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Original Article

Music appreciation and music listening in prelingual and postlingually deaf adult cochlear implant recipients

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Abstract

Objective: To explore the music appreciation of prelingually deaf adults using cochlear implants (CIs). *Design*: Cohort study. Adult CI recipients were recruited based on hearing history and asked to complete the University of Canterbury Music Listening Questionnaire (UCMLQ) to assess each individual's music listening and appreciation. Results were compared to previous responses to the UCMLQ from a large cohort of postlingually deaf CI recipients. *Study sample*: Fifteen prelingually deaf and 15 postlingually deaf adult cochlear implant recipients. *Results*: No significant differences were found between the prelingual and postlingual participants for amount of music listening or music listening enjoyment with their CI. Sound quality of common instruments was favourable for both groups, with no significant difference in the pleasantness/naturalness of instrument sounds between the groups. Prelingually deaf CI recipients rated themselves as significantly less able to follow a melody line and identify instrument styles compared to their postlingual peers. *Conclusions*: The results suggest that the pre- and postlingually deaf CI recipients demonstrate equivalent levels of music appreciation. This finding is of clinical importance, as CI clinicians should be actively encouraging all of their recipients to explore music listening as a part of their rehabilitation.

Key Words: Cochlear implant; hearing loss; music appreciation; adults

Introduction

Following the introduction of multichannel cochlear implants (CIs) in the early 1980s, CIs have become the treatment option of choice for individuals with severe-to-profound sensorineural hearing loss (HL). Modern cochlear implant (CI) systems have proven to be successful in providing a significant auditory benefit, enabling patients improved access to sound and greater open-set speech perception. Research has shown that adults with an acquired, or postlingual (PostL) HL have the potential to achieve significant improvements in their speech perception performance with a CI (Dowell, 2005; Leigh et al, 2010, 2016). Outcomes are more variable with prelingually deaf (PreL) adult CI recipients (i.e. those with a severe to profound HL before the age of three), with this population being highly diverse in areas such as aetiology and mode of communication. Expectations for these patients may be limited to environmental sound awareness and assistance with lip-reading in some cases. While studies have shown that a significant speech perception benefit is possible with a PreL onset of HL, they have also demonstrated that open-set speech recognition post-implant tends to be inferior to those with a PostL onset of HL (Kaplan et al, 2003; Santarelli et al, 2008). Despite differences in their post-operative outcomes, both PreL and PostL adult CI recipients have been shown to have a significant quality of life improvement following implantation (Palmer et al, 1999; Kaplan et al, 2003; Hawthorne et al, 2004).

The fundamental difference between the PreL and PostL populations is the presence of a significant HL at an early age. The literature has shown that outcomes for CI recipients are greatly influenced by the effect of auditory deprivation, and suggest that prolonged periods of auditory deprivation at a young age causes degeneration of the auditory system. This may prevent appropriate maturation of language processing areas within the auditory cortex as a result of failure to develop normally (Kral et al, 2001). This is due to the developing auditory cortex being highly plastic and more capable of change and reorganization than when compared to an adult auditory cortex, a property which decreases with age (Ruben & Rapin, 1980). This concept has been supported by a study by Sharma et al (2002) who showed that cortical waveforms of children implanted prior to age 3.5 were age-appropriate, whereas those children with auditory deprivation of more than seven years demonstrated abnormal and delayed cortical responses.

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Abbreviations

GLM	General Linear Model
HL	Hearing loss
PostL	Postlingual
PreL	Prelingual
UCMLQ	University of Canterbury Music Listening Questionnaire

These studies highlight reasons why individuals with a PreL HL who receive a CI as an adult may not attain the same level of auditory skills with their CI as those recipients with an acquired HL.

While implant recipients with a PostL HL tend to achieve good speech perception outcomes with a CI, it is generally accepted that adults using CIs achieve poor music perception and music appreciation compared to adults with normal hearing (McDermott, 2004). It is thought that much of this can be attributed to poor pitch perception, given that the ability to resolve and discriminate between different pitches is necessary for the appreciation of melody and harmony. Music is a highly complex signal characterized by various perceptual attributes that can be varied independently, including pitch, rhythm, and timbre (Pierce, 1983; Drennan & Rubinstein, 2008; Levitin & Tirovolas, 2009).

