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Speech intelligibility and auditory perception of pre-school children with Hearing Aid, cochlear implant and Typical Hearing

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Purpose: There is a growing interest in speech intelligibility and auditory perception of deaf children. The aim of the present study was to compare speech intelligibility and auditory perception of pre-school children with Hearing Aid (HA), Cochlear Implant (CI), and Typical Hearing (TH).

Methods: The research design was descriptive-analytic and comparative. The participants comprised 75 male pre-school children aged 4–6 years in the 2017–2018 from Tehran, Iran. The participants were divided into three groups, and each group consisted of 25 children. The first and second groups were respectively selected from pre-school children with HA and CI using the convenience sampling method, while the third group was selected from pre-school children with TH by random sampling method. All children completed Speech Intelligibility Rating and Categories of Auditory Performance Questionnaires.

Results: The findings indicated that the mean scores of speech intelligibility and auditory perception of the group with TH were significantly higher than those of the other groups ($P < 0.0001$). The mean scores of speech intelligibility in the group with CI did not significantly differ from those of the group with HA ($P < 0.38$). Also, the mean scores of auditory perception in the group with CI were significantly higher than those of the group with HA ($P < 0.002$).

Conclusion: The results showed that auditory perception in children with CI was significantly higher than children with HA. This finding highlights the importance of cochlear implantation at a younger age and its significant impact on auditory perception in deaf children.

1. Introduction

Deafness and hard-of-hearing (DHH) occur in approximately 1 per 750 live births (Hallahan et al., 2018). To be DHH often places a child in a problematic situation somewhere between the hearing world and the deaf world (Ashori and Jalil-Abkenar, 2019). DHH can put a person at risk of loneliness and isolation. Also, loneliness and isolation are primarily caused by language difficulties, speech intelligibility, and auditory perception (Chen and Wong, 2017). Within the past 30 years, physicians have been able to offer severely and profoundly deaf individuals an opportunity to regain at least partial auditory function through the Cochlear Implant (CI). CI is a device designed to improve hearing by making sound audible to the DHH children. Also, DHH children can hear the sounds through the HA, though they might not still be able to fully understand the amplified sounds. It seems that CI makes a significant contribution to speech perception (Bazon et al., 2016). CI is an accepted method for DHH individuals with a severe, or profound sensorineural hearing impairment. For these individuals, CI has been an effective method (Zhang et al., 2019) and improves verbal intelligibility, language skills, and auditory perception (Holder et al., 2018; Raine et al., 2016).

Speech intelligibility indicates the degree of clarity and comprehensibility of the speaker's speech so that the listener can understand the content or message (Jalil-Abkenar et al., 2013). Auditory perception means the recognition, awareness, and interpretation of auditory stimuli in the brain (Ciscare et al., 2017). Understanding verbal information is related to speech intelligibility and auditory perception (Bazon et al., 2016). The importance of auditory perception, speech intelligibility, and speech development is known to all (Ciscare et al., 2017). Generally, understanding verbal and non-verbal stimuli in any environment needs the intact

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auditory processing abilities to identify them (McDermott et al., 2010; Martines et al., 2013). When environmental sounds become stronger and louder, speech perception becomes harder (Ellis and Zahorik, 2019). The CI speech processor provides relatively weak frequency resolution. CI users have problems in auditory activities, melody perception, tone perception, identification of the gender of the speaker, speech prosody differentiation, and distinguishing the sounds coming from different sources or speakers (Brant et al., 2018; Zhang et al., 2019).

