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

Fuller, Christina Diechina

Chapter 6

Musical background not associated with self-perceived hearing performance or speech perception in postlingual cochlear-implant users

Christina Fuller [1,2] Rolien Free [1,2] Bert Maat [1,2] and Deniz Başkent [1,2]

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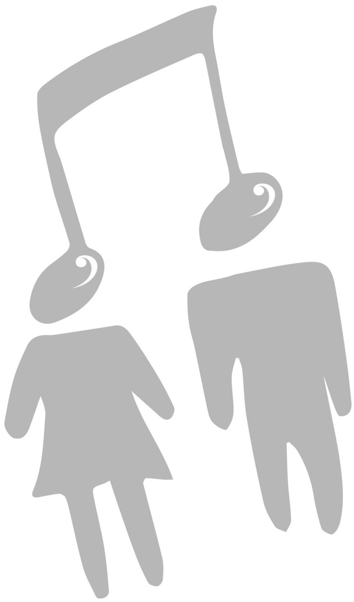

1 Department of Otorhinolaryngology/Head and Neck Surgery, University of Groningen, University Medical Center Groningen, Groningen, The Netherlands
2 Graduate School of Medical Sciences (Research School of Behavioural and Cognitive Neurosciences), University of Groningen, The Netherlands.

ABSTRACT

In normal-hearing listeners, musical background has been observed to change the sound representation in the auditory system and produce enhanced performance in some speech perception tests. Based on these observations, it has been hypothesized that musical background can influence sound and speech perception, and as an extension also the quality of life, by cochlear-implant users.

To test this hypothesis, this study explored musical background [using the Dutch Musical Background Questionnaire (DMBQ)], and self-perceived sound and speech perception and quality of life [using the Nijmegen Cochlear Implant Questionnaire (NCIQ) and the Speech Spatial and Qualities of Hearing Scale (SSQ)] in 98 postlingually deafened adult cochlear-implant recipients. In addition to self-perceived measures, speech perception scores (percentage of phonemes recognized in words presented in quiet) were obtained from patient records.

Self-perceived hearing performance was associated with objective speech perception. Forty-one respondents (44% of 94 respondents) indicated some form of formal musical training. Fifteen respondents (18% of 83 respondents) judged themselves as having musical training, experience, and knowledge. No association was observed between musical background (quantified by DMBQ), and self-perceived hearing-related performance or quality of life (quantified by NCIQ and SSQ), or speech perception in quiet.

INTRODUCTION

Cochlear implants (CIs) are prosthetic devices that restore hearing in profound deafness. Improvements in device design have produced good speech understanding in quiet, but speech perception in noise and enjoyment of music are still not satisfactory (Gfeller et al. 2000b; Leal et al. 2003; Mirza et al. 2003; Kong et al. 2004; McDermott 2004; Kong, Stickney, and Zeng 2005; Lassaletta et al. 2007; Lassaletta et al. 2008; Migirov, Kronenberg, and Henkin 2009; Looi and She 2010). Music is universal, as is language, and is considered the second most important sound processed by humans, after speech (Boucher and Bryden 1997). CI users also rank music, after speech perception, as the second most important acoustical stimulus in their lives (Drennan and Rubinstein 2008). Hence, the improvement of both perception or enjoyment of music can influence the quality of life (QoL) in CI users.

Exposure to music or musical training may also pose specific benefits for sound and speech perception. In normal-hearing (NH) listeners, for example, long-term musical experience can change the sound representation in the auditory system. Enhanced subcortical and cortical representation of speech and brainstem encoding of linguistic pitch are observed with musicians (Musacchia, Strait, and Kraus 2008; Wong et al. 2007; Musacchia et al. 2007). These findings suggest that there may be a shared neural basis for music and language processing (Kraus and Chandrasekaran 2010). Perhaps as a result of this, long-term musically experienced NH adults understand speech in noise better than non-musicians do (Parbery-Clark et al. 2009; Parbery-Clark et al. 2011). Based on these studies with NH musicians, we have hypothesized that musical background might help CI recipients to have better hearing performance and/or speech perception than non-musically trained CI recipients, and thus may increase their health related quality of life (HRQoL).

