ORIGINAL ARTICLE

Speech and music perception in adolescents with cochlear implants or hearing aids

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OBJECTIVE: To compare the effect of electrical and acoustical stimulation on speech and music perception.

METHODS: The study group consisted of 36 adolescents12 with cochlear implants, 12 with hearing aids, and 12 with normal hearing. . Both speech perception and music perception tests were used to compare the performances of the 3 groups.

RESULTS: The aided pure-tone hearing thresholds of the hearing aid users were better at low frequencies. In contrast, the cochlear implant group's thresholds were better at high frequencies. with a statistically significant difference at 250 and 6000 Hz.. The hearing aid users had similar scores to the normal hearing group in vowel identification and pattern perception. In addition, the hearing aid group performed better than did the cochlear implant group in vowel identification, pattern perception, and daily sentences tasks (P = .001, P = .02, P = .0001, respectively). No significant differences were found between the hearing aid and cochlear implant groups in multisyllabic, phonetically balanced words, and consonant identification tasks. Although similar performances were obtained for three groups in music perception tasks, there was a positive and significant correlation was found between pattern perception and rhythmic perception ability of the cochlear implant group, whereas the hearing aid group, who had better performance in multisyllabic word discrimination, also performed better in tonal and rhythmic tasks.

CONCLUSIONS: Cochlear implant users who had a high performance in rhythmic tasks performed better in discrimination of temporal features of speech,. In addition, the hearing aid users who were able to discriminate changes in the periodicity and frequency of speech signals. According to these findings, music perception tasks, in addition to the speech discrimination programs, will be useful for spectral and temporal analysis of electrical and acoustical signals

Music and speech, the most complex processes of sound made by the human species, form an important part of many people's lives. The 2 domains share a number of common properties; they take advantage of modulations of acoustic parameters specifically for information-bearing purposes. Although these functions are processed in different hemispheric regions of the human brain, they are interrelated. The hemispheric interrelation of music and speech domains allows a healthy development of cognitive and psychosocial competence and communication. In the absence of normal acoustic perception of interrelated signals, a healthy development process is expected to be affected negatively.

The hearing world is fascinated with music. Although music and speech consist of sound patterns that are learned over time, they differ dramatically in their auditory processing demands. Whereas reasonable speech perception is possible with intact temporal cues but degraded spectral cues, music perception depends solely on intact spectral cues. Hearing-impaired people who have congenitally or prelingually acquired hearing losses often demonstrate delays in some, though not all, music-based skills. People who are deaf or hard of hearing perform at least as effectively as normal hearing people with respect to rhythmic tasks: beat identification, tempo change, and accent. However, as music is not exclusively formed by rhythmic tasks, hearing-impaired people are usually unable to comprehend music as a whole.

Hearing aids and cochlear implants are the treatment of choice in children with profound to severe congenital sensorineural hearing loss. The 2 devices mainly minimize the negative environmental effects, such as noise and acoustic absorbance, on acoustic signals and transfer the acoustic information to auditory cortex in a natural, clear, and, in most, recognizable pitch and format. Sensory hearing impairments can not be improved surgically, however, many sensory losses can be helped with conventional acoustic hearing aids which deliver an amplified signal into the ear canal. The benefits obtained from early amplification of auditory-verbal programs on speech and music perception have been well documented for profoundly hearing-impaired children.[1,2] However, if there is very little residual hearing, acoustic amplification will not provide significant benefit. for perceiving speech and environmental sounds.

Cochlear implant systems electrically stimulate remaining auditory nerve fibers in the cochlea to induce a sensation of hearing. In recent years, many studies have documented the effectiveness of cochlear implantation on speech perception in children.[3,4] However, the development of speech perception in prelingually deafened children varies greatly from child to child and is characterized by determinants such as age at implantation, duration of deafness, communication mode, etiology of deafness, expectations of parents, and the support of the child's family during the rehabilitation process. The effects of these variables become especially important when considering the implantation of congenitally deaf or early-deafened adolescents. A number of studies dealing with this age-group have revealed that the main effect of implantation was a gradual decrease in lip-reading ability at daily, open-set, speech-understanding situations.[5,6] Another benefit for cochlear implant adolescents was music enjoyment.[7] Gfeller indicates that the teenage years are marked by greater autonomy in music involvement, and the social aspect of music involvement is particularly noticeable during the adolescent years.[7] She also suggests that children who are, in general, more successful with communicating via listening can use these skills to enjoy the music experience as well.

