The effect of music on auditory perception in cochlear-implant users and normal-hearing listeners
Fuller, Christina

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Chapter 2

Music and quality of life in early-deafened late-implanted adult cochlear implant users

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ABSTRACT

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 four 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); 4) Speech, Spatial and Qualities of Hearing Scale (hearing ability). Complementary, behavioral word recognition in quiet tests (phoneme score) were completed.

Results: Twelve out of 20 (60%) 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 post-lingually 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 acoustical hearing. Overall, these positive findings may give extra support for implant candidacy of early-deafened individuals, but further studies should be conducted.

Keywords: Cochlear Implant, Early Deafened, Late Implanted Adults, Music Perception, Music enjoyment, Quality of Life
Music and quality of life in early-deafened late-implanted adult cochlear implant users

INTRODUCTION

Cochlear implants (CIs) restore hearing in severely deafened adults and children. Nowadays, the perception of speech in quiet is fairly good in post-lingually deafened CI users. Nevertheless, the perception of music is still inadequate and dissatisfactory in this population (Boucher and Bryden 1997; Drennan and Rubinstein 2008; Gfeller et al. 2000b; Fuller et al. 2012; Fuller et al. under revision; Looi and She 2010; Migirov, Kronenberg, and Henkin 2009). 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 to normal hearing (NH) listeners (Drennan and Rubinstein 2008; McDermott 2004; Wang et al. 2012). Interestingly, early-deafened, early-implanted (EDEI) young CI users report higher enjoyment of listening to music than post-lingually deafened adult CI users, even though the behaviorally measured ability of music perception in EDEI has been observed to be worse (Mitani et al. 2007; Jung et al. 2012; Vongpaisal, Trehub, and Schellenberg 2009). Based on the observations with EDEI population, early-deafened, late implanted (EDLI; late implantation defined as after the age of sixteen in the present study) CI users may also have a different appreciation of music than the post-lingually implanted group.

Despite a delay between the onset of deafness and the implantation, which has negative consequences for the speech perception outcome in general (Lazard et al. 2012; Blamey et al. 2013), and a potential deficit in language skills due to 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) (Mallinckrodt et al.; Klop et al. 2007; Niparko et al. 2010; Houston and Miyamoto 2010; Santarelli et al. 2008; De Raeve 2010; Most, Shrem, and Duvdevani 2010; Yoshida et al. 2008; Schramm, Fitzpatrick, and Séguin 2002). However, the benefit for enjoyment and perception of music in this group is mostly unknown. To the best of our knowledge, only two studies have examined the self-reported perception of music in EDLI, and both presented some limitations (Migirov, Kronenberg, and Henkin 2009; Eisenberg 1982). While both reported that EDLI CI users enjoy listening to music using their implant, in the study by Migirov et al. (2009) with nine pre-lingually deafened CI users the age at implantation was unknown and the study by Eisenberg with twelve CI users was published in the early days of the CIs in 1982. As the CI technology, surgical techniques, rehabilitation methods, as well as 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 states, to the degree that music therapies can positively influence QoL (Salimpoor et al. 2011; Hilliard 2003). 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 or not 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 (Fuller et al. 2012; Fuller et al. under revision; Lassaletta et al. 2007; Lassaletta et al. 2008). 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 two 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. We first hypothesized that EDLI CI users would enjoy listening to music, similar to EDEI CI users, but unlike the post-lingually 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 post-lingually deafened CI users (Fuller et al. 2012; Fuller et al. under revision; Lassaletta et al. 2007).

MATERIALS AND METHODS

Study population

The inclusion criteria for participation, based on (Mallinckrodt et al.; Klop et al. 2007; Goorhuis-Brouwer and Schaerlaekens 2000), were: severe hearing loss at least since preschool (onset six years of age or earlier), implanted at 16 years of age or later, and more than one year of CI-experience. The criterion sixteen years or later was picked to assure 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. (2012), 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 six or earlier. The demographics of the 22 study participants are shown in Table I. The levels of education refer to the highest completed educational level: low refers to elementary school only; middle refers to middle school or higher; 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 (Gfeller et al. 2000b). The questionnaire
### TABLE I: Demographics of all study participants. N refers to the number of participants in this and following tables and figures.