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The effect of musical background on HRQoL and self-perceived hearing-related performance in CI users has been poorly investigated. The study by Lassaletta et al. (2007) is, to the best of our knowledge, the only study that has explored the correlation between musical background and QoL in CI recipients. Two questionnaires, one that evaluates the musical background and the other the QoL, were used in their study. The QoL questionnaire was the Glasgow Benefit Inventory (GBI), a generic questionnaire that measures the patient benefit after otolaryngological interventions and not of the health status per se (Robinson, Gatehouse, and Browning 1996). It is a post intervention questionnaire, not limited to audiological or otolaryngological use only that addresses the benefit after cochlear implantation surgery. In 52 post-lingually deafened CI users, no association between the musical background and the QoL was found. However, a possible reason for the lack of correlation could be the use of a generic patient benefit questionnaire, as this may not have been sufficiently sensitive to reflect hearing functionality-related effects. No analysis was done regarding speech perception measures.

In the present study, we have explored whether musical background has an effect on QoL in postlingually-deafened adult CI users, similar to the study by Lassaletta et al. (2007), but with a number of modifications. We have: 1) employed a larger CI population; 2) used one CI specific HRQoL questionnaire; 3) used one questionnaire specifically developed for hearing-impaired listeners and CI users to assess the self-perceived hearing-related performance, with components on sound and speech perception; 4) additionally analyzed speech perception scores.

MATERIALS AND METHODS

Study population

From the patients implanted and/or monitored at the University Medical Center Groningen (UMCG), 214 CI users were selected and sent the questionnaires based on: current age (older than 18 years), age at the onset of profound hearing loss (5 years or older) and more than one year of CI experience. To include as many patients as possible, etiology and speech perception performance were not used as inclusion criteria. Ninety-eight (46%) replies were received. No significant differences were shown between the respondents and the non-responders for age, CI experience and gender (T-test: t =-1.038, p = 0.301, t = -1,314 p= 0.191, Chi-square-test: χ^2 0.041, p =0.840, respectively). Among the respondents, one was a bilateral CI recipient. The other demographics of the study participants are shown in the first column of table I.

Dutch Musical Background Questionnaire

The Dutch Musical Background Questionnaire (DMBQ) is a modified and translated version of the Iowa Musical Background Questionnaire (IMBQ; Gfeller et al. (2000b)).[1] Only the first two measurements of the questionnaire assessing the musical background were used. The other parts of the questionnaire are not in the focus of this study as they consider the perception of music with the CI and were therefore excluded from this study.

The first measurement is a musical background score that quantifies formal musical training with questions in six categories: musical instrument lessons, singing lessons, participation in an ensemble, music lessons at elementary school, music lessons at middle school, and music appreciation classes. One point was awarded for each activity that was participated in. Different than the application by Gfeller et al. (2000b), the years of training were left out of the analysis, because many recipients did not know their years of education or were unclear in their answers. Thus, the total scores ranged from 0 (no formal musical training) to 6 (maximum formal musical training), calculated by adding points from all categories. Ninety-four out of 98 respondents completed this section.

The second measurement is a musical background score by self-report in which the respondents rated their musical training, knowledge and experience, in one five-response option question. Hence, each participant had one score varying from 0 (self-report of no

Table I: Demographics of all study participants (first column). The second and the third columns represent the formal musically trained respondents and the respondents without formal musical training based on the first DMBQ measure (N=94).