The purpose of this study was to investigate how the perception of speech and music differs between hearing impaired and normal hearing individuals. The role of electrical and acoustical stimuli on the perception of speech and music was also explored.

METHODS

Subjects. A total of 36 adolescent participants were recruited and randomized to 3 groups: normal hearing, hearing aid users, and cochlear implants. All participants had a neurological evaluation before testing and were found to be neurologically normal. Both participants who had cochlear implant and used hearing aids were enrolled in mainstream school programs and were using auditory-verbal modes of communication

Normal hearing subjects. Twelve adolescents with no reported history of speech and hearing problems attending public schools participated as the control group in this study. The group consisted of 8 adolescent girls and 4 adolescent boys with a mean age of 13.6±1.67 years (range, 13-17). Hearing thresholds for this group were between –5 and 15 dB hearing level (HL) in the right ear and –5 and 20 dB HL in the left ear (Figure 1). No significant difference was found between right and left hearing thresholds between 125 to 6000 Hz.

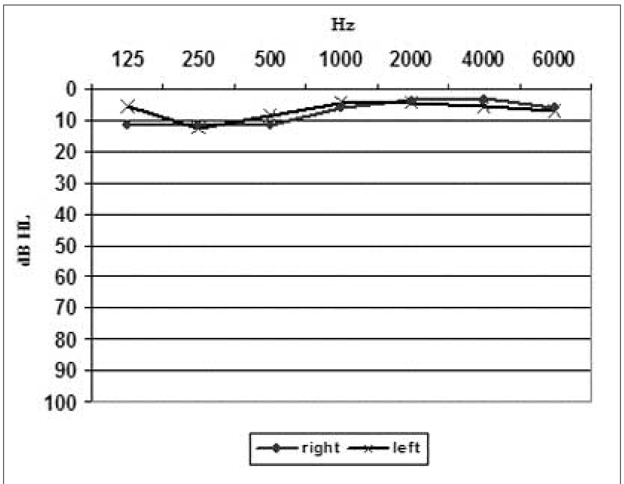

Figure 1: Mean hearing thresholds for the normal hearing group.
(P and t values of the difference between right and left ear for mean hearing thresholds for the frequencies 125-6000; t125 = 1.393, p125 = 0.191; t250 = 1.149, p250 = 0.275; t500 = 1.151, p500 = 0.281; t1000 = 0.248, p1000 = 0.809; t2000 = 1.593, p2000 = 0.139; t4000 = 0.561, p4000 = 0.586; t6000 = 0.632, p6000 = 0.593) dB HL, decibel hearing level.

Hearing aid users. This group consisted of 12 hearing aid–using adolescents, 7 girls and 5 boys, who had bilateral. moderate-to-severe sensorineural hearing loss. Age range was 13 to 18 years (mean, 15.06±1.7) at the time of testing. Mean unaided hearing thresholds between 125 and 6000 Hz for the right ear were 50±9, 57±6,2, 68±11, 77.5±6,3, 82±5,8, 76±10, and 80±9. Unaided mean hearing thresholds for left ear were 44.5±13,4, 57±6,4, 66.5±10, 78±8,2, 79±7.7, 79.5±10.3, and 76±10. Mean aided hearing thresholds between 125 and 6000 Hz are 27.5±8.11, 32±7.2, 39.6±4.9, 36.7±7.2, 37.9±8.4, 47.5±15.1, and 57±13.2. All hearing aid users had 10 to 14 years (mean, 11.58) of hearing aid experience.

Cochlear-implant participants. Twelve profoundly hearing-impaired adolescents, 5 boys and 7 girls, with unilateral cochlear implantation were recruited. All participants started with conventional bilateral hearing aids regularly and were enrolled in auditory-verbal learning programs as soon as they were aided. They were age 16 to 48 months (mean, 29.16) in the preimplantation period. The duration of hearing aid experience for cochlear implant participants was between 8 and 14 years (mean, 10.6±1.69). Their ages ranged from 13 to 18 (mean, 15.99±1.7). All were using Nucleus 24M implants (Cochlear Corp, New South Wales, Australia) in their right ears for 12 to 36 months (mean, 24±0.74) and ACE coding strategy at the time of testing. None of the cochlear implant participants were using hearing aids on the opposite ear. The mean unaided, aided, and implanted thresholds for this group between 125 and 8000 Hz are shown in Table 1.