<table>
<thead>
<tr>
<th>All participants</th>
<th>Number</th>
<th>Mean (Standard deviation)</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td></td>
<td>47.4 ± 15.0</td>
<td>19-68</td>
</tr>
<tr>
<td>Age at onset of severe hearing loss (y)*</td>
<td></td>
<td>0.7±1.3</td>
<td>0-4</td>
</tr>
<tr>
<td>Age at fitting of first hearing aid (y)*</td>
<td></td>
<td>2.5±1.5</td>
<td>0-8</td>
</tr>
<tr>
<td>Age at implantation (y)</td>
<td></td>
<td>41.2±14.3</td>
<td>17-63</td>
</tr>
<tr>
<td>Level of education</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Higher</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Deaf school attendance</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sign language school</td>
<td></td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Aural communication/sign language school</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Aural/oral school</td>
<td></td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Duration of CI use (y)*</td>
<td></td>
<td>5.7±3.3</td>
<td>1-10</td>
</tr>
<tr>
<td>CI use per day (h)*</td>
<td></td>
<td>14.2 ± 4.2</td>
<td>6-24</td>
</tr>
<tr>
<td>Implant type</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI24R CA*</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI24R k*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI24RE CA*</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CI24R CS*</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HiRes90K Helix*</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speech processor type (no.)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Esprit3G*</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Freedom*</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nucleus 5*</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harmony*</td>
<td>5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a Cochlear Corp., Englewood, Australia device. ACE speech strategy. b Advanced Bionics Corp., California, USA device. HiRes speech strategy. y= years. h=hours. * Based on patient reports
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. The DMBQ has three parts that measure: satisfaction with listening to music, self-perceived 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 three option single question: little or no satisfaction with listening to music; the sound of music is okay or improving over time; 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 seven visual analog scales (VASs) with fourteen 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 seven 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:

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 six 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 six 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 (Hinderink, Krabbe, and Van Den Broek 2000). The questionnaire is composed of three categories with six domains: Physical functioning: sound perception-basic, sound perception-advanced, speech production; Social functioning: activity, social functioning; Psychological functioning: self-esteem. The six domains of the NCIQ include ten statements with a five-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 six 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 (Coelho et al. 2009). 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 five 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 eight out of 22 (36%) 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 (Gatehouse and Noble 2004). 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 three domains: Speech, Spatial and Qualities. The self-perceived everyday hearing ability is rated with a score between 0 (least) to 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 post-implantation outpatient visits as a measure of speech perception (Bosman and Smoorenburg 1995). 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 twelve 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 (two tailed) was considered significant.

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

![FIGURE 1. The satisfaction with listening to music in 3 categories of the DMBQ in 20 CI users.](image)

Self-perceived quality of music
Figure II 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 to 100), with standard deviations ranging from 23 to 30. The total score was on the positive side of the scale (i.e., larger than 50) with a mean of 56 and a standard deviation of 19.
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Self-reported perception of the elements of music

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

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

FIGURE 3. The self-reported perception of the elements of music of DMBQ in 22 CI users.
Correlations between DMBQ measures and NCIQ, CIFI and SSQ

Table II 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 to 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) 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 to 10, best hearing related functioning) with a mean of 4.4 in 16 CI 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 III 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.

**TABLE II**: Correlations between all DMBQ measures and the total scores of NCIQ (left column), CIFI (middle column) and SSQ (right column).

<table>
<thead>
<tr>
<th></th>
<th>NCIQ</th>
<th>CIFI</th>
<th>SSQ</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Satisfaction with listening to music</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-0.174</td>
<td>-0.311</td>
<td>0.470</td>
</tr>
<tr>
<td>p</td>
<td>0.462</td>
<td>0.182</td>
<td>0.090</td>
</tr>
<tr>
<td>N</td>
<td>20</td>
<td>20</td>
<td>14</td>
</tr>
<tr>
<td><strong>Self-perceived quality of music</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-0.007</td>
<td>-0.237</td>
<td>0.377</td>
</tr>
<tr>
<td>p</td>
<td>0.974</td>
<td>0.289</td>
<td>0.150</td>
</tr>
<tr>
<td>N</td>
<td>22</td>
<td>22</td>
<td>16</td>
</tr>
<tr>
<td><strong>Perception of the elements of music</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.179</td>
<td>0.079</td>
<td>0.371</td>
</tr>
<tr>
<td>p</td>
<td>0.427</td>
<td>0.727</td>
<td>0.157</td>
</tr>
<tr>
<td>N</td>
<td>22</td>
<td>22</td>
<td>16</td>
</tr>
</tbody>
</table>

**TABLE III**: Correlations between all DMBQ measures and the word recognition in quiet scores measured at 65 and 75 dB SPL.

