Music and Quality of Life in Early-Deafened Late-Implanted Adult Cochlear Implant Users

*†Christina Fuller, *‡Lisa Mallinckrodt, *†Bert Maat, *†Deniz Başkent, and *†Rolien Free

Department of Otorhinolaryngology–Head and Neck Surgery, University of Groningen, University Medical Center Groningen; †Research School of Behavioral and Cognitive Neurosciences, University of Groningen, Graduate School of Medical Sciences; and ‡Department of Surgery, Scheper Ziekenhuis, Emmen, The Netherlands

Hypothesis and Background: The early-deafened, late-implanted (EDLI) CI users constitute a relatively new and understudied clinical population. To contribute to a better understanding of the implantation outcome, this study evaluated this population for self-reported enjoyment and perception of music. Additionally, correlations of these measures with the self-reported quality of life and everyday hearing ability and a behaviorally measured word recognition test were explored.
Materials and Methods: EDLI CI users from the Northern Netherlands were sent 4 questionnaires: 1) Dutch Musical Background Questionnaire (enjoyment and perception of music), 2) Nijmegen Cochlear Implant Questionnaire (quality of life), 3) Cochlear Implant Functioning Index (auditory-related functioning), and 4) Speech, Spatial and Qualities of Hearing Scale (hearing ability). Complementary, behavioral word recognition in quiet tests (phoneme score) were completed.
Results: Twelve (60%) of 20 participants reported music to sound pleasant. In general, the self-perceived quality of music was scored positively. No correlations were observed between enjoyment and perception of music, quality of life, hearing ability, and word recognition.
Conclusion: The results indicate that, differently than postlingually deafened, EDLI CI users enjoy music and rate the quality of music positively. Potential explanations for the absence of correlations between the music measures and the other outcomes could be that other factors, such as speech perception, contribute more to quality of life of EDLI CI users or that this group simply lacks previous exposure to music with acoustic hearing. Overall, these positive findings may give extra support for implant candidacy of early-deafened individuals, but further studies should be conducted. **Key Words:** Cochlear implant—Early deafened—Late implanted adults—Music perception—Music enjoyment—Quality of life.

Otol Neurotol **34:**1041–1047, 2013.

Cochlear implants (CIs) restore hearing in severely deafened adults and children. Nowadays, the perception of speech in quiet is fairly good in postlingually deafened CI users. Nevertheless, the perception of music is still inadequate and dissatisfactory in this population (1–6; C.D. Fuller, et al., unpublished data, 2013). A potential explanation for this dissatisfaction could be that the perception of music (or the processing of its four basic elements; pitch, rhythm, melody, and timbre) is less accurate and more variable in CI users compared with normal hearing (NH) listeners (2,7,8). Interestingly, early-deafened, early-implanted (EDEI) young CI users report higher enjoyment of listening to music than postlingually deafened adult CI users, although the behaviorally measured ability of music perception in EDEI has been observed to be worse (9–12). Based on the observations with EDEI population, early-deafened, late implanted (EDLI; late implantation defined as after the age of 16 in the present study) CI users may also have a different appreciation of music than the postlingually implanted group.

Despite a delay between the onset of deafness and the implantation, which has negative consequences for the speech perception outcome in general (13,14), and a

potential deficit in language skills because of the onset of deafness in early childhood, a subgroup of EDLI CI users have been observed to benefit from implantation regarding speech perception and quality of life (QoL) (E.M. Mallinckrodt, et al., unpublished data, 2013; 15–22). However, the benefit for enjoyment and perception of music in this group is mostly unknown. To the best of our knowledge, only 2 studies have examined the self-reported perception of music in EDLI, and both presented some limitations (5,23). Although both reported that EDLI CI users enjoy listening to music using their implant, in the study by Migirov et al. with 9 prelingually deafened CI users, the age at implantation was unknown, and the study by Eisenberg with 12 CI users was published in the early days of the CIs in 1982. As the CI technology, surgical techniques, rehabilitation methods, and CI outcome have substantially changed since then, an updated and a more comprehensive evaluation of this group is needed.