From a CI clinician's point of view, it is the individual's music appreciation and music listening (rather than perceptual accuracy) that is of greatest consequence as this represents a functional real-world measure of a person's experience with music. Appreciation and enjoyment of music is reportedly poor for PostL CI recipients, though there is limited knowledge on the music appreciation of PreL recipients (Gfeller et al, 2000a). Studies examining music appreciation in PostL recipients have found a decrease in music listening habits from pre- to post-implant, with varying levels of enjoyment reported by the individuals (Gfeller et al, 2000a,b; Looi & She, 2010). On the positive side, some comments from participants of the various studies highlight additional quality of life gains from 'getting music back'. While there have been limited studies on the music appreciation of implanted adults with a PreL onset of HL, Eisenberg (1982) provided some early commentary on the outcomes of PreL CI users. The study reported that the PreL participants found music to be enjoyable and noted that 'in some cases, music has been a major motivating factor behind the acceptance of the implant' (page 65). The author proposed that the reason for increased enjoyment in this group compared to PostL recipients is that knowledge of music for a PreL person is simply rhythm and intensity cues via a hearing aid pre-implant. These recipients have no auditory template of what music 'should' sound like and hence no auditory expectations. The CI maintains the structural integrity the PreL individual is used to, and provides additional information they could not otherwise obtain.

To address the paucity of data related to music outcomes for PreL adult CI recipients, this study aims to explore the music perception and appreciation in this group of CI recipients using current, commercially available CIs. These results will be compared to a group of PostL adult CI recipients and clinical implications will be discussed. Results from the PostL group will then be compared to the PostL CI recipients in Looi and She (2010), which used the same questionnaire.

Methods

Participants

Thirty adult CI recipients from the Melbourne Cochlear Implant Clinic were recruited and asked to complete a questionnaire assessing their music listening and music appreciation. Fifteen participants had a PostL onset of HL and 15 had a PreL onset of HL. The participants were recruited on a volunteer basis from a database of patients at the Royal Victorian Eye & Ear Hospital (RVEEH) across 2012 and 2014, under RVEEH Human Research and Ethics Committee projects 12/1064H and 09/922H.

All participants had received either a Nucleus 22, Nucleus 24, Nucleus Freedom, Nucleus 5, or Nucleus CI422 cochlear implant at least three months prior to testing. All participants used the Advanced Combination Encoder (ACE) speech processing strategy with either a Freedom, CP810, or CP910 sound processor, with the exception of one subject in the PreL group who had a Nucleus 22 implant and used the SPEAK processing strategy.

Table 1 displays the demographics of both the PostL and PreL groups. Aetiology of HL was varied amongst participants, with the dominant aetiology for the PostL group listed as 'unknown' as compared to 'familial' for PreL. All of the PostL participants used a hearing device in their other ear (66.7% bimodal, 33.3% bilateral CI users). Twenty per-cent of the PreL group did not use any device in their contralateral ear, the remaining 12 participant were both bimodal (53.3%) and bilateral CI (26.7%).

Materials

A modified version of The University of Canterbury Music Listening Questionnaire (UCMLQ-modified), developed by Looi and She (2010) was administered to all participants in the study. Participants were given the questionnaire to take home to complete in their own time, and provided with a postage-paid envelope to return to the researchers. As per the methodology in the Looi and She (2010) study, the respondents were not presented with musical stimuli and had to rely on their own memory and knowledge of music. The modified version of the questionnaire is slightly shorter, with only three of the original seven sections included (See Appendix A). The 31 questions in the questionnaire are divided into three sections: (1) Music listening and musical background; (2)

Table 1. Demographics of the pre- and postlingual HL groups who participated in the present study.

