

# Music Listening Habits and Music Perception Abilities of Prelingually Deafened Adolescent Cochlear Implant Recipients

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## Abstract

**Background** Music is a very important art form that can evoke strong emotions and involvement with it can have a considerable impact on cochlear implant (CI) recipients' quality of life. It is well known that music perception is limited in CI with fully electric hearing and CI recipients have significantly poorer music-appraisal ability when compared with normal hearing subjects. Considering the importance of music on the life of an adolescent and negative impact of hearing loss on mental health, understanding and improving music listening habits and perception abilities can have a positive impact on the mental health of CI user adolescents.

**Purpose** This study aims to evaluate music listening habits and music perception abilities of prelingually deafened adolescent CI users to reveal the relationship between self-reported assessment and psychophysical measurement.

**Research Design** The psychophysical measures of music perception and self-reported music listening habits of adolescent CI users were obtained.

**Study Sample** Twenty-nine prelingually deafened adolescent CI users were evaluated in this study.

**Data Collection and Analysis** The Turkish Clinical Assessment of Music Perception (T-CAMP) test was used to evaluate music perception abilities. These abilities were evaluated with a three-item questionnaire assessing enjoyment of music, listening habits, and comprehension of lyrics. Pearson's correlation coefficients were calculated to assess the relationship between the T-CAMP subtests and questionnaire items.

**Results** Statistically significant correlations were observed between the melody-recognition subtest of T-CAMP and all three questionnaire items. The correlation between the enjoyment and rate items on the questionnaire was also statistically significant.

**Conclusion** The present study shows that adolescent CI users also enjoy and listen to music in ways similar to postlingually deafened adult CI users. It also demonstrates that melody-recognition abilities have a significant relationship with music enjoyment and listening habits in prelingually deafened adolescent CI users.

## Keywords

- ▶ cochlear implants
- ▶ music perception
- ▶ listening habits
- ▶ adolescent

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Although cochlear implantation (CI) can restore hearing and improve speech perception in patients with severe and profound hearing loss, other important aspects of hearing should also be restored. Among these aspects is music perception. Music is an important art form that can evoke strong emotions,<sup>1</sup> and involvement with it can have a considerable impact on CI recipients' quality of life.<sup>2</sup> However, music perception is limited in CI with fully electric hearing<sup>3-6</sup> as a result of limited spectral sensitivity and slow varying temporal envelopes.<sup>7</sup>

However, music involves personal and cultural variables, so the psychophysical measures of music perception may not reflect the subjective appreciation and music listening habits of CI recipients. The music appraisal ability of CI recipients is significantly poorer than that of subjects with normal hearing<sup>8,9</sup> and the recipients themselves prior to hearing loss.<sup>10,11</sup> Gfeller et al<sup>12</sup> evaluated 209 adult CI users and found that neither device type nor processing strategy can predict the accuracy of music perception. Speech perception abilities, music listening history, residual hearing, and cognitive factors can be used to predict some aspects of musical appraisal, but the predictive powers of measured variables are generally weak. Philips et al<sup>13</sup> showed a statistically significant correlation between speech perception abilities, music enjoyment, and finding music with the CI sounding more natural in 15 CI users, although CI users with good and poor speech perception abilities describe the importance of music in their life with respect to their own well-being and social life. Wright and Uchanski<sup>14</sup> evaluated 10 CI users by using the Appreciation of Music in Cochlear Implantees, the Montreal Battery of Evaluation of Amusia, Melodic Contour Identification, and the University of Washington Clinical Assessment of Music Perception (UW-CAMP) tests. Drennan et al<sup>15</sup> examined 145 CI users by utilizing the UW-CAMP test and the Iowa Musical Background Questionnaire. Both studies have demonstrated that correlations between musical appraisal and perception scores are weak or nonexistent. These studies have also emphasized that music perception skills and musical appraisal do not always coincide, and both domains need further improvement.