Music is a pleasurable stimulus that can affect emotional state, to the degree that music therapies can positively influence QoL (24,25). Therefore, any improvement to the perception of music could presumably have similar positive effects for CI users. Hence, assessing the perception and enjoyment of music in the understudied group of EDLI CI users could give additional insight in the debate on whether implantation of early deafened adults or adolescents would still be beneficial at a later age. Moreover, the perception and enjoyment of music could influence other outcome factors of implantation, such as QoL, everyday hearing ability and speech perception (6, C.D. Fuller, et al., unpublished data, 2013; 26,27). In the present study, we have explored the self-reported enjoyment and perception of music in EDLI CI users more extensively and systematically than the 2 previous studies, by collecting extensive data on demographics and patient history and careful selection of the participants accordingly. Complementary correlational analyses between the self-reported perception and enjoyment of music, the health-related quality of life (HRQoL), everyday hearing ability, and a behavioral word recognition measure were explored. First, we hypothesized that EDLI CI users would enjoy listening to music, similar to EDEI CI users, but unlike the postlingually deafened CI users. Second, we also hypothesized that higher enjoyment and better perception of music would be correlated with higher QoL, better everyday hearing ability and word recognition, based on the findings with postlingually deafened CI users (6, C.D. Fuller, et al., unpublished data, 2013; 26).

MATERIALS AND METHODS

Study Population

The inclusion criteria for participation, based on (15, E.M. Mallinckrodt, et al., unpublished data, 2013; 28), were as follows: severe hearing loss at least since preschool (onset 6 years of age or earlier), implanted at 16 years of age or later, and more than 1 year of CI experience. The criterion 16 years or later was picked to ensure a period of auditory deprivation in the EDLI. Thirty-seven qualifying EDLI CI users, all patients of our clinic and a subgroup of the participants previously described by

Mallinckrodt et al. (unpublished data, 2013), were sent four questionnaires. Twenty-seven (73%) replies were received. Five CI users were excluded after their responses revealed that they did not strictly meet the inclusion criterion for severe hearing loss onset at the age of 6 or earlier. The demographics of the 22 study participants are shown in Table 1. The levels of education refer to the highest completed educational level: low refers to elementary school only, middle refers to middle school or higher, and high refers to at least a bachelor's degree.

The study was approved by the medical ethical committee of the University Medical Center Groningen. Participants were given detailed information about the study, and written informed consent was obtained. Participation was entirely voluntary, and no financial reimbursement was provided.

Dutch Musical Background Questionnaire

The Dutch Musical Background Questionnaire (DMBQ) is a translated and edited version of the Iowa Musical Background Questionnaire (3). The questionnaire was translated into Dutch by a professional translator with assistance from the first author and was further revised by an audiologist; an Ear-, Nose- and Throat surgeon; audiology scientists and a psychologist (translated by Mynke Trommelen and the first author). The DMBQ has 3 parts that measure: satisfaction with listening to music, self-perceived

TABLE 1. *Demographics of all study participants*

All participants N = 22

	Number	Mean (standard deviation)	Range
Sex			
Male	6		
Female	16		
Age (yr)		47.4 ± 15.0	19–68
Age at onset of severe hearing loss (yr)[a]		0.7 ± 1.3	0–4
Age at fitting of first hearing aid (yr)[a]		2.5 ± 1.5	0–8
Age at implantation (yr)		41.2 ± 14.3	17–63
Level of education			
Lower	3		
Middle	12		
Higher	7		
Deaf school attendance			
Sign language school	9		
Aural communication/sign language school	8		
Aural/oral school	5		
Duration of CI use (yr)[a]		5.7 ± 3.3	1–10
CI use per day (h)[a]		14.2 ± 4.2	6–24
Implant type (no.)			
CI24R CA[b]	4		
CI24R k[b]	1		
CI24RE CA[b]	5		
CI24R CS[b]	7		
HiRes90K Helix[c]	5		
Speech processor type (no.)			
Esprit3G[b]	5		
Freedom[b]	7		
Nucleus 5[b]	5		
Harmony[c]	5		

[a]Based on patients' own reporting.
[b]Cochlear Corp., Englewood, Australia device. ACE speech strategy.
[c]Advanced Bionics Corp., California, USA, device. HiRes speech strategy.

quality of music, and self-reported perception of the elements of music.

Satisfaction With Listening to Music

The satisfaction with listening to music was determined via a 3-option single question: little or no satisfaction with listening to music, the sound of music is okay or improving over time, and music sounds pleasant. The satisfaction was accordingly scored on a 0 (no satisfaction) to 2 (most satisfaction) scale by 20 (out of 22) CI users. Note that not every respondent filled all questions of all questionnaires. Therefore, the number of participants is specified in all results and figures.

Self-Perceived Quality of Music

The self-perceived quality of music is an indication of how music sounds under the best conditions with a CI. Twenty-two respondents scored 7 visual analog scales (VASs) with 14 opposite adjective descriptors (unpleasant-pleasant, mechanical-natural, fuzzy-clear, does not sound like music–sounds like music, complex-simple, difficult to follow–easy to follow, dislike very much–like very much). The scales ranged from 0 (negative quality) to 100 (positive quality). An average across the 7 scales was taken to quantify the self-perceived quality of music.