The findings of Ashori and Jalil-Abkenar (2019) indicated that cognitive rehabilitation intervention had a positive effect on speech intelligibility and auditory perception of DHH children. The results of Flanagan et al. (2018) showed that speech processing led to better speech production and the group with CI performed better at speech perception than peers with HA. The findings of Nagib Azab and Al Sabeela (2018) indicated that early CI considerably influenced the language skills and speech intelligibility in students with CI. The research results showed that CI, compared with HA, was associated with positive outcomes in reading (Van De Velde et al., 2019), language and speech production (Hallahan et al., 2018), and auditory perception (Jalil-Abkenar et al., 2013). The findings also indicated that children with CI who implanted at a younger age had better auditory perception. These children perform equally with severe hearing loss children with HA (Sarant, 2012). Also, the findings of another study showed that very young children with CI could perform equally with moderate hearing loss children with HA on auditory perception tests (Leigh et al., 2008). The findings of the abovementioned studies are inconsistent since various factors contribute to the successful use of CI or HA. The age at which a person receives a CI or HA has been related to literacy, speech, and auditory perception outcomes (Tomblin et al., 2005; Lederber and Spencer, 2005).

Auditory perception has always been a fundamental problem for children with severe or profound hearing impairment. They are not able to hear or monitor other speakers and the speech of most HA users who have severe or profound hearing impairment is either poorly intelligible or unintelligible (Spencer et al., 2011). CI can provide partially intelligible speech and better auditory information for these children. Therefore, they can learn speaking skills from individuals with TH, and monitor their speech. Some of the children with CI have excellent speech abilities; some of them perform at a high level, while others show low levels of performance in auditory perception (Van De Velde et al., 2019). Speech intelligibility and auditory perception of children implanted at older ages and not a long time have passed since they started using CI are generally similar to those with severe or profound hearing impairment children with HA (Flipsen, 2008).

Verbal skills and verbal intelligibility of CI or HA users who used appropriate technology before the age of three are relatively good and almost equal to their TH peers (Blamey et al., 2006). Children who are implanted at younger ages and use CI showed higher achievements in verbal intelligibility and verbal production (Ertmer et al., 2007; Flipsen, 2008). One of the most challenging results of the research about verbal perception, speech production, and auditory perception in users of CI and HA is variations in their level of performance (Hallahan et al., 2018). Many reports describe average performance with CI, i.e., while some individuals do reasonably well, there are still those who gain only limited benefits from CI. These differences in findings make it problematic to predict how a child will perform after CI. So, it seems necessary to determine who is eligible for CI (Sarant, 2012). Therefore, the specific aim of the present study was to compare the speech intelligibility and auditory perception in pre-school children with HA, CI, and TH.

2. Material and method

2.1. Participants

The participants comprised 75 male pre-school children aged 4–6 years in the 2017–2018 academic year from Tehran, Iran. The participants were divided into three groups, and each group consisted of 25 children. The first and second groups were selected respectively from pre-school children with HA and CI using the convenience sampling method, while the third group was selected from pre-school children with TH using the random sampling method. The hearing range of the TH group was from 0 to 20 dB at 500, 1000, and 2000 Hz. The hearing threshold of up to 20 dB is considered normal hearing. The children in the first and second groups were bilaterally and prelingually DHH. Children with CI had severe to profound DHH and bilateral implantation, while children with HA had moderate DHH. Children with CI and HA have been using prosthesis before the age of four. The mean age of using the CI was 3.1. Moreover, the mean age of using the HA was 2.9. All of the participants were Persian native speakers and had no specific disease or neurological disorder. Participants were matched by IQ, age, and gender because the development of language and speech is different in boys and girls. It should be noted that only boys were included in this study since the researchers had no access to girls.

The inclusion criteria were having the IQ between 90 and 105; the age range of 4–6; having prelingual sensorineural DHH in both ears, for the first and second groups; using HA in both ears and moderate DHH in the range of 50–70 dB for participants with HA; and severe or profound DHH in the range of higher than 80 dB for children with CI. Those who displayed any symptoms of a neurodevelopmental disorder were excluded from this study.

The present study was approved by the Exceptional Education Organization Ethics Committee in Tehran, Iran. The importance of the study was explained to the mothers of children, and the informed consent for their children's participation in this study was obtained.