	Postlingual group (n = 15)		*Prelingual group (n = 15)*	
	Mean	***Range***	***Mean***	***Range***
Age	64.41 years	43.35–76.53	51.19 years	33.79–67.23
Age at implantation	60.89 years	40.33–71.71	47.29 years	30.08–63.57
Time since implantation	3.53 years	0.54–8.21	3.9 years	1.52–16.2
Duration of severe HL	11.73 years	1–30	43.13 years	11–63
Best pre-op CVC phoneme score (%)	42%	11–83%	14%	0-76%
Best post-op CVC phoneme score (%)	84%	61–96%	48%	12–93%

Sound quality, and (3) Musical styles. Responses to the various questions were recorded using 100-point visual analogue scales and participants were encouraged to provide further comments and details as required. For a complete description of the UCMLQ, refer to Looi and She (2010).

Responses obtained from the questionnaire were compared to speech perception results for each participant. Speech perception was assessed with consonant-nucleus-consonant (CNC) monosyllabic word test scored for phonemes (Peterson & Lehiste, 1962), and City University of New York open set sentences presented in eight-talker babble with a signal to noise ratio of +10 dB (Boothroyd et al, 1985). Stimuli were presented in a sound-treated room, via a loudspeaker, at 65 dB SPL. The recordings were spoken by a native Australian English speaker. Speech perception scores were obtained in the 'best aided' condition, as it most accurately represents the individual's listening prior to implantation. The 'best aided' post-operative speech perception result obtained from each participant was used for the post-implant analysis; the highest score achieved in any of the 3-, 12- or 24-month post-activation visits.

Statistical analysis

Statistical analysis was conducted using Minitab statistical software version 17 (Minitab Inc, 2014). Comparisons between groups were made by analysis of variance (ANOVA) using a general linear model and using post-hoc t-tests. Correlation analyses were used to assess predictive variables for music enjoyment levels. Responses from the PostL group were compared to the responses from the PreL group, to ascertain if there were any differences in music listening and music appreciation between the two groups. Results from the PostL group were then compared to the one hundred recipients in Looi and She (2010). An α level of 0.05 was used to determine statistical significance in all analyses.

Results

Group comparisons

Demographics

Age at implantation, duration of severe-to-profound HL, and best post-operative speech perception (phonemes and sentences in noise) were analysed between groups to assess differences in group demographics. The PreL group were significantly younger than the PostL group (PreL M = 50.5 years, PostL M = 64.0 years, $p = 0.001$). As would be expected, the PreL group had a significantly longer duration of severe-to-profound HL than the PostL group (PreL M = 43.1 years, PostL M = 11.7 years, $p < 0.001$). The PreL group had a significantly lower post-operative speech perception for phonemes and sentences in noise compared to the PostL group (Phonemes: PreL M = 48.3%, PostL M = 84.1%, $p < 0.001$; Sentences in noise: PreL M = 25.7%, PostL M = 83.0%, $p < 0.001$).

Music listening & music enjoyment

The UCMLQ asked respondents to rate the amount of music listening they undertook and their music enjoyment levels at two separate time points: 'just prior to getting their CI' and 'now, with their CI'. Looking specifically at music listening, there was no significant difference between the groups for amount of music listening in the time just prior to getting a CI ($p = 0.195$) or for amount of music listening now with a CI ($p = 0.527$). For both time points, the mean amount of time rating was subjectively quantified as 'sometimes' along the visual analogue scale.

For music listening enjoyment, there was again no significant difference in ratings between the groups either for the time just prior to getting a CI ($p = 0.859$) or for enjoyment of music with a CI ($p = 0.546$). Music listening enjoyment ratings for both groups were quantified as slightly below neutral before the CI and slightly above neutral with a CI. The mean values and standard deviations for both music listening and music enjoyment are listed in Table 2.

Question 15 of the UCLMLQ specifically asked the respondents to report how much the CI has impacted their overall enjoyment of music, from greatly decreased (0) to greatly increased (10), with a score of '5' representing no effect. There was no significant difference between the groups for CI impact on music listening enjoyment, however the PreL group trended towards CI providing greater enjoyment (PreL M = 7.19, SD = 2.88; PostL M = 5.63, SD = 2.29; $p = 0.113$).