		Participants	**Formal musical training**	**No formal musical training**
		N = 98	N = 41	N = 53
Gender	Male	39 (40%)	13 (32%)	25 (47%)
	Female	59 (60%)	28 (68%)	28 (53%)
Age (y)		65.6 ± 11.9	61.4 ± 16.6	66.6 ± 11.0
Duration of impaired hearing (y)		37.9 ± 18.6	36.0 ± 19.8	37.0 ± 18.0
CI use since implantation (m)		65.7 ± 33.0	69.6 ± 29.8	64.6 ± 33.9
CI use per day (h)		15.0 ± 2.6	15.6 ± 2.8	15.0 ± 1.7
Education	Lower	13 (14%)	4 (10%)	8 (16%)
	Middle	67 (71%)	26 (65%)	39 (76%)
	Higher	14 (15%)	10 (25%)	4 (8%)
Implant type (no.)	CI22M[a]	1 (1%)	-	1 (2%)
	CI24R CA[a]	24 (24%)	9 (22%)	14 (26%)
	CI24R k[a]	3 (3%)	3 (7%)	-
	CI24RE CA[a]	27 (28%)	13 (32%)	13 (25%)
	CI24R CS[a]	19 (19%)	8 (20%)	11 (21%)
	HiRes90K Helix[b]	24 (24%)	8 (20%)	14 (26%)
Speech processor type (no.)	Esprit3G[a]	31 (32%)	14 (34%)	16 (30%)
	Freedom[a]	43 (44%)	19 (46%)	23 (43%)
	Harmony[b]	24 (24%)	8 (20%)	14 (27%)

a Cochlear Corp., Englewood, Australia device. ACE speech strategy.
b Advanced Bionics Corp., California, USA device. HiRes speech strategy

background) to 4 (self-report of maximum background). Eighty-three out of 98 respondents completed this section.

Nijmegen Cochlear Implant Questionnaire

The Nijmegen Cochlear Implant Questionnaire (NCIQ) is a validated CI-specific HRQoL instrument (Lassaletta et al. 2007; Hinderink, Krabbe, and Van Den Broek 2000). It evaluates not only the self-perceived hearing performance, but also the effects of implantation on the social and psychological functioning and is therefore not a measure of patient benefit, but of HRQoL. The questionnaire has six domains in three categories: physical functioning (sound perception-basic, sound perception-advanced, speech production), social functioning (activity, social functioning) and psychological functioning (self-esteem). The category of physical functioning is a measure of self-perceived hearing performance that evaluates the perception and production of speech and sounds. The second category, social functioning, is a measure of the influence of the hearing impairment on activities and social interactions. The last category, psychological functioning, is a measure of the level of self-esteem of the CI user.

Each domain consists of ten statements, with a five-point response scale indicating the degree to which the statement applies to the respondent. In case of more than three incomplete answers, the corresponding domain is excluded. A total score was calculated by averaging across all 6 domains. The total NCIQ scores ranged from 20 to 88 with a mean of 62 on a 0 to 100 (maximum HRQoL) scale.

Speech, Spatial and Qualities of Hearing Scale

The Speech, Spatial and Qualities of Hearing Scale (SSQ) is a validated environmental and spatial hearing questionnaire, especially developed to range the self-perceived hearing-related abilities in hearing-impaired listeners and CI users (Gatehouse and Noble 2004). It has three subdomains: *speech hearing*, perception of speech in varying scenarios with competing sounds and talkers; s*patial hearing,* judgments of directional hearing and distance; and *other qualities,* assessing segregation of sounds and voices, and listening effort. Note that this questionnaire is a measure of self-perceived hearing-related performance only. Respondents rate themselves with scores varying from 0 to 10 (best). A total score was calculated by averaging scores across all 3 domains. The total SSQ scores ranged from 0 to 7.6 with a mean of 3.5 on a 0 to 10 (maximum hearing performance) scale.