Table 1. Unaided, aided, and implanted hearing thresholds for cochlear implant users.

Hz	Unaided Right	Unaided Left	Aided	Implanted
125	75.00±9.12	80.05±10.09	45±2.82	33.3±2.07
250	85.00±9.25	87.50±11.01	47.50±14.63	41.25±2.14
500	95.62±12.37	96.25±6.40	55.00±14.14	45.00±2.82
1000	105.62±9.42	108.75±6.94	52.50±13.36	37.92±2.34
2000	111.25±11.87	113.75±9.54	64.37±11.16	36.67±2.84
4000	112.50±12.53	118.12±3.72	76.87±7.52	36.25±3.70
6000	–	–	–	36.25±2.23
8000	–	–	–	45.00±2.61

MATERIALS

Speech perception test battery

Closed-set speech perception. The Multisyllabic Words Test measures word identification using a 4-choice format for 20 groups of words.[8] In each group, words have similar number of phonemes and syllables. The Vowel Identification Test was used to evaluate vowel identification using 25 groups of 4-choice, single-syllable words.[8] In each group, 4 words are presented on a sheet of paper and differ from each other by their middle vowels. In the Pattern Perception Test, 25 pairs of multisyllable words containing 2 or 3 syllables in a similar phonetic structure but differing in length were presented in 2-choice format.[8]

In all closed-set speech perception tests, the participants were asked to draw a check sign on the written page. Familiarization with each test and talker was initiated before formal testing, by application of stimuli from lists not used in the study.

Open-set speech perception. The Phonetically Balanced Word List measures word recognition using 25 single-syllable words.[8] Participants were asked to repeat or write the word they heard. In the Consonant Identification Test, subjects were asked to judge if a pair of single-syllable words were the same or different.[8] The test contains 50 pairs of monosyllable words. some differing only in middle vowels. Daily sentences in Turkish were also used, 10 lists of 10 sentences each composed of 20 frequently used daily words. The participants were asked to repeat verbally the sentences that they had heard and got 1 point for each correctly repeated word.

Music-perception test battery. This test contains both isolated sequential pitch and rhythmic music patterns. The experimental design was based on the work of Gfeller and colleagues with some modification in music perception subtests.[9] Thirty-four pairs of melodic and rhythmic patterns were created in a professional studio by using a Soundforge computer program. In both rhythmic and tonal subtests, 1.5-second interstimulus intervals were used to separate each member of the pair. Each item pair was separated by a 5 second period of silence. Participants were asked to decide whether the pairs were the same or different by pointing to cards on which were written the words "same" or "different."

Tonal perception. The two 10-pair, short-pitch patterns with each consisted of 2 notes ranging in pitch from C_3 (130.81 Hz) to F_4 (349.23 Hz) were delivered to the listener by way of a loud speaker. Stimuli pairs used in this test are shown in Table 2.

Table 2. Stimuli pairs used in the Tonal Perception Test

1st pair (Hz)		2nd pair (Hz)	
C3-D3	130.813-146.832	C3-F4	130.813-349.228
D#3-G#3	155.563-207.652	D#3-G#3	155.563-207.652
A#3-D4	233.082-293.665	A#3-C4	233.082-261.626
G3-D#4	195.998-311.127	C3-D4	130.813-293.665
C#4-E3	415.305-164.841	C#4-E3	415.305-164.841
A3-F#3	220.000-184.997	E4-D#3	220.000-184.997
G#3-D#4	207.652-311.127	G#3-D#4	207.652-311.127
E4-C4	329.628-261.626	E4-C4	329.628-261.626
D4-F3	293.665-174.614	D3-E4	146.832-329.628
D#3-F4	155.563-369.994	D#3-F4	155.563-369.994

Rhythmic perception. Two 7-pair, short rhythmic patterns were used in this test. All pairs were in C4 range (261.63 Hz) but differed in duration of the notes. Table 3 shows the 14 rhythmic patterns.