Self-Reported Perception of the Elements of Music

Participants reported their ability to perceive the elements of music: rhythm, melody, and timbre and to differentiate between vocalists and lyrics. The specific questions were as follows: 1) Can you hear the difference between singing and speaking? 2) Are you able to differentiate between a male and a female vocalist? 3) Are you able to follow the rhythm of a music piece? 4) Are you able to recognize the melody of a music piece? 5) Are you able to differentiate the instruments in a piece of music? 6) Can you follow the lyrics of a song?

The 6 questions were scored on a scale from 1 (never) to 7 (always). The scores 1 to 3 were classified as a ''negative'' ability, 4 as a ''neutral'' ability, and 5 to 7 as a ''positive'' ability. By averaging all 6 scores, a total score was calculated for 22 CI users.

Nijmegen Cochlear Implant Questionnaire

The Nijmegen Cochlear Implant Questionnaire (NCIQ) is a validated, CI-specific health-related QoL (HRQoL) instrument (29). The questionnaire is composed of 3 categories with 6 domains: physical functioning: sound perception–basic, sound perception–advanced, speech production; social functioning: activity, social functioning; and psychological functioning: self-esteem. The 6 domains of the NCIQ include 10 statements with a 5-point response scale. Scores per domain could range from 0 (worst) to 100 (best). A total score was calculated by averaging the scores from all 6 domains in 22 CI users.

Cochlear Implant Functioning Index

The third questionnaire was the Cochlear Implant Functioning Index (CIFI), a tool to assess the auditory-related functioning of CI users (30). The CIFI was scientifically translated to Dutch by the University of Groningen Language Center and was further revised by an audiologist; Ear-, Nose- and Throat surgeon; and audiology scientists. This questionnaire scores 5 fields of auditory functioning: 1) reliance on visual assistance, 2) telephone use, 3) communication at work, 4) 'hearing' in noise, 5) hearing in groups, and 6) hearing in large room settings. The third field communication at work was excluded because 8 (36%) of 22 respondents were unemployed, making this item not informative for this specific study population. We used total scores ranging from 0 (worst) to 19 (best functioning) in 22 CI users.

Speech, Spatial, and Qualities Questionnaire

The Speech, Spatial and Qualities of Hearing Scale (SSQ) is a validated environmental and spatial hearing questionnaire (31). The Dutch translated version 3.1.2 (2007) was used in this study. The SSQ was developed to quantify the abilities, in particular for speech perception and spatial hearing, in hearing-impaired people and CI users. The questionnaire is composed of 3 domains: speech, spatial and qualities. The self-perceived everyday hearing ability is rated with a score between 0 (least) and 10 (maximum ability). A total score was calculated by averaging the scores of all domains in 16 CI users who filled this questionnaire entirely.

Word Recognition

Word recognition scores were gathered by trained audiologists during the regular postimplantation outpatient visits as a measure of speech perception (32). In the test, meaningful consonant-vowel-consonant words were presented in quiet at 65 and 75 dB SPL (free field) in an audiometry booth. In a list of 12 words, the ratio of correctly repeated phonemes to the total number of phonemes presented was used to calculate a percent correct score. These scores were available for 19 participants at 65 dB SPL and for 20 participants at 75 dB SPL.

Statistical Analysis

Spearman's correlation coefficient was used to evaluate the relationships between the scores from DMBQ, NCIQ, SSQ, and the word recognition test. Statistical analyses were processed in Predictive Analytic Software (PASW) software package version 18.0. A level of $p < 0.05$ (2 tailed) was considered significant.

RESULTS

Enjoyment of Music

Figure 1 shows the satisfaction with listening to music through a CI. A majority of EDLI CI users who answered this section of the DMBQ (12 of 20 CI users; 60%) rated the sound of music as pleasant.

### Self-Perceived Quality of Music

Figure 2 shows the scores of the self-perceived quality of music. The mean scores of 22 CI users ranged from 42 to 68 (within the range of 0–100), with standard deviations ranging from 23 to 30. The total score was on the positive side of the scale (i.e., >50) with a mean of 56 and a standard deviation of 19.