<table>
<thead>
<tr>
<th></th>
<th>Word recognition 65 dB (%)</th>
<th>Word recognition 75 dB (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-perceived quality of music</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>-0.194</td>
<td>-0.050</td>
</tr>
<tr>
<td>p</td>
<td>0.425</td>
<td>0.843</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td><strong>Satisfaction with listening to music</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.107</td>
<td>-0.010</td>
</tr>
<tr>
<td>p</td>
<td>0.672</td>
<td>0.968</td>
</tr>
<tr>
<td>N</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td><strong>Perception of the elements of music</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>r</td>
<td>0.242</td>
<td>0.301</td>
</tr>
<tr>
<td>p</td>
<td>0.319</td>
<td>0.197</td>
</tr>
<tr>
<td>N</td>
<td>19</td>
<td>20</td>
</tr>
</tbody>
</table>
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 six years of age or younger, and who were implanted at 16 years of age or older. Due to the potentially negative factors, such as less-than complete language development due to early onset of hearing loss and a delay between the onset of severe hearing loss and implantation, this population has historically been not strong candidates for CI implantation. As a result, while 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 post-lingually deafened CI users (Boucher and Bryden 1997; Drennan and Rubinstein 2008; Gfeller et al. 2000b; Looi and She 2010; Migirov, Kronenberg, and Henkin 2009; Fuller et al. 2012), this group may enjoy music perception, based on previous studies with EDEI CI users. We had further hypothesized, based on post-lingual 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 recognition scores (Fuller et al. under revision; Lassaletta et al. 2007; Lassaletta et al. 2008).

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 (Migirov, Kronenberg, and Henkin 2009; Eisenberg 1982). However, both satisfaction and quality ratings within these populations are in contrast to the reports of post-lingually deafened CI users, who showed dissatisfaction and lack of enjoyment with music (Boucher and Bryden 1997; Drennan and Rubinstein 2008; Gfeller et al. 2000b; Fuller et al. 2012; Fuller et al. under revision; Looi and She 2010; Migirov, Kronenberg, and Henkin 2009). Several interpretations are possible for the differences observed in music appreciation by EDLI and post-lingually deafened CI users. Firstly, 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 acoustical 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, due to 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 (Mitani et al. 2007; Eisenberg 1982; Trehub, Vongpaisal, and Nakata 2009). Moreover, the additional benefit of the implant for music perception compared to 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 (Eisenberg 1982). Concluding, 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 post-lingually deafened CI users (Fuller et al. under revision). Post-lingually 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 post-lingually deafened CI users, which show rhythm to be perceived best and melodies worst (Gfeller et al. 2010; Gfeller et al. 2008; Kong et al. 2009; Galvin, Fu, and Nogaki 2007; Galvin, Fu, and Shannon 2009; Gfeller et al. 2005; Nimmons et al. 2008). Based on these findings in post-lingually 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 behavioural perception of music of EDLI CI users has not been studied yet, we might, with some caution, conclude on the basis of the comparison with post-lingually deafened CI users and the findings of our study, that the self-reported perception of the elements of music of EDLI CI user may not be in accordance with the expected behavioural scores. Again this may be explained by a possibly different interpretation of rhythm or melody in EDLI CI users compared to post-lingually deafened based on different reference points. To gain more insight in the differences between early and post-lingually 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 post-lingually deafened CI users (Fuller et al. under revision; Lassaletta et al. 2007; Lassaletta et al. 2008), 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 post-lingually 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 above. 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. (in revision) did show such correlations in 52 and 98 post-lingually 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, both subjectively and behaviorally tested.

CONCLUSION

Concluding, overall results of the study showed that EDLI CI users enjoy the 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 (Luxford 1989). In the last decade, however, while the outcomes in EDLI CI users tend to be poorer for speech perception compared to EDEI, an improvement in speech perception due to CIs has consistently been shown with this population (Mallinckrodt et al. ; Klop et al. 2007; Schramm, Fitzpatrick, and Séguin 2002; Dowell et al. 2002; Waltzman, Roland, and Cohen 2002; Waltzman and Cohen 1999). Complementing these earlier studies that showed a speech perception benefit, the present study showed high enjoyment and satisfaction with listening to music post-implantation. These new findings of the present study may give additional support for cochlear implant candidacy of (well-selected) early-deafened individuals.
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