Although previous studies examined different aspects of music in the life of CI users in a broad sense, music can have different social and psychological impacts on people at different developmental periods.<sup>16</sup> This impact is significant in the contemporary lives of adolescents who live in a new media age and listen to a considerable amount of music daily.<sup>17</sup> Adolescence is an important period of changes, challenges, and identity reconstruction; in this complex period, adolescents experience serious stress and anxiety.<sup>18</sup> Music can be an important tool to cope with stress because it can influence emotions and mood and reflect the emotional turbulence experienced by adolescents.<sup>19,20</sup> Moreover, music should not always be considered a passive listening activity; in many instances, adolescents can participate in music by singing, playing an instrument, and dancing. Participating in music has a positive influence on anxiety and depression<sup>21</sup> and is related to a high quality of life and satisfaction with health.<sup>22</sup> Therefore, how adolescent CI users listen to music should be understood in terms of listening frequency, enjoyment, and perception. This under-

standing can help hearing professionals develop awareness on the positive impact of music on the mental health of adolescent CI users in consideration of the negative impact of hearing loss on mental health.<sup>23,24</sup>

To our knowledge, only one study has focused on the music perception abilities of adolescents. Driscoll et al<sup>25</sup> evaluated and compared the music perception abilities of adolescents by using electroacoustic hearing, children and adolescent CI recipients with traditional CI electrodes, and a control group of children with normal hearing. The performance of the electroacoustic CI group is better than that of the traditional CI group and similar to that of subjects with normal hearing in terms of pitch ranking, melodic error detection, and melody recognition tests on music perception. However, with the benefits of electroacoustic hearing, researchers cannot easily present a conclusion that considers the age of participants. Few studies have also evaluated smaller age groups. Jung et al<sup>26</sup> examined the music perception abilities of prelingually deafened pediatric CI recipients aged 8 to 16 years and compared their findings with those of a similar previous study involving adult CI recipients.<sup>27</sup> The pitch discrimination subtest performance is not significantly different between groups, but the melody and timbre recognition scores of pediatric CI recipients are worse than those of adult CI recipients; the melody recognition performance of participants is also below the chance level. Yüksel et al<sup>28</sup> analyzed pediatric CI recipients aged 9 to 13 years with very good residual hearing and found that the performance of participants is similar to that of subjects with normal hearing in the pitch discrimination test.

To describe the relationship between the musical appraisal and music perception abilities of adolescent CI users in detail, we aimed to evaluate music listening habits with a self-reported numeric rating scale and examine music and speech perception abilities with psychoacoustic measurements. We believed that we could comprehensively investigate the significance of music in the life of a teenage CI user by using both methods.

## Materials and Methods

### Participants

Twenty-nine prelingually deafened CI user adolescents (13 males and 16 females) were involved in this study. Patients who received implants between 2003 and 2018 were examined, and patients who met the inclusion criteria were recruited. The inclusion criteria were as follows: having severe-to-profound hearing loss before the age of 60 months, more than 1 year of CI use, age between 12 and 18 years during the test, and normal auditory nerve and cochlear anatomy. All the subjects were able to orally communicate and gain speech perception scores after CI use (monosyllabic word recognition score range = 96–66%). Subjects were excluded if they had any formal music education beyond regular music lessons in grade school or additional mental and neurological disorders, including auditory neuropathy spectrum disorder. The detailed information of the CI recipients is listed in **Table 1**. Their age upon diagnosis, implantation, and testing were also recorded.

**Table 1** Demographic variables of study participants

Age (y)	HL age (mo)	CI age (mo)	Bimodal	Device	Processor
12	6	24	No	CI24RE	CP1000
17	12	24	No	Pulsarci100	Sonnet
15	6	36	No	CI24RE	CP910
16	6	42	No	CI24RE	CP910
13	6	48	No	CI24R(CS)	CP910
17	6	48	No	Sonataci100	Opus 2
18	42	48	No	CI24RE	CP810
16	18	49	No	CI24RE	CP910
18	42	57	No	CI24RE	CP950
18	12	60	No	CI24RE	CP950
18	12	72	No	CI24RE	CP950
17	6	78	No	CI24M	CP950
15	8	78	No	CI422	CP810
12	42	84	No	Concerto	Opus2
18	60	90	No	CI24RE	CP910
17	18	96	Yes	CI24RE	CP910
14	6	24	Yes	CI24RE	CP950
13	50	84	No	CI24RE	CP950
14	6	36	No	CI24RE	CP810
13	48	70	No	CI422	CP810
13	24	60	No	CI24R(CS)	CP950
15	12	36	Yes	CI24RE	CP810
18	11	38	No	CI24RE	CP810
15	40	84	Yes	CI24RE	CP950
16	42	90	Yes	CI24RE	CP910
16	12	48	Yes	CI24RE	CP910
18	18	60	Yes	CI24RE	CP810
18	48	96	No	CI24RE	CP810

Abbreviations: CI, cochlear implantation; HL, hearing loss.