Self-Reported Perception of the Elements of Music

Figure 3 shows the scores of the self-reported perception of the elements of music. A majority indicated to be able to follow the lyrics (18 of 22 CI users; 82%), recognize the instruments (15 of 22 CI users; 68%), and follow the melody (13 of 22 CI users; 59%). The ability to differentiate between singing and speaking was scored negatively in general (16 of 22 CI users; 73 %).
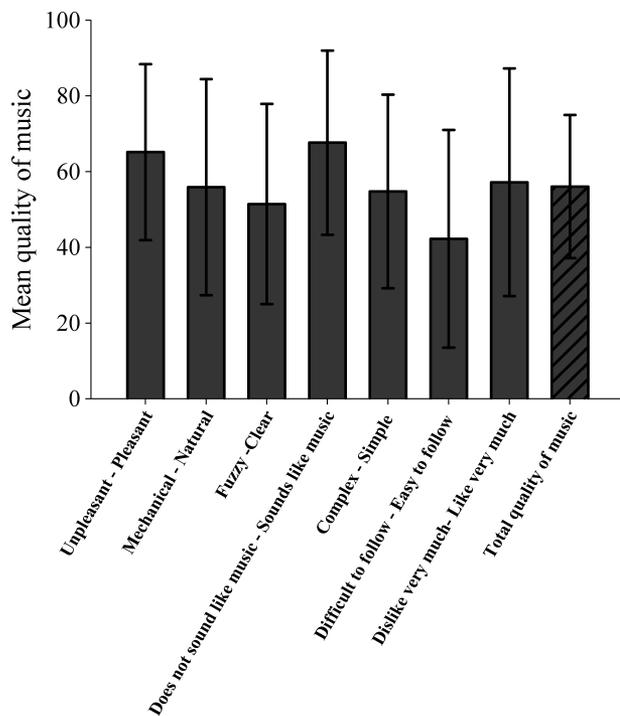
Correlations Between DMBQ Measures and NCIQ, CIFI, and SSQ

Table 2 shows the correlations between the scores of the DMBQ measures and the NCIQ, CIFI, and SSQ. The total NCIQ scores ranged from 44 to 92 (within the range of 0–100, best HRQoL) with a mean of 72 in 22 CI users. The total CIFI scores ranged from 4 to 19 (within the range of 4, worst, to 19, best auditory-related functioning)
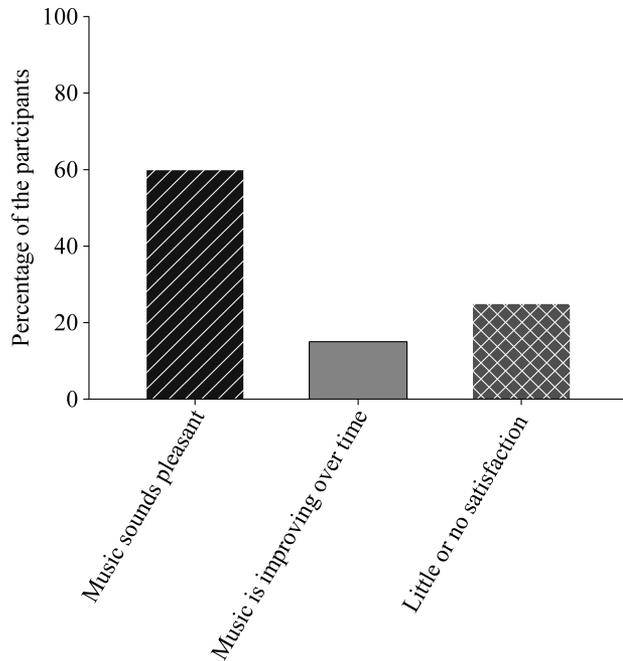
FIG. 1. The satisfaction with listening to music in 3 categories of the DMBQ in 20 CI users.

with a mean of 11 in 22 CI users. The total SSQ scores ranged from 0.6 to 7.6 (within the range of 0–10, best hearing-related functioning) with a mean of 4.4 in 16 CI

FIG. 2. The self-perceived quality of music of DMBQ averaged across all 22 participants. The error bars denote 1 standard deviation.

users. No significant correlations were shown between the DMBQ measures and the NCIQ, CIFI, and SSQ scores.

Correlations Between DMBQ Measures and Word Recognition Scores

Table 3 shows the correlation analysis between the DMBQ measures and the word recognition scores, ranging from 0 to 95 and a mean of 59%. No significant correlations were observed.