Speech perception in quiet

During regular post-implantation clinic visits, identification of phonemes in recorded consonant-vowel-consonant (CVC) words, presented at 65 and 75 dB SPL (free field) in audiometry booths, is measured with most CI patients (Bosman and Smoorenburg 1995). Percent correct scores are calculated by the ratio of correctly repeated phonemes to the total number of phonemes presented per list at 65 or 75 dB. The highest percent correct score after implantation on either 65 or 75 dB SPL will be used. Scores ranged from 0 to 100%, with a mean of 66%.

Data analysis

Statistical analyses were done using Predictive Analytic Software (PASW) software package version 18.0. Due to non-normality Spearman's correlation coefficient was used to identify and quantify relationships between the scores from DMBQ, NCIQ, SSQ and speech perception. Partial correlation coefficients were conducted between the formal musical training and self-reported musical background and scores of NCIQ, SSQ, and speech perception, corrected for the influence of the educational level, duration of impaired hearing (y), CI use since implantation (m) and CI use per day (h). T-test and Mann-Whitney-U test were conducted for demographic differences between formal musically and non-musically trained and the self-reported musically and non-musically trained. Missing values were excluded by pair and a level of $p<0.05$ (two tailed) was considered significant.

RESULTS

Validation of the SSQ

Table II shows the Spearman's correlation coefficients between the scores per domain and the total score of SSQ and the speech perception score. Significant associations were shown between the domains and total score of the SSQ and the speech perception score.

Table II: Correlations between the speech perception score and the scores of the domains and total score of the SSQ.

	Speech	Spatial	Qualities	Total SSQ
Speech perception score	r = 0.519* (p = 0.000) N = 62	r = 0.483* (p = 0.000) N = 60	r = 0.516* (p = 0.000) N = 60	r = 0.523* (p = 0.000) N = 60

* = Significant

Musical background and HRQoL, self-reported hearing performance and speech perception

Tables III and IV show the results of the first (formal musical training) and second (self-report of musical training, knowledge and experience) measures of DMBQ, respectively. Table V shows the correlation analyses between these measures and the scores of HRQoL (measure of NCIQ) and self-perceived hearing-related performance (measure of SSQ) and speech perception. Figure 1 shows the correlations between the scores of formal musical training (left column) and self-reported musical background (right column) and the total NCIQ score (upper panels), the total SSQ score (middle panels) and speech perception scores (lower panels).

Table III shows the results for formal musical training in 94 respondents. Less than half of the respondents (41 respondents, 44%) had a formal musical training score larger than 0, indicating some form of musical training or lessons taken. The category that was participated in most was musical instrument lessons (26 respondents, 28%; lower part of Table III).

Table IV shows the results for the self-reported musical background in 83 respondents. As seen in the lowest two rows, 15 respondents (18%) judged themselves as having musical training, experience and knowledge.

The main objective of this study was to explore the effect of musical background on speech perception, an objective measure of hearing performance, on HRQoL, as measured by NCIQ, and on self-perceived hearing performance, as measured by SSQ.

Table V and figure 1 show the Spearman's correlation coefficients between the scores of formal musical training and self-reported musical background (left and right columns,

Table III. Musical background shown by the first measure of DMBQ.

Formal musical training		Respondents (%)
Formal musical training scores		N = 94 (100%)
Participation in no category	(0 points)	53 (56%)
Participation in one category	(1 point)	11 (12%)
Participation in two categories	(2 points)	19 (20%)
Participation in three categories	(3 points)	8 (9%)
Participation in four categories	(4 points)	1 (1%)
Participation in five categories	(5 points)	2 (2%)
Participation in all six categories	(6 points)	0 (0%)
Participation in each category[a]		N = 94 (100%)
Musical instrument lessons		26 (28%)
Singing lessons		5 (5%)
Participation in musical ensemble		18 (19%)
Music lessons at the elementary school		12 (13%)
Music lessons at the middle school		15 (16%)
Musical theory or appreciation classes		10 (11%)
No formal musical training		53 (56%)

[a] Note that subjects could participate in more than one category

Table IV. Musical background shown by the second measure of DMBQ.

