PREPRINT VERSION

FOR RESEARCH DATA UNIPD

Original Study: Application of Patients Reported Outcome measures in Cochlear Implant patients: implications for the design of specific rehabilitation programs

Authors: Andrea Frosolini [1,*], Giulio Badin [1], Flavia Sorrentino [1], Davide Brotto [1], Nicholas Pessot [1], Francesco Fantin [1], Federica Ceschin [1], Andrea Lovato [1], Nicola Coppola [2], Antonio Mancuso [2], Luca Vedovelli [3], Gino Marioni [4] and Cosimo de Filippis [1]

[1] Department of Neuroscience DNS, Audiology Unit, University of Padova, 31100 Treviso, Italy; segaudiologiatv@aulss2.veneto.it

[2] Department of Information Science, University of Milan, 20133 Milan, Italy

[3] Unit of Biostatistics, Epidemiology, and Public Health, Department of Cardiac, Thoracic, Vascular Sciences, and Public Health, University of Padova, 35100 Padova, Italy

[4] Department of Neuroscience DNS, Otolaryngology Section, University of Padova, 35100 Padova, Italy

* Correspondence: andrea.frosolini@studenti.unipd.it; Tel.: 0422.322318

Abstract:

Introduction: Cochlear implants (CI) had been developed to enable a satisfying verbal communication, music experiences have remained in the background of research and development and consequently many CI users are dissatisfied by the music they listen to. Nonetheless, concise indications for clinicians to test music abilities and prescribe rehabilitation programs are still lacking. The main aim of the present study was to test the utility of the application of two different Patient Reporting Outcomes (PRO) measures in a group of CI users. A secondary objective was to identify items capable of driving the indication and design specific music rehabilitation programs for CI patients.

Material and Methods: A consecutive series of 73 CI patients referred to the Audiology Unit - University of Padova - was enrolled from November 2021 to May 2022 and evaluated with

audiological battery test and PRO measures: Musica e Qualità della Vita (MUSQUAV) and Nijmegen Cochlear Implant Questionnaire (NCIQ) Italian version.

Results: The Reliability analysis showed good consistency between the different PRO measures, (Cronbach alpha = 0.873). After accounting for epidemiological and clinical variables, PRO measures showed a correlation with audiological outcomes in only one case (rho=-0.170 for NCIQ-T with CI-Pure Tone Average. A willingness for musical rehabilitation was present in 63% of patients, (Rehab Factor, mean value of 0.791±0.675).

Conclusions: we support the role of the application of MUSQUAV and NCIQ to improve the clinical and audiological evaluation of CI patients. Moreover, we proposed a derivative item, called Rehab Factor, which could be used in clinical practice and future studies to clarify the indication and priority of specific music rehabilitation programs.

1. Introduction

Bionic hear, the gold standard treatment for profound hearing loss, has improved hearing functionality, communication skills and social life of millions of people around the world in the last decades [1]. Although cochlear implants (CI) had been developed to enable a satisfying verbal communication [2], music experiences remained in the background of research and development and consequently many CI users are dissatisfied by the music they listen to [3]. Despite this fact being widely known by clinicians and patients, a recent systematic review concluded that currently no single test has been widely used, in a research or clinical context, to assess music experience after cochlear implantation [4]. This is reasonably due to the complexity and dynamicity of music experiences in everyday life as well as in the differences in acoustic discrimination, self-efficacy and cognitive resources available in hearing impaired patients for managing a complex listening environment [5].

Patient-reported outcomes (PROs) are increasingly used to assess, with standardized methods, a range of outcomes including symptoms, functional health, well-being and psychological issues from the patients' perspective. Among these instruments, the Nijmegen Cochlear Implant Questionnaire has been applied in different populations to evaluate both specific and general functional outcomes [6], while The Music Related Quality of Life was definitively developed to test music perception and engagement of CI patients in several real-life contexts [7]. Music experience has been studied in different subgroups of CI patients such as preverbal pediatric patients, post-verbal, pre-verbal lately implanted, bilateral users, bimodal users, unilateral users [5]. These different populations reported heterogeneous rehabilitation needs, but concise indications are lacking for clinicians to develop and prescribe music rehabilitation programs for CI users [3].

The main objective of the present study was to test the utility of the application of two different PRO measures in a group of CI users. A secondary aim was to identify items capable of driving the indication and design of specific music rehabilitation programs for CI patients.