Table 3. Short rhythmic patterns used in Rhythmic Perception Test

1st pair (sec:msec)	2nd pair (sec:msec)
01:584-00:493	01:584-00:493
00:650-01:645	01:383-00:222
00:819-00:467	00:840-00:476
00:217-00:484	00:217-00:484
00:584-01:233	01:470_00:255
00:519-01:015	01:475-00:245
00:753-00:232	00:753-00:232

Music-experience questionnaire. Two open-ended questions were addressed to evaluate music training and experience:

1. How much time do you spend listening to music during the day?

2. Have you ever played any kind of musical instrument?

PROCEDURE

The speech perception tests were recorded by a Rode NT_2 microphone, Behringer MX-8000 sound mixer, and Behringer Composer Pro Compressor on a compact disc and prepared by using NCH Tone Generator software (NCH Swift Sound, Canberra, Australia). All speech-perception tests were administered by using recorded voice in standard sound-proof rooms (Industrial Acoustic Company) by using 1 DALI 2BL VIN 9942 speaker at a 0° azimuth with the hearing aids and cochlear implants activated at the 'use' setting. Stored as digital files, the stimuli were routed to an audiometer for amplification and delivered to the listener by way of a loud speaker at 50 dB sound pressure level (SPL) for the normal hearing group and 70 dB SPL for hearing aid and cochlear implant users. Before experimental testing of electroacoustic measurements were performed on the hearing aids to verify that the instruments were operating properly. All speech-perception tests were administrated in a single session with 2 minutes time intervals between the tests.

Music-perception tests were prepared by using Soundforge (Sonicfoundry, Madison, Wisconsin, USA) software in a PC. The administration of the music-perception tests were administered as explained above and there was a time interval of 2 minutes between the 2 music-perception tests. Both speech- and music-perception tests were done in the same session with a time interval of 20 minutes between the 2 test batteries.

Statistical analysis. Statistical analysis of the data was made by using SPSS software (Statistical Package for the Social Sciences, version 11, SSPS Inc, Chicago, Ill, USA). Right and left ear hearing thresholds of the normal hearing group were compared with paired-sample t-tests. Hearing thresholds at 125 to 6000 Hz of cochlear implant and hearing aid users were compared with independent-sample t-tests.

Univariate variance analysis (ANOVA) and a homogeneity test for variation (Levene Test) were carried out for differences in speech- and music-perception abilities of the 3 groups. As the variations of the data were not homogeneous (excluding the tonal perception), Kruskall-Wallis analysis (the nonparametric counterpart of ANOVA) was used to analyze music-perception data. Mann-Whitney U Test (with Bonforini correction) was used for comparison of different variables for the groups. Simple correlation analysis (Pearson Correlation Coefficient) was computed between speech- and music-perception data for the 3 groups of participants.

RESULTS

Hearing thresholds for hearing aid and cochlear implant groups. The mean hearing thresholds at 125, 250, 500, 1000, 2000, 4000, and 6000 Hz for hearing aid and cochlear implant groups were compared using independent-sample t-tests and the hearing aid group was found to have lower thresholds at low frequencies—125 Hz (mean, 27.5), 250 Hz (mean, 32.08), and 500 Hz (mean, 39.58)—whereas, the cochlear implant group had better thresholds at 4000 Hz (mean, 36.25) and 6000 Hz (mean, 36.25). However, statistically significant differences were found only for frequencies 250 and 6000 Hz between groups. For 250 Hz, the hearing aid group (mean, 32.08) had better thresholds than the cochlear implant group (mean, 41.25; t = 3.067, P = .006).On the other hand, for 6000 Hz, the cochlear implant group (mean, 36.25) had better thresholds than the hearing aid group (mean, 57.14; t = 4.394, P = .0001) (Figure 2, Table 4).

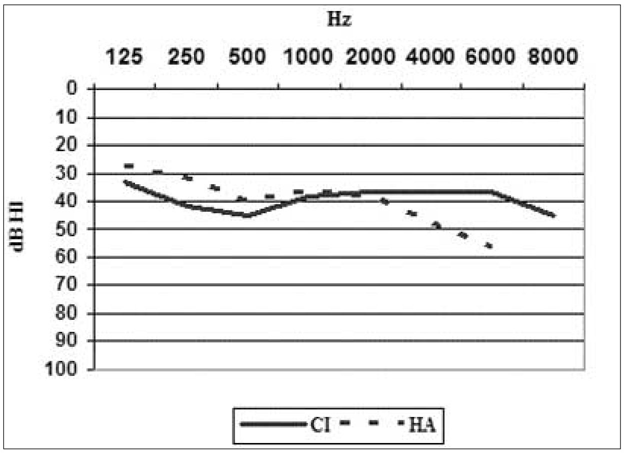

Figure 2: Comparison of hearing thresholds of hearing aid and cochlear implant groups