Self-reported musical background	Respondents N = 83 (100%)
No formal training, little knowledge about music, and little experience in listening to music (0 points)	29 (35%)
No formal training or knowledge about music but informal listening experience (1 point)	36 (43%)
Self-taught musician who participates in musical activities (2 points)	3 (4%)
Some musical training, basic knowledge of musical terms, and participation in music classes or ensembles (3 points)	14 (17%)
Several years of musical training, knowledge about music, and involvement in music groups (4 points)	1 (1%)

respectively, in the table, and the left and right panels, respectively, in the figure) and scores of NCIQ, SSQ, and speech perception (top to bottom rows in the table, and top to bottom panels in the figure). The results showed that there were no significant correlations between formal musical training and self-reported musical background and scores of NCIQ, SSQ and speech perception.

Table V. Correlations between the total scores of health-related quality of life (NCIQ), self-perceived hearing performance (SSQ) or speech perception, and the scores of formal musical training and self-reported musical background (first and second measures of DMBQ, respectively).

	Formal musical training		**Self-reported musical background**	
NCIQ	N = 90		N = 79	
	r	p	r	p
Total NCIQ	-0.040	0.708	0.037	0.745
SSQ	N = 75		N = 65	
	r	p	r	p
Total SSQ	-0.194	0.095	-0.030	0.815
Speech perception	N = 70		N = 65	
	r	p	r	p
Speech perception score	0.123	0.311	0.106	0.405

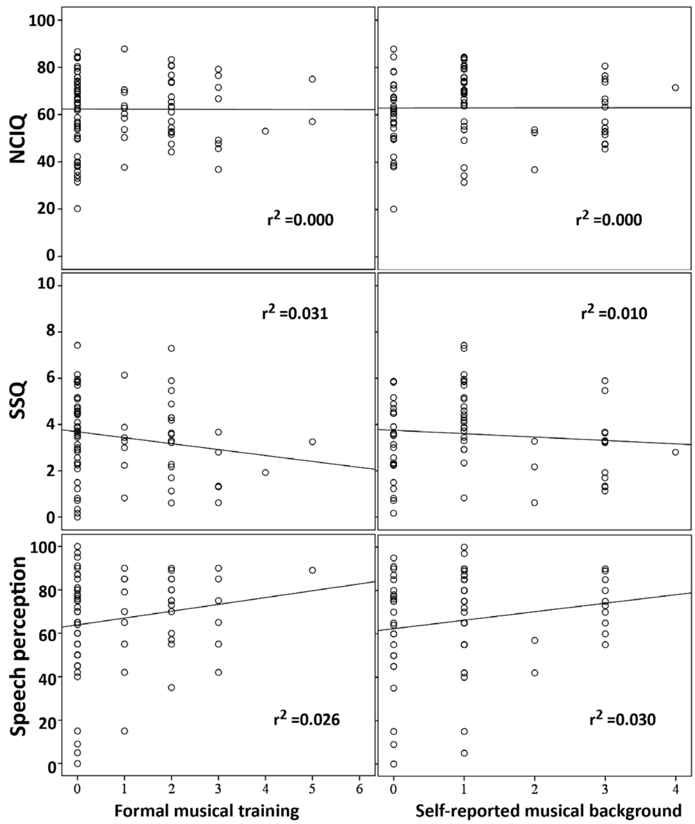

FIGURE 1. Correlations between the scores of formal musical training (left column) and self-reported musical background (right column), and the total scores from NCIQ (upper panels), SSQ (middle panels), and speech perception score (lower panels).

To correct for the influence of the educational level, duration of impaired hearing (y), CI use since implantation (m) and CI use per day (h) on the analyses between NCIQ, SSQ and speech perception and the first two DMBQ measures partial correlation analyses were conducted. Table VI shows the partial correlation coefficients between the scores of formal musical training and self-reported musical background (left and right columns, respectively) and scores of NCIQ, SSQ, and speech perception (top to bottom rows). The results showed that there were no significant correlations.