2. Materials and Methods

2.1 Study design and Ethical approval

This mixed embedded study, composed of a survey combined with a retrospective data collection, was conducted in accordance with the principles of the Helsinki Declaration [8]. Data were examined in compliance with Italian privacy and sensitive data laws, and with the in-house rules of our institution. Informed consent was obtained from each participant. Ethical approval was obtained by the local committee ("Comitato Etico Marca Trevigiana" number 1196/CE).

2.2 Participants

A consecutive cohort of CI patients referred to the Audiology Unit - Treviso Hospital, Neuroscience Department, University of Padova - was enrolled from November 2021 to May 2022.

Inclusion criteria were the following:

1. age greater than 11 years;
2. last CI surgery at least 12 months before evaluation;
3. regular follow-up controls.

Exclusion criteria were:

1. not willing to complete the survey;
2. presence of neurological or psychiatric disorders.

The following demographic and clinical data were recorded: age, gender, temporal and etiological classification of deafness, years of hearing deprivation, years of CI use, linguistic and musical skills.

2.3 PRO measures

The Italian Nijmegen Cochlear Implant Questionnaire (I-NCIQ) and the Musica e Qualità della Vita (MUSQUAV) questionnaires [9] (Italian translation of Music related Quality of Life [7]) were administered to the enrolled patients. Both tests are based on a 5-point Likert scale that can be transformed into a 0-100 score. The MUSQUAV questionnaire is a novel instrument for the assessment of the patients' perception and musical engagement with the possibility to give specific indications for rehabilitation programs [9]. The I-NCIQ is a widely used instrument designed to quantify the quality of life in patients with CIs [10]. It is composed of six different sub-domains: basic sound perception; advanced sound perception; speech production; self-esteem; activity limitations and social interactions. The time needed to complete the two surveys is approximately 20 minutes. The patients manually filled in and answered the

questionnaires [9-10]; the data were then acquired in an Excel spreadsheet (Microsoft Excel 2019 for Windows 10) by researchers of our group.

2.4 Developing of the Rehab Factor

In order to propose a numerical factor to quantify the individual musical rehabilitation needs, for each patient the difference between the Frequency score and Importance score was calculated, as expressed in the two sections of the MUSQUAV (MUSQUAV Importance - MUSQUAV frequency). Patients who had values of importance less than 2 out of 5 of the Likert scale (not at all relevant or not very relevant) were excluded. The value obtained, by definition greater than 0, was called the Rehab Factor.

2.5 Audiological evaluation

Audiological results at last evaluation (within 12 months before the day of the observation) were considered for each patient. Audiometry was performed with Madsen Astera by GN Otometrics (Denmark), in accordance with European (IEC 60645-I) and ISO (389-1) standards, in a sound-attenuating room. We tested hearing thresholds without hearing devices and hearing thresholds and speech audiometry with hearing devices in the best-aided condition. The Pure Tone Average (PTA2, considering threshold levels at 0.5, 1, 2, and 4 kHz), the Speech Reception Threshold and Speech Intelligibility Threshold (SRT and SIT respectively, the intensity in decibels at which 50% and 100% of a disyllabic word were recognized) were considered, as previously reported [9].

2.6 Statistical analysis

Reliability analysis was done to test correlation between MUSQUAV and NCIQ, Cronbach alpha value was calculated, Pearson correlation heat map was reported.

Correlation and partial correlation analysis was done using the Spearman test for PRO measures and all the previously cited demographical, clinical and audiological variables. For all measures, a multiplicity test to rule out False discovery rate was run and an alpha of 0.05 was set: when $p > 0.05$, correlations are reported as not significant.

The *jamovi* software (version 1.6, 2021, open access software available at https://www.jamovi.org) was used for our statistical purposes [11].

3. Results

3.1 Group data

Seventy-three patients were included (46 females and 27 males); Table 1 summarizes main demographic, clinical and audiological characteristics, reporting mean values, median, standard deviation, interquartile range, range. The average age was 47.1±23.1 years (range 11.0 to 89.0). The main hearing loss etiologies (genetic, infective, autoimmune and idiopathic) were present. The onset of hearing loss was slightly predominantly post-verbal (40 cases, 54.8%). Rehabilitation strategies were distributed between unilateral CI (29 cases, 39.7%), bilateral CI (21 cases, 28.8%) and bimodal rehabilitation CI (23 cases, 31.5%). The average implant usage period was 9.75±6.32 years and varied from a minimum of one to a maximum of 27 years. The average auditory residue, in the absence of Hearing Aid or CI, was 104±22.6dB. At pure tone audiometry, participants in the best fitting condition had an average hearing threshold of 29.8±5.84dB, with a range of 20.0 to 50.0 dB. The SRT at speech audiometry (average 40.6±9.27 dB) was not reached by four patients (5.5%), while the SIT (average 51.9±9.94 dB) was not reached by 31 patients (42.5%).