Correlation analyses were performed to assess music enjoyment with their CI against age, duration of severe-to-profound HL pre-implant, amount of music listening with their CI, and best post-operative speech perception (phonemes and sentences in noise). No significant correlations were found for the PostL group, however the PreL group showed large significant correlations for level of music enjoyment with both duration of loss ($r = 0.612$, $p = 0.015$), and amount of music listening ($r = 0.814$, $p < 0.001$). The correlation analysis of music enjoyment with amount of music listening for both groups is shown in Figure 1.

Sound quality of common musical instruments

The UCLMQ recorded the implant recipients' judgements of sound quality for various musical instruments and singers. Sound quality ratings were made on scales where a value of 5 represented the 'as expected' value, referring to how the recipient would 'expect' it to sound to a person with normal hearing, and values of '0' and '10' represented the greatest deviation away from the 'expected' sound. Accordingly, one-sample t-tests were used to determine which

Table 2. Mean values and standard deviation for amount of time spent listening to music, and music listening enjoyment at different time intervals between the 15 prelingual and 15 postlingual respondents using the UCMLQ questionnaire. Noted in italics are the normative data values provided from the 100 postlingually deaf respondents from Looi & She (2010) for comparison.

		Pre HL	*In the time just prior to getting a CI*	*Now, with a CI*
Amount of time spent listening to	PostL	M = 7.51 (SD = 2.23)	M = 4.40 (SD = 3.19)	M = 5.20 (SD = 2.80)
Music (0 = never; 5 = sometimes;	PreL	N/A	M = 5.68 (SD = 1.81)	M = 5.91 (SD = 3.27)
10 = very often)	*Norms*	*M = 7.20 (SD = 2.93)*	*M = 3.30 (SD = 3.12)*	*M = 4.58 (SD = 3.34)*
Music listening enjoyment	PostL	M = 8.30 (SD = 2.63)	M = 4.77 (SD = 3.66)	M = 6.27 (SD = 2.58)
(0 = did not enjoy at all;	PreL	N/A	M = 4.57 (SD = 2.27)	M = 6.89 (SD = 2.97)
5 = neutral; 10 = greatly enjoyed)	*Norms*	*M = 8.37 (SD = 2.17)*	*M = 3.71 (SD = 3.28)*	*M = 5.15 (SD = 3.61)*

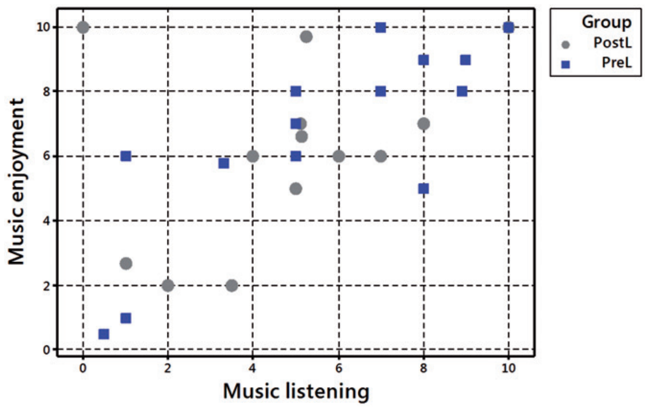

Figure 1. Music listening enjoyment with the CI versus amount of music listening with the CI. There was no significant correlation found for the postlingual group ($r = 0.401$, $p = 0.138$) however a significant relationship was found for the prelingually deaf group ($r = 0.814$, $p < 0.001$).

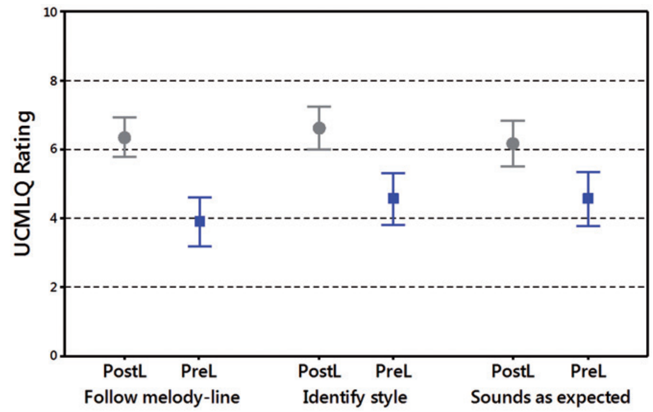

Figure 2. Interval plot for sound quality ratings of ability to follow the melody line, ability to identify musical style, and sounding as expected to normal hearing. Mean UCMLQ ratings are plotted, bars represent 95% confidence intervals. Individual standard deviations were used to calculate the intervals.The prelingual group rated significantly lower on all of these scales compared to the postlingual group.