Table VI. Partial correlations between the scores of health-related quality of life (NCIQ), self-perceived hearing performance (SSQ) or speech perception, and the scores of formal musical training and self-reported musical background (first and second measures of DMBQ, respectively) corrected for the educational level, duration of impaired hearing, CI use since implantation, and CI use per day.

	Formal musical training		**Self-reported musical background**	
NCIQ	N = 81		N = 71	
	r	p	r	p
Total NCIQ	-0.088	0.429	-0.093	0.432
SSQ	N = 63		N = 56	
	r	p	r	p
Total SSQ	-0.217	0.083	-0.117	0.381
Speech perception	N = 62		N= 58	
	r	p	r	p
Speech perception score	0.183	0.147	0.089	0.499

To explore the effect of the musical background in more depth the respondents were divided into musically trained and non-musically trained groups on the basis of the first two measurements of DMBQ shown in table III and IV. The formal musically trained group is the 44% of the 94 respondents that scored 1 or higher on the first DMBQ measure. The self-reported musically trained group is the 18% of the 83 respondents that reported themselves as musically trained. The demographics of the formal musically trained and non-musically trained groups are shown in the second and third columns of table I. The demographics of the self-reported musically trained and non-musically trained are shown in table VII.

Only the distribution of the educational levels was unequal between the groups of formal musically trained and non-musically trained respondents (T-test: $t = -2.005$, $p = 0.049$) and between the self-reported musically trained and non-musically trained (Mann-Whitney-U test: $Z = -3.011$, $p = 0.003$). Tables VIII and IX show the correlations and partial correlations corrected for the educational level between the formal musically trained and self-reported musically trained groups and the total NCIQ and SSQ scores and the speech perception score. No associations between the total NCIQ and SSQ scores or the speech perception score and the formal musically trained and the self-reported musical trained were shown. It must be noted that the number of respondents that reported a musical background was too low to conduct an analyses between the self-reported musically trained and the speech perception score.

Table VII. Demographics of the respondents with a self-reported musical background and without a self-reported musical background based on the second DMBQ measure (N=83).

		Self-reported musical background	No self-reported musical background
		N = 15	N = 68
Gender	Male	4 (27%)	30 (44%)
	Female	11 (73%)	38 (56%)
Age (y)		68.5 ± 8.0	62.8 ± 14.9
Duration of impaired hearing (y)		40.4 ± 19.6	35.2 ± 18.9
CI use since implantation (m)		63.3 ± 28.9	67.8 ± 31.8
CI use per day (h)		14.8 ± 3.8	15.4 ± 1.8
Education	Lower	-	9 (13%)
	Middle	8 (57%)	51 (75%)
	Higher	6 (43%)	7 (12%)
Implant type (no.)	CI22M[a]	-	1 (2%)
	CI24R CA[a]	6 (40%)	16 (24%)
	CI24R k[a]	-	2 (3%)
	CI24RE CA[a]	4 (27%)	21 (31%)
	CI24R CS[a]	1 (7%)	14 (20%)
	HiRes 90K 1J[b]	-	-
	HiRes90K Helix[b]	4 (27%)	14 (20%)
Speech processor type (no.)	Esprit3G[a]	5 (33%)	21 (31%)
	Freedom[a]	6 (40%)	33 (49%)
	Harmony[b]	4 (27%)	14 (20%)

a Cochlear Corp., Englewood, Australia device. ACE speech strategy.
b Advanced Bionics Corp., California, USA device. HiRes speech strategy

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Table VIII. Correlations between the scores of health-related quality of life (NCIQ), self-perceived hearing performance (SSQ) or speech perception, and the respondents with a formal musical training and a self-reported musical background (first and second measures of DMBQ, respectively).