2.2. Procedure

The Speech Intelligibility Rating and Categories of Auditory Performance Questionnaires were administered individually in the presence of the mothers of children. It should be noted that mothers did not interfere with the evaluation of their children. These questionnaires are language-independent and are designed to evaluate speech intelligibility and auditory perception. Three experienced audiologists administered Speech Intelligibility Rating and Categories of Auditory Performance Questionnaires in all the three groups. It should be noted that audiologists were trained in two training sessions (each session lasted about 1 h) on how to administer these questionnaires. The Speech Intelligibility Rating and Categories of Auditory Performance Questionnaires include five and nine levels, respectively. Participants received a score for each correct answer. They took a break for 5 min after answering the first questionnaire, and then answered the second questionnaire. In fact, the evaluation was terminated after an incomplete or incorrect response at the first level of each questionnaire.

To assess speech intelligibility, the Speech Intelligibility Rating was used. This questionnaire was designed and developed by Allen et al. (1998) to obtain information about the speech intelligibility of DHH individuals. Speech intelligibility indicates the degree of clarity and comprehensibility of the speaker's speech so that the listener can understand the content or message. The Speech Intelligibility Rating is a five-point Likert scale ranging from 1 to 5. Words are unrecognizable and they might use their hands to communicate (1); Connected speech is unintelligible, but when they use lip-reading, speech can be understood at the level of single words (2); Connected speech is intelligible to a listener who concentrates, and using lip-reading within a known context (3); Connected speech is intelligible to a listener who has few experiences of hearing a deaf person's speech. The listener does not need to concentrate unduly (4); Connected speech is intelligible to all listeners. The child is easily understood in everyday contexts (5). The reliability of this questionnaire was confirmed, and a high agreement was found between observers using the scale to evaluate the speech intelligibility for DHH individuals (Mahmoodi et al., 2017). Allen et al. (1998) reported the inter-rater reliability of 0.53 based on average Cohen's kappa coefficient. In Iran, Hasanzadeh, 2015 reported the inter-rater reliability of 0.70 based on average Cohen's kappa coefficient for this scale. Also, the test-retest reliability was 0.99 and its construct validity ranged between 0.66 and 0.69, and the concurrent validity of this questionnaire was 0.69.

Categories of Auditory Performance II was used to assess the auditory perception. This questionnaire was designed by Archbold et al. (1995), and revised by Archbold et al. (1998) to obtain information about the receptive language ability of DHH individuals. The Categories of Auditory Performance evaluate auditory perception, which is the recognition, awareness, and interpretation of auditory stimulus received by the brain. The Categories of Auditory Performance include a nine-point rating Likert scale ranging from 0 to 9: No awareness of environmental sounds or voice (0); Awareness of environmental sounds (1); Responding to speech sounds (2); Identifying environmental sounds (3); Discriminating speech sounds without lip-reading (4); Understanding common phrases, e.g., "open the door"; "push the car" without lip-reading (5); Understanding conversation without lip-reading (6); Using telephone with a known speaker (7); Following group conversation in a reverberation room where there is some interfering noise such as a classroom or a restaurant (8); Using telephone with an unknown speaker in an unpredictable context (9) (Mahmoodi et al., 2017). Archbold et al. (1998) reported appropriate reliability and validity for this questionnaire. Gilmour (2010) reported the inter-rater reliability of 0.76 based on average Cohen's kappa coefficient. In Iran, Hasanzadeh, 2015 reported the inter-rater reliability of 0.73 based on average Cohen's kappa coefficient for this scale. Also, the test-retest reliability was 0.82, and its construct validity ranged between 0.58 and 0.74, and its concurrent validity was 0.64.

2.3. Data analysis

All participants were assessed with Speech Intelligibility Rating and Categories of Auditory Performance Questionnaires. Mean and standard deviation of scores were reported for each variable in the three groups. Analysis of Variance (ANOVA) was used to find if there is any significant difference in the age of the three groups. The speech intelligibility and auditory perception in the participants with CI were compared with those of the participants with HA and TH. The obtained data were analyzed by MANOVA using SPSS 24.

3. Results

There were no significant differences among the groups with HA, CI, and TH in terms of age (*F = 0.83, P < 0.18*). Mean and standard deviations of speech intelligibility and auditory perception of the three groups are reported in Table 1.