For the PRO measures scores, the average NCIQ was 3.59±0.524 (median 3.60, range 2.05-4.66); the mean F-MUSQUAV was 3.00±0.864 (median 3.11, range 1.50-4.65) and the mean I-MUSQUAV was 3.34±0.798 (median 3.44, range 1.50-5.00).

3.2 PRO measures correlations

The Reliability analysis showed good consistency between the different PRO measures (MUSQUAV and NCIQ), with a Cronbach alpha value of 0.873. Pearson's test showed a significant positive correlation between the Frequency section of the MUSQUAV and the Total NCIQ ($r = 0.632$; $p<0.001$) as well as all of its subdomains, with the exception of the NCIQ2 (Enhanced Sound Perception), as depicted in Figure 1. The correlation of the Importance section of the MUSQUAV was weaker with the total NCIQ ($r = 0.246$; $p=0.036$) and only with subdomains NCIQ1 ($r = 0.277$; $p=0.018$) and NCIQ3 ($r = 0.425$; $p<0.001$). The expected correlations between subdomains of the NCIQ are reported in Figure 1.

Spearman's correlation for PRO measures with epidemiological, clinical and audiological variables found that age (rho = -0.399, adj. p=0.004), time of onset of hearing loss (rho = -0.367, adj. p=0.003), CI-PTA (rho = -0.292, adj. p=0.021), SRT (rho = -0.365, adj. p=0.005), SIT (rho = -0.427, adj. p=0.010) were all negatively correlated with the MUSQUAV Frequency. NCIQ-T was negatively correlated with CI-PTA (rho = -0.352, adj. p=0.020). Other correlations between demographic, clinical and audiological variables are shown in **Table 3a**. We further conducted a partial regression including epidemiological and clinical data as control variables for PRO

measures and audiological outcomes. The correlations were confirmed for F-MUSQUAV with I-MUSQUAV (rho = 0.447, adj. p=0.005) and NCIQ-T (rho = 0.582, adj. p=0.003) and for NCIQ-T with CI-PTA (rho = -0.304, adj. p=0.039). The correlation between the following audiological measures was also confirmed**:** CI-PTA with SRT (rho = 0.520, adj. p=0.002); CI-PTA with SIT (rho = 0.403, adj. p=0.016); SRT with SIT (rho = 0.540, adj. p<0.001), as expected (see **Table 3b**).

3.3 The REHAB Factor

The Rehab Factor was present for 46 out of 73 patients (63%), with a mean value of 0.791±0.675 (range 0.033-2.44). Descriptive values of patients with rehab factors are reported in Table 4.

The Partial correlation for audiological outcome and NCIQ scores, considering epidemiological and clinical data as control variables, showed a positive correlation of REHAB with SRT (rho = 0.417, adj. p=0.050) and a negative correlation with NCIQ-3 (rho = -0.570, adj. p=0.01), NCIQ3 (rho = -0.570, adj. p=0.010) and NCIQ4 (rho = -0.344, adj. p=0.080) (see Table 5).

4. Discussion

In recent years, after achieving strong, stable and vast results with verbal communication [12], CI research has focused much more on how to improve music listening and participation of implanted patients [13]. Some open questions, at the actual state of the art, need to be addressed: should clinicians try to improve music perception [14] or rather focus on eliciting an equivalent emotional response to music [15]? How can we bring research toward more ecological, real-life-like situations and how should a clinician indicate dedicating time for music when resources are already severely limited for speech focused interventions [3]?

In this original research, we tried to assess some of these questions by examining 73 consecutive patients presenting to a tertiary referral center for audiological and phoniatric diseases. Due to unrestricted inclusion criteria, the study group had a wide age distribution, different etiologies, time of onset of hearing loss, hearing rehabilitation strategies and CI experience, as summarized in **Table 1**. CI-PTA (29.8±5.84 dB) and SRT (40.6±9.27 dB) tests, as expected, revealed auditory performances adequate to ensure good verbal perception in most of the patients. These good audiological outcomes had consequently a positive impact on the quality of life, as confirmed by the average scores of 3.59±0.524 at the I-NCIQ. Nonetheless, the I-NCIQ scores showed considerable variability (from 2.05 to 4.66), justifiable by the heterogeneity of a consecutive group of patients. Accordingly, the scores of the MUSQUAV showed marked variability: the mean F-MUSQAV was 3.00±0.864 (median 3.11, range 1.50-4.65), consistent with a self-rating of musical abilities in the study group overall adequate for individual expectations but inferior to the median value of 3.94 previously found in a group of 97 normal hearing subjects [9]. The mean Importance section of MUSQUAV was 3.34±0.798 (median 3.44, range 1.50-5.00). The higher value of I-MUSQUAV section in comparison with F-MUSQUAV section indicates a frequent discrepancy between self-evaluation of musical abilities/engagement (F-MUSQUAV) and individually rated importance of such properties (I-MUSQUAV). This is typical of an impaired hearing group and absent in normal hearing subjects, as previously reported [9].