The music perception abilities of the subjects were evaluated with the Turkish version of the Clinical Assessment of Music Perception (T-CAMP) test.<sup>29</sup> Music listening habits were evaluated using a three-item 11-point scale developed for this study.

The protocol of this study was approved by the ethics committee, and informed written consent was obtained from all the subjects and their parents (for subjects under 18 years of age).

### Procedure

T-CAMP and speech perception tests were conducted in a double-walled audiometric booth (Industrial Acoustics Company Inc., USA) during the same session. Sound intensity was set at 65 dB A for T-CAMP testing, and a custom-made MATLAB (MathWorks Inc., Matick, MA) program was used to present stimuli on a computer connected to a Madsen

Astera audiometer (Otometrics, Natus Medical, Denmark) with a single JBL Control One loudspeaker (JBL, Harman International, USA) positioned at 1 m distance with 0 degrees azimuth and elevation from the participants. The CI users were evaluated using the same open-set monosyllable word list. Word recognition scores were obtained with a monitored live voice and calculated by counting the number of a CI user's correctly repeated words, dividing this number by the total number of words, and multiplying the result by 100.

### Musical Appraisal and Listening Habits

Musical appraisal and listening habits were evaluated with three questions. For the first two questions, 11-point numeric rating scales with opposite adjectives and numeric response descriptors were used. Studies have described the use of 5-, 7-, 10-, or 11-point scales in questionnaires<sup>30</sup> and suggested that an 11-point scale can minimize categorization effects, improve data analysis, and minimize measurement errors.<sup>31</sup> Therefore, an 11-point numeric rating scale with a real midpoint was chosen to conduct detailed measurements in this study.

The three items pursued in the scale were enjoyment of music, lyric comprehension, and listening habits. The following enjoyment item question was asked to understand musical appraisal: "How much do you enjoy listening to music?" A rating of 0 was given for "not at all," and 10 was given for "to a great extent."

For the lyrics, the question was "Can you understand the lyrics of a song that you listen to?" Understanding lyrics in music can help CI recipients compensate for poor pitch, melody, and timbre recognition and improve their ability to recognize melodies<sup>4</sup>; therefore, measuring lyric comprehension with self-reported measures could also be helpful.

For listening habits, the question was "How often do you listen to music?" Scoring was made on a rating scale of 0 to 10: 0 = never, 2 = once a month, 4 = few times a month, 6 = once a week, 8 = a few times a week, and 10 = every day.

### T-CAMP

T-CAMP testing was performed in accordance with the procedure previously described by Nimmons et al<sup>6</sup> and Yüksel and Çıprut.<sup>29</sup> Each subtest was initiated with short training sessions. In these sessions, the subjects were asked to listen to 4 different pitch pairs, 12 melodies, and 8 instruments twice. The pitch direction discrimination (PDD) subtest was preserved, but melody and timbre recognition tests were modified for Turkish listeners.

In the PDD subtest, a two-alternative forced choice was used: one-up and one-down adaptive procedures. Synthesized complex tones with a 760-ms duration were used. Two buttons (labeled as one and two) were presented on a computer screen, and the subjects were instructed to select the button corresponding to the tone with a higher pitch. Testing began with four practice intervals, including feedback, but no feedback was given to the subjects in the actual testing. Three base frequencies were set (262 Hz, C4; 330 Hz, E4; and 392 Hz, G4), and the interval of the higher pitch tone was changed between 1 and 12 semitones. The initial pitch pair had an interval of 12 semitones. Each correct response was followed by a smaller

interval, and each incorrect response was followed by a larger interval. Every incorrect response after a correct response was defined as a reversal, and a PDD threshold for each base frequency was calculated from the mean pitch interval in semitones by using the last six of the eight reversals. The mean of the three base frequencies was determined to arrive at the final PDD score.