P and t values of the difference between cochlear implant and hearing aid groups for mean hearing thresholds for the frequencies 125-6000; t125 = 1.865, p125 = 0.076; t250 = 3.067, p250 = 0.006; t500 = 1.711, p500 = 0.101; t1000 = 0.400, p1000 = 0.693; t2000 = 0.335, p2000 = 0.741; t4000 = 1.964, p4000 = 0.062; t6000 = 4.394, p6000 = 0.0001 (dB HL, decibel hearing level; CI, cochlear implant; HA, hearing aid.)

Table 4. Statistical values obtained from the comparison of hearing thresholds for hearing aids and cochlear implant groups. (CI, cochlear implant; HA, hearing aid.; SE, standard error; SD, standard deviation)

Frequency	HA					CI				
(Hz)	Min	Max	Mean	SE	SD	Min	Max	Mean	SE	SD
125	15.00	40.00	27.50	2.34	8.11	20.00	45.00	33.33	2.07	7.18
250	20.00	45.00	32.08	2.08	7.21	30.00	55.00	41.25	2.14	7.42
500	35.00	50.00	39.58	1.43	4.98	25.00	60.00	45.00	2.82	9.77
1000	25.00	45.00	36.67	2.07	7.18	15.00	45.00	37.92	2.34	8.11
2000	30.00	55.00	37.91	2.41	8.38	20.00	55.00	36.67	2.84	9.85
4000	15.00	70.00	47.50	4.37	15.15	15.00	55.00	36.25	3.70	12.81
6000	45.00	80.00	57.14	4.98	13.18	25.00	45.00	36.25	2.23	7.72
8000	-	-	-	-	-	30.00	60.00	45.00	2.61	9.045

Speech perception. Univariate variance analysis revealed that the hearing aid and cochlear implant groups had significantly lower scores on the Multisyllabic Words, Single-Syllable Identification, Phonetically Balanced Words, and daily sentences compared with the normal hearing group. The hearing aid group achieved better scores on the Vowel Identification and Pattern Perception tests and in Turkish daily sentences than did the cochlear implant participants. However, the hearing aid group has also achieved lower scores on the Multisyllabic Words (u = 24.00, P = .005), Phonetically Balanced Words (u = 6.00, P = .0001), and Consonant Identification (u = 1.00, P = .0001) tests and daily sentences (u = 21.00, P = .002) compared with the normal hearing group. In Table 5, speech perception results for the 3 groups are shown. Table 6 shows compared statistical values for the hearing aid and cochlear implants groups on speech perception measurements.

Table 6. Compared statistical values for hearing aid and cochlear implant groups on speech perception tests (*P<.05)

Speech Perception Tests	u	P
The MultisyllabicWord Test	24.00	.005*
The Vowel Identification Test	51.50	.242
Pattern Perception Test	54.00	.319
The Phonetically Balanced Word List	6.00	.0001*
Consonant Identification Test	1.00	.0001*
Daily Sentences	21.00	.002*

Music perception. On the Tonal and Rhythmic Perception Tests, all groups had similar scores, as shown in Table 7. According to the results of the music-experience questionnaire, the normal hearing and hearing aid groups were found to spend a much longer time listening to music. Music-instrument–playing subjects were fewer in the cochlear implant group compared with the normal hearing and hearing aid groups. Figures 3 and 4 show daily music-listening expe-

Table 5. Speech perception results for normal hearing, cochlear implant, and hearing aid groups (NH, normal hearing; CI, cochlear implant; HA, hearing aid; min, minimum; max, maximum.)

Speech Perception Tests	NH			CI			HA		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
The Multisyllabic Word Test	20.00	20.00	20.00	7.00	20.00	14.08	10.00	20.00	16.91
The Vowel Identification Test	23.00	25.00	24.41	11.00	23.00	16.75	14.00	25.00	22.50
Pattern Perception Test	25.00	25.00	25.00	18.00	25.00	22.50	18.00	25.00	24.25
Phonetically Balanced Word List	20.00	25.00	21.58	2.00	14.00	8.00	2.00	21.00	8.66
Consonant Identification Test	40.00	50.00	47.50	18.00	32.00	23.33	17.00	40.00	26.00
Daily Sentences	9.00	10.00	9.91	2.00	9.00	4.416	4.00	10.00	8.08

rience and the number of participants in the 3 groups who played an instrument.