DISCUSSION

The present study evaluated the self-perceived enjoyment and perception of music in the EDLI adult CI users, whose onset of severe hearing loss was at 6 years of age or younger, and who were implanted at 16 years of age or older. Because of the potentially negative factors, such as less-than complete language development because of early onset of hearing loss and a delay between the onset of severe hearing loss and implantation, this population historically has not been strong candidates for implantation. As a result, although implantation in this group has now become more common, very limited knowledge on their music perception is available. The motivation for this study was, therefore, to comprehensively and systematically investigate music-related outcomes of implantation in this understudied group of CI users. We had hypothesized that, unlike the postlingually deafened CI users (1–6), this group may enjoy music perception, based on previous studies with EDEI CI users. We had further hypothesized, based on postlingual CI studies, that the enjoyment and perception of music could be correlated with other outcome factors such as the self-reported quality of life, the self-perceived hearing performance, and the behaviorally measured word
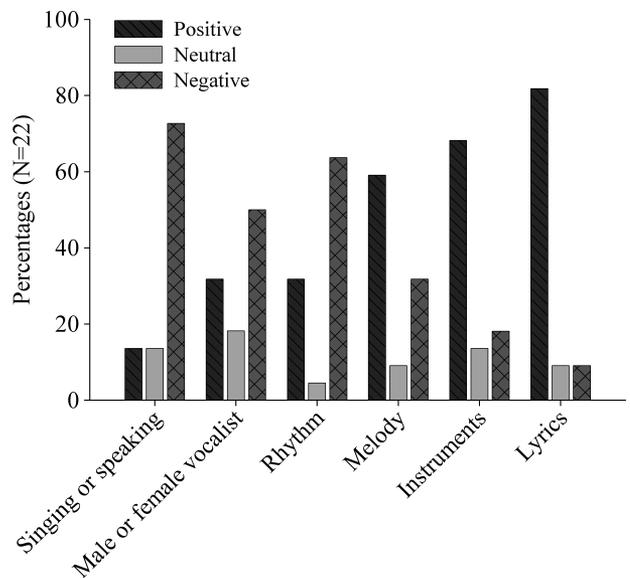
FIG. 3. The self-reported perception of the elements of music of DMBQ in 22 CI users.

TABLE 2. *Correlations between all Dutch Musical Background Questionnaire measures and the total scores of Nijmegen Cochlear Implant Questionnaire (left column); Cochlear Implant Functioning Index (middle column); and Speech, Spatial and Qualities of Hearing Scale (right column)*

	Nijmegen Cochlear Implant Questionnaire	Cochlear Implant Functioning Index	Speech, Spatial and Qualities of Hearing Scale
Satisfaction with listening to music	$r = -0.174$ $p = 0.462$ (n = 20)	$r = -0.311$ $p = 0.182$ (n = 20)	$r = 0.470$ $p = 0.090$ (n = 14)
Self-perceived quality of music	$r = -0.007$ $p = 0.974$ (n = 22)	$r = -0.237$ $p = 0.289$ (n = 22)	$r = 0.377$ $p = 0.150$ (n = 16)
Perception of the elements of music	$r = 0.179$ $p = 0.427$ (n = 22)	$r = 0.079$ $p = 0.727$ (n = 22)	$r = 0.371$ $p = 0.157$ (n = 16)

recognition scores (C.D. Fuller, et al., unpublished data, 2013; 26,27).

Self-Perceived Enjoyment and Perception of Music

The results from the music questionnaire on self-perceived enjoyment and perception of music showed that the majority of the EDLI CI users found music to sound pleasant. Additionally, the quality of music was also rated on the positive side of the scale. These observations reconfirm the findings of former studies that showed both the EDEI and EDLI CI users report high satisfaction with listening to music (5,23). However, both satisfaction and quality ratings within these populations are in contrast to the reports of postlingually deafened CI users, who showed dissatisfaction and lack of enjoyment with music (1–6, C.D. Fuller, et al., unpublished data, 2013). Several interpretations are possible for the differences observed in music appreciation by EDLI and postlingually deafened CI users. First, the EDLI CI users might have a different reference point to judge the quality of music with respect to definitions such as complex or simple, or mechanical or natural, due to an underdeveloped acoustic music memory. This situation could be further intensified by years of music listening without proper feedback, and/or with a different modality of listening, such as the tactile representation of music. For example, a song could sound natural to an EDLI but mechanical to a NH person listening to CI simulations because of the different states of the auditory exposure and memories of individuals. As a result, different listener groups may be making their music judgment using different standards and reference points (9,23,33). Moreover, the

additional benefit of the implant for music perception compared with the music perception during the period of deafness using a hearing aid may also differ. This would be most likely in the form of more temporal cues and vibrations (23). Overall, the positive self-perceived enjoyment and perception of music in the EDLI group indicates that music could be addressed as an extra factor for implant candidacy of early-deafened clinical populations.