To compare the mean scores of speech intelligibility and auditory perception in groups, MANOVA was used. At first, the equality of variances was confirmed by Levene's test (Table 2). Besides, the equality of the variance-covariance matrix assumption was confirmed by the Box test (*P = 0.11*).

To compare the means of total scores of speech intelligibility and auditory perception in groups, MANOVA was used. The overall Wilk's lambda was significant, [*F (2, 71) = 28.39, P < 0.0001]* which showed overall differences among the three groups. MANOVA was used to find the differences between the mean scores of speech intelligibility and auditory perception in the three groups (Table 3).

As it is shown in Table 3, there was a significant difference in mean scores of speech intelligibility (*F = 45.59, P < 0.0005*) and auditory perception (*F = 42.99, P < 0.0005*) in the three groups. Furthermore, to compare the mean scores of speech intelligibility and auditory perception in the three groups, a Bonferroni post hoc test was used (Table 4).

As can be seen in Table 4, the results of the Bonferroni test indicated that the mean scores of speech intelligibility and auditory perception in children with TH were significantly higher than the children in other groups (*P < 0.0001*). Also, the mean scores of speech intelligibility in children with CI did not significantly differ from those of the children with HA (*P < 0.38*), while the mean scores of auditory perception in children with CI were significantly higher than the mean scores of the children with HA (*P < 0.002*).

Table 1
Mean and standard deviation of variables in three groups.

Variables	C HA		C CI		C TH	
	Mean	SD	Mean	SD	Mean	SD
Speech intelligibility	3.18	0.26	3.23	0.25	4.92	0.33
Auditory perception	5.03	0.37	6.84	0.62	8.81	0.39

C HA= Children with Hearing Aids, C CI= Children with Cochlear Implant, C TH = Children with Typical Hearing.

Table 2
Result of Levene's test.

Variables	F	df_1	df_2	P
Speech intelligibility	1.82	2	72	0.23
Auditory perception	1.96	2	72	0.12

(n = 75).

4. Discussion

The present research aimed to compare speech intelligibility and auditory perception in the groups with HA, CI, and TH in Tehran, Iran. The results of MANOVA showed a significant difference in the mean scores of speech intelligibility and auditory perception in the three groups. Bonferroni post hoc test showed that speech intelligibility and auditory perception scores in participants with TH were significantly higher than the other two groups. This finding was similar to the findings of Flanagan et al. (2018), Nagib Azab and Al Sabeela (2018), Jalil-Abkenar et al. (2013) and Peng et al. (2008) who concluded that the mean scores of speech intelligibility and auditory perception in children with TH were significantly higher than those of the children with CI. Besides, this finding was similar to the finding of Lee et al. (2002) who reported that auditory perception in children with CI was significantly lower than the children with TH. This finding indicates that the hearing experiences of children with TH are more than children with CI. The second group obtained better results. Hearing

Table 3
Results of MANOVA in three groups.

Variables	SS	Df	MS	F	P	η^2
Speech intelligibility	42.28	2	21.14	27.26	<0.0001	0.61
Auditory perception	86.22	2	43.11	33.04	<0.0001	0.60

Table 4
Results of the Bonferroni test in three groups.

Variables	Groups	Comparisons	Mean difference	P
Speech intelligibility	C TH	C CI	1.69	<0.0001
		C HA	1.74	<0.0001
	C CI	C HA	0.05	<0.38
Auditory perception	C TH	C CI	1.97	<0.0001
		C HA	3.78	<0.0001
	C CI	C HA	1.81	<0.002

impairment, especially, speech intelligibility and auditory perception affect all aspects of life (Zhang et al., 2019). On the other hand, the development of speech intelligibility and auditory perception usually causes many problems for DHH individuals, and they do not have the sufficient auditory ability to monitor their own speech or to hear the speech of the individuals with TH (Spencer et al., 2011; Ciscare et al., 2017).