Table 7. Compared statistical values for normal hearing, hearing aid, and cochlear implant groups on musical perception tests (*P<.05)

Musical Perception Tests	χ^2	F	P
Rhythmic Perception	3.269	–	.195*
Tonal Perception	–	0.654	.526*

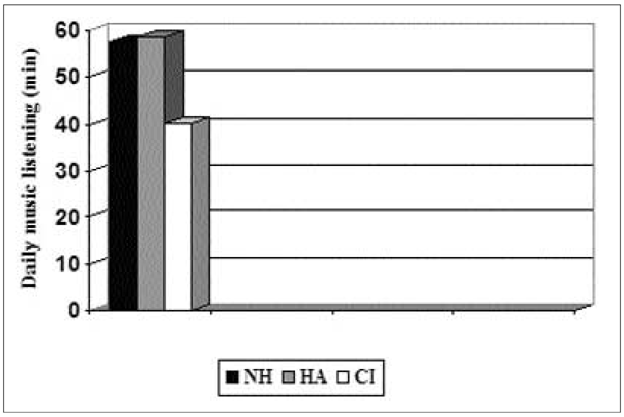

Figure 3: The daily music-listening experience of normal hearing, hearing aid, and cochlear implant subjects (NH, normal hearing; HA, hearing aid; CI, cochlear implant)

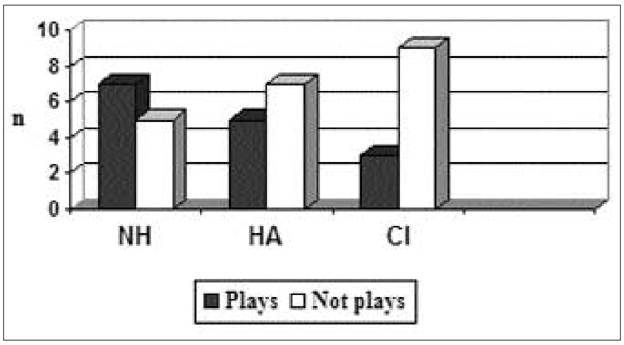

Figure 4: Number of subjects playing a musical instrument ((NH, normal hearing; HA, hearing aid; CI, cochlear implant)

Music perception and speech perception. A significant positive correlation was found between music perception (rhythmic perception) and speech perception (pattern perception) for the cochlear implant group (r = .0.633, P<.05).

Correlations between multisyllabic words and rhythmic tasks (r = 0.023, P<.05) and multisyllabic words and tonal tasks (r = 0.651, P<.05) were significant for the hearing aid group.

Table 8 shows the correlation between speech-perception– and music-perception–tasks for the normal hearing, hearing aid, and cochlear implant groups.

DISCUSSION

In this study, cochlear implant adolescents had significantly lower scores on vowel identification, pattern perception, and word-sentence recognition compared with their hearing aid peers. The unique combination of acoustic features that characterizes each speech sound ensures that each phoneme has a different acoustic make-up. It is not surprising, therefore, that a hearing impairment will affect the reception of the acoustic pattern of various phonemes differently. It is necessary to receive the first- and second-formant information to identify a vowel in isolation on the basis of its acoustic structure alone, especially identification of the second formant. Its transition is particularly important for vowels. The second formant is keyed to the place in the oral cavity where the vowel is produced.[10] From it, we can determine whether the vowel is a front vowel such as "i", which produces a high F_2 (2300 Hz), or a back vowel such as "u," in which the F_2 is much lower (900 Hz). However, it is not the absolute values of F_1 and F_2 that determine the vowel perception because these change with the pitch of the glottal tone. It is the relative spacing of the formants (the difference frequency) that remains constant for all pitches that provides the information for identification. A vowel is subject to distortion when a hearing impairment erodes acoustic information in the F_2 range. A severe hearing impairment above approximately 1000 Hz may so erode the F_2 information as to make discrimination between some front and back vowels impossible even though F1 makes both audible. Hearing must be presented up to 3000 Hz to ensure positive discrimination of all vowels.[10] Although the cochlear implant group in this study had similar hearing thresholds as their hearing aid peers at 1000 and 2000 Hz, they were not successful on vowel recognition when compared with hearing aid group. The answer to this finding can be explained