Self-Reported Perception of the Elements of Music

The results from the music questionnaire on self-reported perception of the elements of music showed that EDLI CI users indicated to be best able to follow the lyrics and the melody of songs and to differentiate between musical instruments. They reported that following the rhythm and differentiating between singing and speaking and a male or female vocalist was most difficult. These findings are surprising as they are in contrast to the self-reported perception of these elements of music in postlingually deafened CI users (C.D. Fuller, et al., unpublished data, 2013). Postlingually deafened CI users report to perceive rhythm best, followed by melody and instrument recognition. These self-reports are consistent with the behaviorally tested perception of the elements of music by postlingually deafened CI users, which show rhythm to be perceived best and melodies worst (34–41). Based on these findings in postlingually deafened CI users and keeping in mind the techniques that the CI uses to process sounds leading to loss of fine temporal information, one would expect the EDLI group to be able to follow the rhythm best and not to be able to differentiate the instruments. Although the perception of

TABLE 3. *Correlations between all Dutch Musical Background Questionnaire measures and the word recognition in quiet scores measured at 65 and 75 dB SPL*

	Word recognition 65 dB (%)	Word recognition 75 dB (%)
Self-perceived quality of music	$r = -0.194$ $p = 0.425$ (n = 19)	$r = -0.050$ $p = 0.843$ (n = 20)
Satisfaction with listening to music	$r = 0.107$ $p = 0.672$ (n = 18)	$r = -0.010$ $p = 0.968$ (n = 18)
Perception of the elements of music	$r = 0.242$ $p = 0.319$ (n = 19)	$r = 0.301$ $p = 0.197$ (n = 20)

music is not behaviorally tested with EDLI CI users, we might, with some caution, conclude on the basis of the comparison with postlingually deafened CI users and the findings of our study, that the self-reported perception of the elements of music of EDLI CI users may not be in accordance with the expected behavioral scores. Again, this may be explained by a possibly different interpretation of rhythm or melody in EDLI CI users compared with postlingually deafened based on different reference points. To gain more insight in the differences between early and postlingually deafened groups and between self-reported and behaviorally measured music perception, behavioral or objective tests need to be conducted in EDLI CI users to validate this hypothesis.

Correlations Between DMBQ and NCIQ, CIFI, SSQ, and Word Recognition

Based on the findings in postlingually deafened CI users (C.D. Fuller, et al., unpublished data, 2013;7,26,27), we had hypothesized that higher enjoyment and better perception of music would be correlated with higher QoL, better everyday hearing ability, and better word recognition. As no such correlations were shown, the results did not support this hypothesis. The different findings between these groups may imply that the self-perceived enjoyment and perception of music is not a significant contributing factor to the QoL and hearing-related functioning for the EDLI users, unlike for the postlingually deafened CI users. QoL is a complex entity that depends on many factors in life, factors that are probably not all taken into account in this study and that might differ between different CI populations. For example, the gain in speech perception, which can be substantial, might have a larger contribution to the quality of life in EDLI than in postlingually deafened, reducing the potential effects of music-related factors. Also, the absence of correlations between the perception of music and the other outcomes could be caused by the different interpretation of music by EDLI CI users, as mentioned previously. A last factor that should be discussed for better interpretation of our data is the number of participants of the current study (n = 22). Although the group of EDLI CI users is a slowly expanding group, currently, this clinical population is still small worldwide. Reflecting this general limitation, the number of participants in this study might have been insufficient to find significant correlations between the perception and enjoyment of music and the quality of life. In comparison, with the larger groups of postlingually deafened CI users, Lasaletta et al. (2007) and Fuller et al. (unpublished data, 2013) did show such correlations in 52 and 98 postlingually deafened CI users, respectively. Therefore, further research needs to be conducted in the growing group of EDLI CI users to gain more insight in the outcome measures including music perception and enjoyment, using a variety of methods, including both subjective and behavioral.

CONCLUSION

Concluding, overall results of the study showed that EDLI CI users enjoy perception of music, rate the quality of music high, and are satisfied with listening to music using their CIs. Traditionally, the criteria for implantation have excluded early-deafened adults and adolescents because the long duration of auditory deprivation; the minimal exposure to important sounds, such as speech and music; and the underdeveloped auditory memory may make the brain unable to adapt to the implant, preventing effective use of it (44). In the last decade, however, although the outcomes in EDLI CI users tend to be poorer for speech perception compared with EDEI, an improvement in speech perception because of CIs has consistently been shown with this population (E.M. Mallinckrodt, et al., unpublished data, 2013;15,22,43–45). Complementing these earlier studies that showed a speech perception benefit, the present study showed high enjoyment and satisfaction with listening to music after implantation. These new findings of the present study may give additional support for cochlear implant candidacy of (well-selected) early-deafened individuals.