We chose MUSQUAV, Italian translation of The Music related Quality of Life questionnaire [7], to test music perception and engagement of CI patients in several real life contexts, since no standard of evaluation of music perception is available to date [4]. The original author of the questionnaire stated that, considering the pervasive presence of music in daily life and its role in emotional expression, social and cultural connection, musical perception and consequently participation could have a correlation with quality of life [7]. Following the results of the present research, we can support this statement due to the moderate-strong positive association revealed in our sample between F-MUSQUAV and NCIQ scores ($r = 0.632$, $p<0.001$) at the Pearson's test.

Moreover, the Factor analysis of MUSQUAV and NCIQ items resulted as having a Chronbac's alpha value higher than 0.8, which can be interpreted as a relevant indicator of external consistency of the MUSQUAV questionnaire, never before tested to the best of our knowledge (see **Figure 1**).

We also aimed to investigate the associations between PRO measures and clinical/audiological outcomes. Since several correlations were observed at an exploratory analysis, as expected, with age, hearing loss onset and CI-use (**Table 3a**), we further conducted a partial correlation using epidemiological and clinical variables as controlling factors (**Table 3b**). The already reported association between F-MUSQUAV, I-MUSQUAV and NCIQ was confirmed in both analyses; solely the association between PRO measures and audiological outcome was found for NCIQ and CI-PTA, revealing a weak negative correlation (rho = -0.304, **Table 3b**). These results are in line with those reported by Vasil et al. [6]; on a group of 44 CI users, they found that NCIQ had no correlation with standard audiological outcome, concluding that clinicians might integrate information obtained by PRO measures to better estimate real-world performance of CI patients and improved counseling and development of recommendations [6]. Accordingly, in response to our primary research question, our data support the hypothesis that validated PRO measures, such as MUSQUAV and NCIQ, may be applied in the context of CI clinics to test abilities and weaknesses that go unnoticed at standard audiology battery tests with the purpose of giving a better indication to rehabilitation programs.

In this study, an innovative quantitative item for the analysis of individual rehabilitation needs was introduced. The REHAB Factor was determined by the difference between MUSQUAV Importance and Frequency, in other words, the delta between the importance given to music and the executable skills and activities in the field of music as expressed by individual subjects when answering the two specular sections of the MUSQUAV questionnaire [9]. The REHAB Factor is not valid in the event that the subject gives no or scarce importance to music, which happens when the I-MUSQUAV score is lower than or equal to 2 on the 5-point Likert scale. The REHAB Factor was present in 46 out of 73 patients (63%), with a mean value of 0.791±0.675 (median 0.514, range 0.032-2.44). It follows that the majority of patients referred to a CI clinic could require a direct rehabilitative intervention in various areas of the musical experience. This confirms data previously reported, in which even 90% of CI users were subjectively wishing to undergo a music rehabilitation program [5]. In the partial correlation, the REHAB factor showed a positive correlation with SRT (rho = 0.417, adj. p=0.05) and a negative one with NCIQ3 (rho = -0.570, p=0.01). Therefore, the REHAB factor correlates with weaker audiological performances (higher

SRT values) and poor self-rated outcomes (lower NCIQ scores), data which can preliminary suggest an ability of the REHAB factor to intercept rehabilitation needings within the patient group.
The fact that the difference between importance and frequency could be proportional to the impact on quality of life was reported by the authors of the questionnaire as well as the possibility to plot individual data in a matrix to draw rehabilitation programs [7], but to the best of our knowledge a numerical factor was not previously proposed by any other research group. In answer to the second objective of our study, the REHAB Factor could be proposed in clinical practice after the verification, in future research, of the validity measures of the test, such as sensitivity, specificity, positive predictive and negative predictive values.
The limits of this work are mainly related to the single center design of the study. Moreover, the data collection was done during the COVID-19 pandemic period and this could have decreased the score of some items of PRO measures, especially considering that pandemic restrictions had a negative impact on individual musical activities [16].