instruments sounded emptier or fuller, tinnier or richer etc., than expected. While mean ratings for both groups trended around the expected value of 5, the PostL group rated the piano as significantly tinnier than expected (M = 4.21, $p = 0.008$), and rated male singers to be significantly rougher than expected (M = 4.17, $p = 0.029$).

For the ratings of 'pleasantness' and 'naturalness', a visual analog scale was used where a rating of '10' represented the most favourable response, and '0' represented the least favourable response. The ratings of 'pleasantness' and 'naturalness' for the whole group were highly correlated (p $\leq$0.001) for each instrument/singer, therefore they were combined for further analyses.

Using a general lineal model (GLM) ANOVA for the combined 'pleasant and natural' ratings, there was no significant difference for the between-subject factor of group ($p = 0.274$) or the within-subject factor of instrument ($p = 0.375$), and there was no significant interaction. The PreL group had a mean 'pleasant and natural' rating of 7.09 for all instruments combined (SD = 2.46), compared to the PostL group who had a mean 'pleasant and natural' rating of 7.34 (SD = 2.15).

Musical styles

As per the procedure described in Looi and She (2010), ratings from the UCMLQ for the musical styles questions were combined to provide an overview of the responses in addition to being analysed individually. Table 3 describes the results of a GLM ANOVA for the combined ratings in addition to the individual musical styles (between-subject factor: group; within-subject factor: style). There were no significant style effects or interactions. Significant group effects were found for the combined ratings, in addition to the following individual items: 'can never follow the melody line - can always follow the melody line', 'can never identify style - can always identify style' and 'doesn't sound like normal - sounds like normal'. In all of these scales, the PreL group had significantly lower mean ratings than the PostL group (see Figure 2).

Postlingual group compared to norms

Demographics

Age at test and duration of severe-to-profound HL were analysed between the PostL group and the large group of PostL normative data (norms) from Looi and She (2010). There was no significant difference in age at test between the groups (PostL M = 64.0 years, norms M = 61.9 years, $p = 0.503$). There was no significant difference in duration of severe-to-profound loss between the groups (PostL M = 11.7 years, norms M = 7.9 years, $p = 0.170$).

Music listening & music enjoyment

To assess the representativeness of the participants in this study, results for PostL were compared to the music listening and enjoyment ratings from Looi and She (2010) participants.

For amount of music listening, it was found that there was no significant difference between the PostL group and the norms at any of the time points of before HL ($p = 0.640$), just prior to getting a CI ($p = 0.229$), or for amount of music listening now with a CI ($p = 0.448$). The mean values and standard deviations are listed in Table 2.

For music listening enjoyment, it was found that there was no significant difference in ratings between the PostL group and the norms in any of the time points of before HL ($p = 0.922$), just prior to getting a CI ($p = 0.305$), or for enjoyment of music with a CI ($p = 0.155$). As for amount of music listening, the mean rating values and standard deviations are listed in Table 2. A graphical comparison of music listening and enjoyment comparing the norms to the PreL and PostL groups from the present study can be found in Figure 3.