	Formal musical training		**Self-reported musical background**	
NCIQ	N = 41		N = 15	
	r	p	r	p
Total NCIQ	-0.015	0.926	0.247	0.347
SSQ	N = 31		N = 13	
	r	p	r	p
Total SSQ score	-0.301	0.100	-0.077	0.802
Speech perception				
Speech perception score	N = 28			
	r	p		
	0.099	0.614		

Table IX: Partial correlations between the scores of health-related quality of life (NCIQ), self-perceived hearing performance (SSQ) or speech perception, and the respondents with a formal musical training and a self-reported musical background (first and second measures of DMBQ, respectively) corrected for the educational level.

	Formal musical training		**Self-reported musical background**	
NCIQ	N = 37		N = 11	
	r	p	r	p
Total NCIQ	-0.081	0.623	0.287	0.342
SSQ	N = 27		N = 10	
	r	p	r	p
Total SSQ score	-0.264	0.167	0.072	0.823
Speech perception				
Speech perception score	N = 22			
	r	p		
	0.078	0.717		

DISCUSSION AND CONCLUSIONS

In the present study, we have explored musical background in a large population of CI recipients using two measures of DMBQ, one for formal musical training and one for self-reported assessment of musical training. Furthermore, we have explored the correlations and partial correlations of these musical background scores with scores of a CI-specific HRQoL questionnaire, NCIQ, a questionnaire to assess the self-perceived hearing-related performance, SSQ, and phoneme recognition in words in quiet test.

With the first measure of DMBQ, we have observed that 44% of 94 respondents had some formal musical training. Our finding is different than that reported by Leal et al. (2003), who had observed that 62% of 29 participants had some formal musical background. Note that the numbers of the participants (94 vs. 29) and the inclusion criteria in the two studies are vastly different. In our study, we had aimed to have a realistic representation of CI users and therefore had sent the questionnaires to all post-lingually deafened adult CI patients of UMCG, while Leal et al. (2003) had selected patients with very good speech perception performance (all with scores > 75% correct), compared to mean scores in our study of 66%. For the subcategories of musical instrument lessons, participation in a musical ensemble, and musical appreciation classes, we have observed the participation percentages of 28%, 19%, and 11%, respectively. With a similar questionnaire, but again with a smaller number of participants (67), Lassaletta et al. (2008) had observed percentages of 6%, 9% and 22%, respectively, for the same musical subcategories. Philips et al. (2012) found that 20% of 40 CI-recipients followed musical lessons. This variation is not surprising as the results with this measure could vary across different countries and cultures, for example, depending on the mandatory musical training in schools.

With the second measure of DMBQ, the self-reported musical background, we have observed, when we combined the two categories with highest musical training, knowledge, and experience, that 18% of the 83 participants have rated themselves as musically trained. Note that although 44% of the CI recipients had formal musical training, shown by the first DMBQ measure, only 18% have reported themselves as musically trained. One cause for the discrepancy might be the scoring of the first measure of the DMBQ in the present study, where the years of musical training were not taken into account in the formal musical training score. Alternatively, another cause might be that, although a recipient may have played a musical instrument as a child, they may now find themselves, many years later and having been deaf for a long period of time (see Tables I and II), not musically trained. Hence, some CI recipients who had had some previous training might have given up on music now, either due to a long period of deafness or the lack of pleasure in listening to music with the CI, and may not see themselves as musically trained anymore. Our finding of 18% of 83 CI listeners rating themselves as musically trained falls within the results of previous studies; 31% of 65 CI recipients (Gfeller et al. 2000b), 10% of 52 CI recipients (Lassaletta et al. 2007), and 14% of 67 CI recipients (Lassaletta et al. 2008).

Note that in comparison to previous studies our population was, with 94 and 83 participants for the first and second measures, respectively, the largest. Due to this and because we have not pre-selected our patients on performance criteria or etiology of deafness, we argue that our results present a good representation for musical background of typical post-lingually deafened adult CI users.