In the melody recognition subtest, previously selected and tested 12 melodies were used.<sup>29</sup> All the melodies were played isochronously to eliminate rhythm cues with synthesized notes for 500 ms in an 8-note pattern at a tempo of 60 beats per minute. Five versions of each melody were prerecorded with different note intensities ( $\pm 4$  dB), and a different version was played randomly at each time to avoid intensity cues. The total melody recognition score was calculated after 36 presentations.

In the timbre recognition test, eight musical instruments, namely, a Turkish saz, a piano, a guitar, a violin, a trumpet, a flute, a clarinet, and a saxophone, were used. All instruments were played with the same five-note sequence with the same articulation, duration (5 seconds), phrasing, and mezzo-forte intensity and recorded in a professional studio environment with professional musicians. The amplitudes of the instruments were normalized using root mean square, followed by peak normalization. Total timbre recognition was calculated after 24 presentations.

**Statistical Analysis**

Statistical analysis was performed using SPSS 21.0 (SPSS Inc., Chicago, IL). Descriptive statistics (mean, media, standard deviation, range, and interquartile range) were used to describe study variables. Histograms and Shapiro–Wilk normality test were utilized to assess the normal distribution of means. Spearman’s correlation coefficients were calculated to analyze the relationship between numeric rating scale scores and T-CAMP subtests. A 0.05 significance level was set.

**Results**

The question responses, PDD, melody recognition, and timbre recognition scores are presented in ► **Table 2**.

Melody recognition was significantly correlated with three-scale items ( $p < 0.05$ ; ► **Table 3**). However, no statistically significant correlation between other T-CAMP measures and scale items was observed.

Enjoyment and rate items showed statistically significant correlations ( $p < 0.05$ ; ► **Table 4**).

**Discussion**

**T-CAMP and Scale**

Our findings showed that the self-reported measurements of music were related to psychophysical ones. The most striking finding was the relationship between melody recognition and music enjoyment. Melody is arguably the most prominent musical feature of modern rhythmic music and has been used in different studies to evaluate the effect of music on emotion and memory.<sup>32,33</sup> Melodies create a sensory expectation by using sequential tones.<sup>34</sup> Contrary to pitch or instrument perception, melodies connect with inner experiences and memories to reflect a place, pleasure, culture, and experience.<sup>35</sup> Melodies can also be used as a primary cue when a person tries to remember or identify a song. Therefore, melody recognition appears to have an important connection with music enjoyment among adolescent CI users. The melodies used in the T-CAMP were generated and isolated, so they could not completely reflect a real-world melody recognition performance. Nevertheless, the connection was still a remarkable and consistent finding, considering the additional relationship between melody recognition and the self-reported measures of lyric comprehension and music listening habits.

Previous studies suggested that training can improve music perception and appraisal.<sup>36,37</sup> In our study, another important consideration was that the relationship between melody recognition and music enjoyment could not explain whether CI users with good music perception listen to and enjoy music more than they did before or whether CI users who listen to more music might develop better music perception abilities. The lack of a significant correlation between the PDD and the scale could contribute to this discussion. Music exposure is possibly beneficial to the recognition of familiar melodies used

**Table 2** Descriptive statistics

	Questionnaire			T-CAMP		
	Enjoyment	Lyrics	Rate	PDD (ST)	Melody (%)	Timbre (%)
Mean	8.14	5.46	8.32	3.44	13.89	30.21
Median	9	5	10	2.84	8.33	27.09
SD	2.19	2.27	2.54	2.06	14.26	15.86
Minimum	3	0	0	0.54	0	4.17
Maximum	10	10	10	8.22	69.44	70.83
25th percentile	7	5	8	1.78	5.56	16.67
50th percentile	9	5	10	2.84	8.33	27.09
75th percentile	10	6.75	10	4.59	15.97	40.63

Abbreviations: PDD, pitch direction discrimination; SD, Standard deviation; ST, semitones; T-CAMP, Turkish Clinical Assessment of Music Perception.

**Table 3** Spearman's correlation coefficients between study variables

		PDD		Timbre recognition		Melody recognition	
		<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>	<i>r</i>	<i>p</i>
Questionnaire	Enjoyment	-0.35	0.07	0.35	0.07	0.62 <sup>a</sup>	0.00
	Rate	-0.23	0.23	0.25	0.21	0.45 <sup>a</sup>	0.02
	Lyrics	-0.12	0.56	0.18	0.36	0.43 <sup>a</sup>	0.02

Abbreviations: PDD, pitch direction discrimination; *r*, Spearman's correlation coefficient.