Sound quality of common musical instruments

The PostL group's judgements of sound quality for various musical instruments and singers were compared to those from the Looi and She (2010) data. Using a GLM ANOVA for the combined sound quality ratings across all instruments, there was a significant difference found for the between-subject factor of group ($p = 0.046$), but not the within-subject factor of instrument ($p = 0.802$), and there was no significant interaction. The PostL group had a mean sound quality rating of 4.62 across all the

Table 3. Musical style ratings, results of a general linear model ANOVA analysis.

	n[a]	*Group effect*c	*Style effect*	*Group by style interaction effect*
Combined ratingsb	108	$\mathbf{p<0.001}$	$p=0.962$	$p=0.935$
Unpleasant-Pleasant	106	$p=0.243$	$p=0.639$	$p=0.963$
Complexity	105	$p=0.324$	$p=0.242$	$p=0.427$
Can never follow the melody line - Can always follow the melody line	108	$\mathbf{p<0.001}$	$p=0.890$	$p=0.925$
Can never identify style - Can always identify style	108	$\mathbf{p<0.001}$	$p=0.960$	$p=0.647$
Doesn't sound like normal - Sounds like normal	105	$\mathbf{p=0.002}$	$p=0.867$	$p=0.955$

[a]'*n*' refers to the total number of ratings for that particular scale across the six musical styles in the UCMLQ. The 'n' may differ between the scales as not all respondents provided ratings for all scales, and not all respondents were familiar with all styles. [b]An average of all ratings except the complexity ratings. [c]Prelingual group compared to postlingual group.

instruments and, as discussed previously, most ratings were not significantly different to the expected value of '5'. In comparison, the group from the Looi and She cohort reported a mean sound quality rating of 4.39 across all instruments with more than half the scales being significantly different to the expected value.

Results from a GLM ANOVA for the combined 'pleasant and natural' ratings indicated a significant difference for the between-subject factor of group ($p<0.001$), but not for the within-subject factor of instrument ($p=0.651$), with no significant interaction. The PostL group had a mean 'pleasant and natural' rating of 7.34 for all instruments combined, compared to the group from Looi and She whose mean rating was 5.45.

Musical styles

As above, ratings from the UCMLQ for the musical styles questions were combined to provide an overview of the responses for the PostL group and the group from Looi and She (2010). A GLM ANOVA using the between-subject factor of group, and within-subject factor of style showed no significant style effects or interactions. However, significant group effects were found for the combined ratings, in addition to the individual scales of 'unpleasant-pleasant', 'can never follow the melody line - can always follow the melody line', 'can never identify style - can always identify style' and 'doesn't sound like normal sounds - like normal' ($p \leq 0.001$). In all of these scales, the PostL group had significantly higher mean ratings than the Looi and She group.

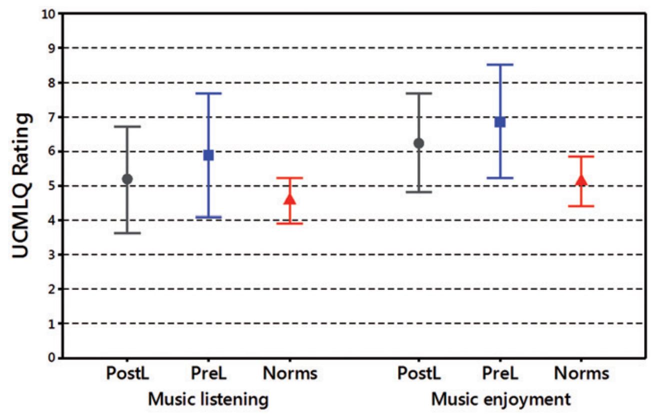

Figure 3. A comparison of the UCMLQ ratings for amount of music listening and music enjoyment ?now, with a CI? for the postlingual, prelingual, and normative data groups. Mean UCMLQ ratings are plotted, bars represent 95% confidence intervals. Individual standard deviations were used to calculate the intervals. Question was rated between 0 and 10, where 0 = never / did not enjoy at all; 5 = sometimes/neutral; 10 = very often/greatly enjoyed.

Discussion

The data from the present study demonstrates that PreL and PostL adult CI recipients show equivalent music listening and music enjoyment post-implantation. There were, however, clear differences observed in the PreL group's ratings of their ability to follow a melody or identify a musical style compared to the PostL group, which underlines the theory that music perception and music appreciation should be considered separately. Additionally, the comparison of the PostL data to the normative data from the Looi and She (2010) study showed no significant differences in the key areas of music listening and music enjoyment, validating the data from the current study.