Table 8. Correlation between speech- and music-perception tests for normal hearing, hearing aid, and cochlear implant. Groups (*P<.05, NH, normal hearing; HA, hearing aid,; CI, cochlear implant)

Groups	Musical Perception Tests		Speech Perception Tests					
			Multisyllabic Word	Vowel Identification	Pattern Perception	The Phonetically Balanced Word List	Consonant Identification	Daily Sentences
NH	Rhythmic Perception	r	–	–.078	–	0.553	0.190	–0.213
		P	–	.811	–	.062	.555	.506
	Tonal Perception	r	–	0.173	–	0.478	0.127	–0.95
		P	–	.590	–	.116	.694	.769
CI	Rhythmic Perception	r	0.073	0.122	0.633*	–0.105	0.183	0.008
		P	.821	.706	.027*	.746	.568	.981
	Tonal Perception	r	0.106	0.456	0.477	0.000	0.085	0.072
		P	.743	.136	.117	1.000	.793	.824
HA	Rhythmic Perception	r	0.648*	0.245	0.436	0.301	0.321	–0.373
		P	.023*	.443	.157	.341	.308	.232
	Tonal Perception	r	0.651*	0.125	0.399	0.131	0.025	–0.123
		P	.022*	.699	.199	.686	.940	.704

by recent studies questioning the neurophysiology of cochlear implants and concluding that cochlear implants preferentially stimulate basal-turn neurons normally carrying high-frequency signals. The lower-frequency neurons, which are normally best suited for temporal coding, are not directly exposed to the stimulation electrode.[11,12] The pitch of complex tones, particularly vowels, is usually composed by low-frequency sounds. Cochlear implant adolescents could have performed better on vowel recognition tasks if they had better hearing acuity at low frequencies so that they would perceive F_2 information for vowels. Godfrey has explained that top-down and bottom-up processing in psycholinguistic research interacts in numerous complex ways, so that any change of acoustic input or any change in available interpretive information may have affects at any level.[13] As most of the adolescents in our study have coded the acoustic information incorrectly in the preimplantation period, they were not able to transfer their acoustic background to the new stimulation mode. Although they had better hearing thresholds, preferably at high frequencies, by cochlear implant, they were not able to perform as well as their hearing aid–using peers because of their deprived auditory mechanisms. The hearing aid group, with their minimum 10 years of functional hearing experience, were able to perceive and recognize several spectral combinations of speech successfully. Although it might be expected that they may overcome this deprivation in the long run, it doesn't seem to be a realistic expectation, as central auditory maturation is almost completed by this age.

Music-perception findings in this study indicate that quantifiable characteristics of music perception such as rhythm and tones have an association with some of the parameters of speech perception in both the hearing aid and cochlear implant groups. There was significant correlation between pattern perception and rhythm perception in the cochlear implant group. These results reflect the similarity with previous research that points out that cochlear implant users show more consistent reactions to rhythmic patterns. Duration, rhythmic patterns, and such, which are defined as temporal information, are found to correlate with temporal-based cues of speech perception for the cochlear implant group. There was an association of multisyllabic identification with both rhythm and tonal perception in the hearing aid group. Thus, the results of this study might be interpreted that as the performance in multisyllabic word perception improves, the performances in pattern and rhythm perception also improve.[14-16] Unlike the cochlear implant group, the adolescents who used hearing aids perceived not only temporal but spectral information by their functional-hearing ability. This shows that the adolescents in this group were as interested in listening to music and playing musical instruments as were their normal hearing peers. The cochlear implant group was familiar with a completely different nature of sounds of music and found a new meaning for listening with their implants. They can listen for frequency, rhythm, and timbre of sound in a higher level; understanding rhythm helps in better performance in syllable understanding, the count of phonemes, and recognizing the length of words and sentences.[17]

Auditory training will be improved for these teenagers if they can incorporate their new understanding of rhythm-and frequency-differentiating skills into their speech. Introducing new concepts of music and speech sounds, with temporal and frequency-related characteristics, should be a crucial part of the cochlear implant rehabilitation program. With this integration, auditory-training skills will be improved and psychological issues such as self-esteem and reduction in anxiety could be attained.

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