ignoring other acoustic environments in which these individuals will be in daily life (Qin & Oxenham, 2003). In HINT, speech-like noise is used as a noise signal. Therefore, our findings show how the speech understanding performances of children with CI and children with normal hearing are in daily speech environments.

In our study, the technical features provided by the cochlear implant system, which may affect the speech understanding skills of children with a cochlear implant, the preferred surgical approach, the social and cognitive status of the children, the frequency and motivation of the family and the child's participation in auditory education were not investigated, and these could be admitted as the limitations of the study. In addition, the fact that the factors that may cause cochlear implant users to be excluded from the study were not examined can be shown as another limitation. Only 52% (15/29) of the users we evaluated in the study were able to achieve SRT and were included in the study. This showed us that the speech understanding skills of children with CI significantly differ within themselves.

To improve speech understanding of cochlear implanted children, language abilities can be developed (Ching et al., 2018) and auditory training on understanding speech in noise can be given (Zhang et al., 2021). Implantation for contralateral ear or hearing aid use should be offered to ensure binaural hearing (Choi et al., 2017). Educational settings should be made to support the academic success of children with CI. In order to provide a good learning environment, it is recommended that the SNR in the classrooms be + 15 dB (Plomp, 1977). Children could use an adaptive digital microphone and remote microphone technology to overcome difficult listening situations in classrooms (Johnstone et al., 2018).

It is known that not only peripheral factors, but also cognitive factors are effective in the speech understanding skills of cochlear implant users (O'Neill et al., 2019). It can be

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accepted that the HINT gives an idea about cognitive functions and Turkish HINT is a appropriate test to evaluate the speech understanding skills of CI users. In future studies with cochlear implanted children whose first language is Turkish, it is recommended to use children's version of Turkish HINT (Turkish HINT-C) which is prepared, and age-specific norms were determined by Kartal et al. as master thesis (KARTAL, 2019). In our study, Turkish HINT-C was not used as it was just being prepared during that time.

Conclusion

The main objective of this study was to determine the effects of a cochlear implant on the ability of speech understanding in noise. This study showed that children with a cochlear implant need a higher signal-to-noise ratio to understand speech in noise than children with normal hearing. Looking at this result, an appropriate rehabilitation approach should be shown, acoustic arrangements should be made, and assistive hearing solutions should be recommended for these children so that the learning skills of them are not affected, and their social adaptation is ensured. On the other hand, this study was thought to have some limitations in that we didn’t evaluate the language development levels of participants. Analyzing the relationship between receptive and expressive language could increase the reliability of the results. In addition, including bilateral cochlear implant users in the study and investigating speech understanding performance of them would have provided important results in terms of establishing the relationship between binaural and monoaural hearing in CI use. In future studies, including bilateral users, the assessment of speech understanding of CI users with a larger sample size will provide more reliable results.

Conflict of Interest

The authors confirm that there is no conflict of interest.

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