It must be noted that while levels of music listening and music enjoyment remained the same between the current PostL group and the comparison group from Looi and She (2010), there were notably higher ratings of sound quality, pleasantness/naturalness of instruments, and more favourable perceptions of various musical styles in the contemporary PostL group. As data for the Looi and She study was collected in 2009, this may suggest that improvements in sound processing technology, greater awareness of how to improve music appreciation post-implant, and/or ongoing research in the area has led to improvements in the quality of musical sound perceived by CI recipients. Alternatively given the size difference between the cohorts, the respondents in the present study may have more favourable music appreciation than compared to the general population. Further research with large groups is warranted in this area to address differences seen in the quality and pleasantness ratings.

Although not statistically significant, there was a trend for the PreL group to rate their enjoyment of music post CI as slightly higher than the PostL group. A power analysis revealed for this group size, if the difference between the group ratings was two units there is a 72% of detecting is. Hence the lack of a significant relationship is potentially due to the small number of participants. The observed trend may be due to the extra information available to the PreL recipients through the CI that was not available via their hearing aids, supporting the theory of Eisenberg (1982) in her early study of prelingually deafened adults. PostL CI recipients store a normal representation of musical memory in their brain, and it has been shown that the CI is unable to portray all aspects of music accurately, ultimately leading to some dissatisfaction with the musical sound quality (McDermott, 2004; Gfeller et al, 2000a).

That is, the expectation and knowledge of what music should sound like is not met with the CI. PreL CI recipients, on the other hand, have probably never experienced music in its entirety before, and certainly not with 'normal' acoustic hearing; hence they do not have this auditory memory and expectation of the sound. Their auditory knowledge of music is the sound heard pre-implant with hearing aids, which probably only provided low frequency information for those with severe-to-profound sensorineural HL. Thus, the addition of high-frequency information provided by the CI may add to their music listening experience. As a comparison, PreL children who receive CIs also have no 'normal' construct of music through acoustic hearing, however they have been shown to enjoy music (Nakata et al, 2005; Vongpaisal et al, 2006). A significant percentage of children with CIs are enrolled in formal musical instruction, demonstrating a high level of engagement with music (Gfeller et al, 1998).

Similar to the results from Looi and She (2010), this current study also showed no significant correlation between the (1) time spent listening to music, or (2) levels of enjoyment, to the length of implant use, length of severe to profound deafness, or speech perception in quiet. Looi and She did, however, find a correlation between the time spent listening to music and speech perception in noise, with those subjects with better speech in noise scores also reporting higher levels of music listening and enjoyment. No significant correlation was found with phoneme perception or sentence in noise perception and music enjoyment in this study, with either the PreL or PostL participants.

In the present study, when assessing the area of sound quality of common musical instruments, it was found that the participants in the study provided generally favourable responses irrespective of group. There were no significant differences found in pleasantness and naturalness between groups, and individual musical instruments were generally rated to sound 'as they would expect it to sound to someone with normal hearing'. By comparison, subjects in Looi and She (2010) rated all instruments except the drum kit as 'emptier', and more than half as 'tinnier' than they would have expected them to sound to a person with normal hearing. It is possible that smaller subject numbers coupled with larger variability in the present study obscured these differences noted in the Looi and She study. Indeed when assessing the power of these analyses, the is a 72% chance of detecting a change of two units with the present study group compared to a 99.6% chance in the Looi and She (2010) group of 100 participants. In addition, the participants who volunteered for the present study may have had greater affinity for music when compared to the large group in the comparison study and been more likely to rate the sound of instruments 'as expected'.

When analysing at the results for musical styles, while there was no significant difference between the groups for pleasantness or complexity of the styles, the PreL group demonstrated significantly lower mean ratings than the PostL group for ability to follow the melody line, ability to identify the style, and whether the style sounds like normal. Whilst it is recognized that this was subjectively reported via the UCMLQ, this finding potentially demonstrates a difference in the perceived ability that PreL and PostL CI recipients have of their music perception skills. Concepts such as 'melody', 'music style', 'timbre', and even 'pitch' would be likely more abstract to PreL adults than to their PostL or normally-hearing peers, and their interpretation of these terms may be different. It is important to note that despite this difference in perceived music listening ability, there were no differences between the groups in their enjoyment of music.