The main finding of this research indicated that the mean scores of auditory perception in the participants with CI were significantly higher than those with HA. In other words, the main finding is that the scores of auditory perception in CI patients are considerably higher than those of the HA ones. This finding is consistent with the finding of Flanagan et al. (2018), Jalil-Abkenar et al. (2013), Blamey et al. (2006) and Tyler et al. (2001) who concluded that the mean scores of auditory perception in children with CI were significantly less affected. Also, this result was in concordance with the finding of Ghasemei et al. (2006) who found that CI would have more effect on the auditory perception in the subjects with severe or profound DHH.

The findings of the present study are not so surprising, it can be concluded that differences in auditory perception stem from the significant benefits of CI for individuals with severe or profound hearing impairment (Ciscare et al., 2017). This finding emphasizes on cochlear implant at a younger age and its significant impact on auditory perception in deaf children. CI is an accepted and well-known treatment method for individuals with severe to profound sensorineural hearing loss (Hallahan et al., 2018). CI is recommended for children and adults suffering from sensorineural single-sided or bilateral hearing loss who are unable to communicate effectively with a hearing aid (Ellis and Zahorik, 2019). Because CI technology optimizes pitch encoding and auditory perception abilities, one can expect improvements in the auditory perception of people with CI (Zhang et al., 2019). Moreover, CI can provide auditory information that improves the auditory perception of its users. Therefore, they can learn from individuals with TH, receive feedback and monitor their speech (Van De Velde et al., 2019).

The final finding of this research indicated that the mean scores of speech intelligibility of children with CI did not significantly differ from those of the children with HA. This finding was similar to that of Most and Peled (2007) who concluded that speech perception in the group with CI did not significantly differ from the perception of children with HA. Besides, this finding was consistent with the finding of Jalil-Abkenar et al. (2013) and Mahmoudi et al. (2009) suggesting that voice abnormalities in the speech of individuals with CI did not significantly differ from those with HA. This final result was not similar to the findings of Tyler et al. (2001) who showed that the use of a CI had been associated with better outcomes in verbal intelligibility, compared with children with HA.

To explain the discrepancy between the results of the study by Tyler et al. (2001) and the findings of this study, it can be stated that the demographic characteristics of the participants in these two studies were different. Also, a properly functioning CI does not guarantee this outcome (Hallahan et al., 2018). Therefore, it can be concluded that sometimes children with CI perform equally with the children with severe hearing impairment. It has recently been revealed that younger children can perform better than their counterparts with moderate hearing loss in the speech intelligibility tests (Leigh et al., 2008).

The findings differ from each other considering different groups because various factors play a role in the successful use of CI. The rate and type of hearing impairment, the use of rehabilitation programs, and the age of CI are related to speech intelligibility (Hasanzadeh, 2012; Ellis and Zahorik, 2019).

There were several limitations in the present research. First, the sample size was relatively small. Second, only male children in Tehran city participated in this study. Speech intelligibility and auditory perception are different in individuals with CI and those with HA, and various factors such as the type of HA, age and duration of use, and the degree of using hearing rehabilitation services are effective. Therefore, caution should be exercised in generalizing the results.

The present research makes some recommendations for future research. First, it is suggested that paying attention to the hearing status of parents of children, personality characteristics, and hearing loss levels of the children can provide more detailed results, which are beneficial for comparing the speech intelligibility and auditory perception in DHH children. Second, since speech intelligibility and auditory perception are complex and multidimensional phenomena, they require a unique rehabilitation program to further develop the speaking skills of children with CI or HA. Therefore, regarding psychological problems related to speech intelligibility and auditory perception of DHH children, it is valuable to develop and plan programs that are aimed at improving speaking skills of the affected children.

5. Conclusion

To summarize, the mean scores of speech intelligibility and auditory perception in the participants with TH were significantly higher than the mean scores of those with HA or CI. Besides, the mean scores of auditory perception in the participants with CI were considerably higher than those with HA. Also, the mean scores of speech intelligibility of children with CI did not significantly differ from children with HA. This study confirms that speech intelligibility and auditory perception are two complex and multidimensional phenomena that require a unique rehabilitation program to further develop speaking skills.

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Declaration of competing interest

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Appendix A. Supplementary data

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