REFERENCES

1. Boucher R, Bryden MP. Laterality effects in the processing of melody and timbre. *Neuropsychologia* 1997;35:1467–73.
2. Drennan WR, Rubinstein JT. Music perception in cochlear implant users and its relationship with psychophysical capabilities. *J Rehabil Res Dev* 2008;45:779–89.
3. Gfeller K, Christ A, Knutson JF, Witt S, Murray KT, Tyler RS. Musical backgrounds, listening habits, and aesthetic enjoyment of adult cochlear implant recipients. *J Am Acad Audiol* 2000;11:390–406.
4. Looi V, She J. Music perception of cochlear implant users: a questionnaire, and its implications for a music training program. *Int J Audiol* 2010;49:116–28.
5. Migirov L, Kronenberg J, Henkin Y. Self-reported listening habits and enjoyment of music among adult cochlear implant recipients. *Ann Otol Rhinol Laryngol* 2009;118:350–5.
6. Fuller C, Free R, Maat B, Başkent D. Musical background not associated with self-perceived hearing performance or speech perception in postlingual cochlear-implant users. *J Acoust Soc Am* 2012; 132:1009–16.
7. McDermott HJ. Music perception with cochlear implants: a review. *Trends Amplif* 2004;8:49–82.
8. Wang S, Liu B, Dong R, et al. Music and lexical tone perception in chinese adult cochlear implant users. *Laryngoscope* 2012;122:1353–60.
9. Mitani C, Nakata T, Trehub SE, et al. Music recognition, music listening, and word recognition by deaf children with cochlear implants. *Ear Hear* 2007;28:29S–33S.
10. Jung KH, Won JH, Drennan WR, et al. Psychoacoustic performance and music and speech perception in prelingually deafened children with cochlear implants. *Audiol Neurootol* 2012;17:189–97.

11. Vongpaisal T, Trehub SE, Schellenberg EG. Identification of TV tunes by children with cochlear implants. *Music Perception* 2009; 27:17–24.

12. Nakata T, Trehub SE, Mitani C, Kanda Y, Shibasaki A, Schellenberg EG. Music recognition by Japanese children with cochlear implants. *J Physiol Anthropol Appl Human Sci* 2005;24:29–32.

13. Lazard DS, Vincent C, Venail F, et al. Pre-, per- and postoperative factors affecting performance of postlinguistically deaf adults using cochlear implants: a new conceptual model over time. *PLoS One* 2012;7:e48739.

14. Blamey P, Artieres F, Başkent D, et al. Factors affecting auditory performance of postlinguistically deaf adults using cochlear implants: an update with 2251 patients. *Audiol Neurootol* 2012;18:36–47.

15. Klop WM, Briaire JJ, Stiggelbout AM, Frijns JH. Cochlear implant outcomes and quality of life in adults with prelingual deafness. *Laryngoscope* 2007;117:1982–7.

16. Niparko JK, Tobey EA, Thal DJ, et al. Spoken language development in children following cochlear implantation. *JAMA* 2010;303:1498–1506.

17. Santarelli R, De Filippi R, Genovese E, Arslan E. Cochlear implantation outcome in prelingually deafened young adults. A speech perception study. *Audiol Neurootol* 2008;13:257–65.

18. Houston DM, Miyamoto RT. Effects of early auditory experience on word learning and speech perception in deaf children with cochlear implants: implications for sensitive periods of language development. *Otol Neurotol* 2010;31:1248–53.

19. De Raeve L. A longitudinal study on auditory perception and speech intelligibility in deaf children implanted younger than 18 months in comparison to those implanted at later ages. *Otol Neurotol* 2010; 31:1261–7.

20. Most T, Shrem H, Duvdevani I. Cochlear implantation in late-implanted adults with prelingual deafness. *Am J Otolaryngol* 2010; 31:418–23.

21. Yoshida H, Kanda Y, Miyamoto I, Fukuda T, Takahashi H. Cochlear implantation on prelingually deafened adults. *Auris Nasus Larynx* 2008;35:349–52.

22. Schramm D, Fitzpatrick E, Seguin C. Cochlear implantation for adolescents and adults with prelinguistic deafness. *Otol Neurotol* 2002;23:698–703.