The main interest of the present study was in the correlations between the DMBQ scores and the HRQoL, self-perceived hearing-related performance or speech perception in quiet. Based on previous studies with NH listeners, assessing the influence of musical training on speech perception and on QoL, (Drennan and Rubinstein 2008; Musacchia, Strait, and Kraus 2008; Wong et al. 2007; Musacchia et al. 2007), we had hypothesized that musical background could be positively correlated with self-perceived hearing-related performance or speech perception performance in CI users, as well as HRQoL. Contrary to our hypothesis, no such association was found. Lassaletta et al. (2007) have similarly found no association between the musical background and the QoL in 52 CI recipients. One potential cause for these comparable findings may be methodological. As both studies showed, the musical background observed in general populations of CI recipients is quite limited, which may make it difficult to produce strong correlations. Focusing only on the CI users that reported a formal musical training or a self-reported musical background matched for all demographic factors and corrected for the differences in educational level, also showed no benefit of musical training on the HRQoL, the self-perceived hearing performance or the speech perception.

Another potential cause for the lack of an association might be the sensitivity of the questionnaires used. Even though we have aimed to use a HRQoL questionnaire specifically prepared for CI users, and a self-perceived hearing-related performance questionnaire specifically prepared for hearing-impaired listeners to assess their own performance of sound and speech perception, it is possible that these questionnaires might still not be sufficiently sensitive. Alternatively, the scoring system used in the DMBQ may not be sufficiently sensitive, as each category participated in was counted as one point, while in reality these categories may have contributed to the musical background in varying levels.

Regarding the (lack of) association between musical background and speech perception in CI recipients, there is no previous study that the present study can be compared to. Our hypothesis on this correlation was based on previous findings with NH populations (Musacchia, Strait, and Kraus 2008; Wong et al. 2007; Musacchia et al. 2007; Kraus and Chandrasekaran 2010; Parbery-Clark et al. 2009; Parbery-Clark et al. 2011). Perhaps the influence of musical training on the auditory system differs between NH listeners and CI users, as damage in the peripheral auditory system can cause the peripheral and central parts of the auditory system to operate differently in hearing impaired listeners compared to normal hearing listeners (Won et al. 2010). Not only the damage to the auditory system on the basis of the etiology of deafness could cause the lack of correlation, also other factors related to CI users, such as duration of deafness, may also have affected the results, but were not taken into account.

Although no associations were found between the musical background and the QoL or speech perception in quiet, we should note that this study was only one measurement in time, and that a relatively small percentage of the study population was musically trained. Hence, this snapshot implies that with no intervention there seems to be no effect of musical background on the QoL or the speech perception within a typical post-lingually deafened adult CI population. However, this finding does not dismiss potential benefits of a systematic musical training program. Focused musical training has been shown to be beneficial in CI users, for example, concerning melodic contour identification (merged), timbre recognition and appraisal (Gfeller et al. 2002), and complex melody task recognition (Gfeller et al. 2000a). This last study by Gfeller et al. (2000a) additionally showed that the CI recipients in the training group also 'liked' music more after training, compared to before. Future research should focus on the effects of such musical training on both adult and pediatric CI population, preferably with longitudinal studies, as the positive effect of musical training in normal-hearing listeners on the perception of speech is influenced by the amount of time that is invested (Parbery-Clark et al. 2009). In addition to potential enhancement of sound or speech perception, such a training program may have other benefits, such as an increase in music appreciation, augmentation of psychosocial wellbeing or development of social skills during group musical therapy. As music is, after all, a significant part of many social and cultural events, the appreciation of music may increase the QoL of CI recipients. In a recent study by Philips et al. (2012) the need of implementing music into the rehabilitation after cochlear implantation was emphasized by CI users themselves, while they believe that musical training might lead to maximal performance with their CI. Therefore, active participation in a musical training program might be of great influence on the QoL of CI recipients.

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