<sup>a</sup>Statistically significant correlation coefficient.

**Table 4** Spearman's correlation coefficients between questionnaire items

Questionnaire items		<i>r</i>	<i>p</i>
Enjoyment	Rate	0.78 <sup>a</sup>	0.00
Enjoyment	Lyrics	0.35	0.07
Rate	Lyrics	0.35	0.07

Abbreviation: *r*, Spearman's correlation coefficient.

<sup>a</sup>Statistically significant correlation coefficient.

in the T-CAMP as a result of the relationship of melody recognition with memory and the effect of learning on central auditory processing.<sup>38</sup> Pitch perception has a simpler and more peripheral nature than melody recognition and is possibly more related to auditory abilities when CI is considered. This possibility is also supported by the fact that CI users with good residual acoustic hearing benefit the most in pitch perception tasks, and their performance is similar to that of subjects with normal hearing.<sup>28</sup> Therefore, music exposure and training could be beneficial to central auditory processing tasks, such as melody recognition.

The timbre recognition of the CI users was relatively poor as a result of the poor temporal fine structure information conveyed by the CI processor. Timbre recognition does not improve with exposure.<sup>39</sup> The limitation of timbre recognition can also restrict the relationship between music listening habits and timbre recognition, as observed in our study.

### Music Listening Habits

The group mean for the enjoyment item was close to "a few times in a week," but some participants marked this question 0 even when they had better-than-average T-CAMP scores. This observation emphasized the importance of an individually crafted approach to music-related training in clinical settings. Some of the subjects mentioned that they never had any interest in listening to music, and this phenomenon could be a natural consequence of being prelingually deafened at a young age. Some subjects probably never had an opportunity to perceive music as something enjoyable or natural. However, the enjoyment and listening rates of our subjects were better than that reported in many previous studies. Previous studies used various questionnaires and scales, and our study employed an in-house test; hence, previous and present results might not be directly compared. The lack of studies on prelingually deafened adolescents or young adults also limits the possibility

of comparison. Thus far, only Moran et al<sup>40</sup> evaluated the music listening habits of prelingually deafened adult CI users. They found that the mean amount of music listening among subjects is close to "sometimes," and enjoyment is better than "neutral." However, the average chronological age (51.19 years) and age-at-implantation (47.29 years) of the participants in our study were well above our study sample. Therefore, the difference in enjoyment and habit scores in our study could be a result of the younger age of our participants, in addition to our use of a different scale.

The average self-reported lyric comprehension score was close to the midpoint of the scale. In modern music, lyrics are usually accompanied with other instruments, and this complex structure can make auditory scene analysis difficult. This difficulty may in turn increase if subjects are unfamiliar with a song, considering the effect of the masking of other instruments in spectral and temporal domains. However, the important point in our study was that no statistically significant correlation was observed between lyric comprehension and music enjoyment. This finding supported previous reports on the positive effect of pre- and postimplantation music experience on music enjoyment measures<sup>12</sup> when they are evaluated in conjunction with statistically significant and strong correlation between enjoyment and rate items. The frequency of listening to music of the subjects who enjoyed doing it was higher than that of the subjects who did not enjoy this activity. However, the possible influence of music exposure on enjoyment should still be considered.

### Limitations

The most important limitation of our study was the scale used. None of the previously used and validated questionnaires or scales were adapted for our culture and language; therefore, a simple three-item scale was chosen in our study to minimize measurement errors. Despite this limitation, correlations between scale items were similar to those in previous studies, and a significant correlation coefficient between music enjoyment and listening habits was observed.

### Conclusion

The present study shows that melody recognition abilities are significantly related to music enjoyment and listening habits in prelingually deafened adolescent CI users. This relationship is possibly bidirectional. As music exposure

increases the melody recognition abilities of CI users, melody recognition enhances because of more listening time and enjoyment. Being prelingually deafened does not prevent CI users from enjoying and listening to music, and this finding is important for adolescents who are in the critical period of development between childhood and adulthood.

#### Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

#### Conflict of Interest

All authors declare there are no conflicts of interest.

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