23. Eisenberg LS. Use of the cochlear implant by the prelingually deaf. *Ann Otol Rhinol Laryngol Suppl* 1982;91(2 Pt 3):62–6.

24. Salimpoor VN, Benovoy M, Larcher K, Dagher A, Zatorre RJ. Anatomically distinct dopamine release during anticipation and experience of peak emotion to music. *Nat Neurosci* 2011;14:257–62.

25. Hilliard RE. The effects of music therapy on the quality and length of life of people diagnosed with terminal cancer. *J Music Ther* 2003;40:113–37.

26. Lassaletta L, Castro A, Bastarrica M, et al. Does music perception have an impact on quality of life following cochlear implantation? *Acta Otolaryngol* 2007;127:682–6.

27. Lassaletta L, Castro A, Bastarrica M, et al. Musical perception and enjoyment in post-lingual patients with cochlear implants]. *Acta Otorrinolaringol Esp* 2008;59:228–34.

28. Goorhuis-Brouwer SM, Schaerlaekens AM, eds. *Handbook of Language Development, Language Pathology, and Language Therapy in Dutch-Speaking Children*. 2nd ed. Utrecht, The Netherlands: De Tijdstroom; 2000.

29. Hinderink JB, Krabbe PF, Van Den Broek P. Development and application of a health-related quality-of-life instrument for adults with cochlear implants: the Nijmegen cochlear implant questionnaire. *Otolaryngol Head Neck Surg* 2000;123:756–65.

30. Coelho DH, Hammerschlag PE, Bat-Chava Y, Kohan D. Psychometric validity of the Cochlear Implant Function Index (CIFI): a quality of life assessment tool for adult cochlear implant users. *Cochlear Implants Int* 2009;10:70–83.

31. Gatehouse S, Noble W. The Speech, Spatial and Qualities of Hearing Scale (SSQ). *Int J Audiol* 2004;43:85–99.

32. Bosman AJ, Smoorenburg GF. Intelligibility of Dutch CVC syllables and sentences for listeners with normal hearing and with three types of hearing impairment. *Audiology* 1995;34:260–84.

33. Trehub SE, Vongpaisal T, Nakata T. Music in the lives of deaf children with cochlear implants. *Ann N Y Acad Sci* 2009;1169:534–42.

34. Gfeller K, Jiang D, Oleson JJ, Driscoll V, Knutson JF. Temporal stability of music perception and appraisal scores of adult cochlear implant recipients. *J Am Acad Audiol* 2010;21:28–34.

35. Gfeller K, Oleson J, Knutson JF, Breheny P, Driscoll V, Olszewski C. Multivariate predictors of music perception and appraisal by adult cochlear implant users. *J Am Acad Audiol* 2008;19:120–34.

36. Kong YY, Deeks JM, Axon PR, Carlyon RP. Limits of temporal pitch in cochlear implants. *J Acoust Soc Am* 2009;125:1649–57.

37. Galvin JJ 3rd, Fu QJ, Nogaki G. Melodic contour identification by cochlear implant listeners. *Ear Hear.* 2007;28:302–19.

38. Galvin JJ 3rd, Fu QJ, Shannon RV. Melodic contour identification and music perception by cochlear implant users. *Ann N Y Acad Sci* 2009;1169:518–33.

39. Gfeller K, Olszewski C, Rychener M, et al. Recognition of ''real-world'' musical excerpts by cochlear implant recipients and normal-hearing adults. *Ear Hear* 2005;26:237–50.

40. Gfeller K, Witt S, Woodworth G, Mehr MA, Knutson J. Effects of frequency, instrumental family, and cochlear implant type on timbre recognition and appraisal. *Ann Otol Rhinol Laryngol* 2002;111:349–56.

41. Nimmons GL, Kang RS, Drennan WR, et al. Clinical assessment of music perception in cochlear implant listeners. *Otol Neurotol* 2008;29:149–55.

42. Luxford WM. Cochlear implant indications. *Am J Otol* 1989;10:95–8.

43. Dowell RC, Dettman SJ, Hill K, Winton E, Barker EJ, Clark GM. Speech perception outcomes in older children who use multichannel cochlear implants: older is not always poorer. *Ann Otol Rhinol Laryngol Suppl* 2002;189:97–101.

44. Waltzman SB, Roland JT Jr, Cohen NL. Delayed implantation in congenitally deaf children and adults. *Otol Neurotol* 2002;23:333–40.

45. Waltzman SB, Cohen NL. Implantation of patients with prelingual long-term deafness. *Ann Otol Rhinol Laryngol Suppl* 1999;177:84–7.