In addition to the fact that PreL adults have no 'normal hearing' auditory template for musical stimuli and hence potentially a different expectation of what music should sound like, the finding that PreL deafened adults rated music to be equally enjoyable as the PostL deafened adults may be related to central processes. Although the auditory cortex is central to the processing of musical sounds, functional MRI studies of normally-hearing adults have provided evidence that other brain structures play a role in analysing the music signal (Sakai et al, 1999; Tramo, 2001; Limb, 2006). For example, the motor or pre-motor areas of the brain would likely be activated as a person taps their fingers along to a musical beat or plans their dance moves to a song. Emotional centres of the brain such as the ventral striatum, midbrain, amygdala, orbitofrontal cortex, and ventral medial prefrontal cortex have also been shown to be activated when listeners hear particularly moving music (Limb, 2006). Music shares some of the features of language, such as vocabulary, structure, temporal and spectral properties, so while the processing of music is done in part by the same neural substrates that process speech, it is also done by areas of the brain which are traditionally responsible for the processing of motor and/or emotional responses. Further research by Limb et al (2010) using positron emission tomography scans showed that PostL adult CI listeners' tended to use more non-traditional brain areas in auditory tasks than normally-hearing listeners—e.g. the temporal and prefrontal cortices, and supplemental motor areas. Further, CI users showed greater intensity and extent of brain activation in all conditions than NH adults, with more non-auditory areas activated for music than speech. Should this difference be noted when comparing normally-hearing adults to PostL deafened adults, it would be feasible that a similar difference is noted between PreL and PostL deafened adults, with even more non-auditory areas being activated for the former group when listening to auditory stimuli.

This may partially help to explain why PreL adult CI recipients, who usually have a poorer ability to process speech input than PostL deafened adults still find music to be equally enjoyable. While the auditory cortex of these subjects may not be able to interpret the lyrics of the music to the same extent as those CI recipients with a PostL HL, the activation of the emotional, and other non-auditory areas of the brain by a piece of music may still evoke an appreciation and enjoyment of music listening.

Comments from participants in published studies reflect socio-cultural aspects of music wherein individuals felt music provided opportunities for social engagement, a sense of belonging and involvement in life events such as weddings or holiday celebrations (Gfeller et al, 2000). Lassaletta et al (2007) showed significant positive correlations between music enjoyment levels and quality of life in CI recipients. Looi et al (2007) demonstrated an improvement in music satisfaction for implant recipients compared to individuals with a severe-to-profound deaf ear using a hearing aid, noting that 'some of the subjects commented they 'got more' of the sound with the CI,' and that the CI provided 'a 'broader picture' of the musical sounds with more detail' (page 61S). In the present study, it was found that there was no significant difference between the groups for the impact of the CI to their overall enjoyment of music, however some of the PreL participants made the following comments indicating a variety of experiences: 'I listen to the radio in the car all the time – something I was not able to do before'; 'listening to music is getting easier and more relaxed'; 'I'm still learning'; 'I can pick up variation in sounds, but never words nor type of instrument'. One PreL recipient commented that he watched subtitled music on youtube.com to train his music listening. Another commented that he had tried and had 'lost interest'' in music since his CI.

The small number of participants was a limiting factor for power in this study, and it is acknowledged that ratings were retrospectively made by all participants. Future research to explore the acute music quality ratings of PreL adults, and any change in these ratings pre-to-post implant is warranted, and would provide valuable information to this new research area.

In summary, the results of the present study suggest that the PreL and PostL adult CI populations demonstrate equivalent levels of music appreciation. This finding is of clinical importance, as CI clinicians should be actively encouraging all of their recipients to explore and persevere with music listening as a part of their rehabilitation. This is of particular importance for the PreL population, given a significant correlation was found between time spent listening to music and music listening enjoyment for this group. CI clinicians should be encouraging their patients to explore new music, different ways to listen, and explore the social aspect of music listening. Further, music may be a motivating reason for PreL deafened adults to get an implant, and expectations around music listening could be gauged pre-implant, and in the post-operative habilitation phase.

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