5. Conclusions

The preliminary results of the present research support the role of the application of two different PRO measures (MUSQUAV and NCIQ), to improve the clinical and audiological evaluation of CI patients. Moreover, we proposed a derivative item (the REHAB Factor) which, after verification of its statistical power in future research projects, could be used in clinical practice to clarify the indication and priority of specific music rehabilitation programs for CI patients.

Author Contributions: Conceptualization, A.F., A.M. and C.d.F.; methodology, A.F., A.M.; software, A.F., G.B.; validation, A.F., and A.M.; formal analysis, A.F., A.M., N.C., L.V.; investigation, A.F., F.F. N.P. and G.B.; resources, A.F., G.B.; data curation, A.F., G.B., F.C.; writing—original draft preparation, A.F., G.B.; writing—review and editing, A.L., F.S., A.F., L.V., G.M.; visualization, G.B.; supervision, A.L., G.M. and C.d.F.; project administration, A.F., C.d.F; funding acquisition, not applicable.

All authors have read and agreed on the Preprint version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Comitato Etico Marca Trevigiana (protocol code 1196/CE, 07/04/2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patients to publish this paper.

Data Availability Statement: The data that support the findings are stored on the online repository https://researchdata.cab.unipd.it/

Acknowledgments: The authors thank Ms Alison Garside for correcting the English version of this paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Sorrentino, F.; Gheller, F.; Lunardi, G.; Brotto, D.; Trevisi, P.; Martini, A.; Marioni, G.; Bovo, R. Cochlear Implantation in Adults with Auditory Deprivation: What Do We Know about It? *Am. J. Otolaryngol.* **2020**, *41*, 102366, doi:10.1016/j.amjoto.2019.102366.
2. Favaretto, N.; Marioni, G.; Brotto, D.; Sorrentino, F.; Gheller, F.; Castiglione, A.; Montino, S.; Giacomelli, L.; Trevisi, P.; Martini, A.; et al. Cochlear Implant Outcomes in the Elderly: A Uni- and Multivariate Analyses of Prognostic Factors. *Eur. Arch. Otorhinolaryngol.* **2019**, *276*, 3089–3094, doi:10.1007/s00405-019-05613-3.
3. Lehmann, A.; Limb, C.J.; Marozeau, J. Editorial: Music and Cochlear Implants: Recent Developments and Continued Challenges. *Front. Neurosci.* **2021**, *15*, 736772, doi:10.3389/fnins.2021.736772.
4. Hwa, T.P.; Wen, C.Z.; Ruckenstein, M.J. Assessment of Music Experience after Cochlear Implantation: A Review of Current Tools and Their Utilization. *World J. Otorhinolaryngol. - Head Neck Surg.* **2021**, *7*, 116–125, doi:10.1016/j.wjorl.2021.02.003.
5. Gfeller, K.; Driscoll, V.; Schwalje, A. Adult Cochlear Implant Recipients' Perspectives on Experiences With Music in Everyday Life: A Multifaceted and Dynamic Phenomenon. *Front. Neurosci.* **2019**, *13*, 1229, doi:10.3389/fnins.2019.01229.
6. Vasil, K.J.; Lewis, J.; Tamati, T.; Ray, C.; Moberly, A.C. How Does Quality of Life Relate to Auditory Abilities? A Subitem Analysis of the Nijmegen Cochlear Implant Questionnaire. *J. Am. Acad. Audiol.* **2020**, *31*, 292–301, doi:10.3766/jaaa.19047.
7. Dritsakis, G.; van Besouw, R.M.; Kitterick, P.; Verschuur, C.A. A Music-Related Quality of Life Measure to Guide Music Rehabilitation for Adult Cochlear Implant Users. *Am. J. Audiol.* **2017**, *26*, 268–282, doi:10.1044/2017_AJA-16-0120.
8. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA* **2013**, *310*, 2191, doi:10.1001/jama.2013.281053.
9. Frosolini, A.; Parrino, D.; Mancuso, A.; Coppola, N.; Genovese, E.; de Filippis, C. The Music-Related Quality of Life: Italian Validation of MuRQoL into MUSQUAV Questionnaire and Preliminary Data from a Cohort of Postlingually Deafened Cochlear Implant Users. *Eur. Arch. Otorhinolaryngol.* **2022**, doi:10.1007/s00405-022-07258-1.
10. Ottaviani, F.; Iacona, E.; Sykopetrites, V.; Schindler, A.; Mozzanica, F. Cross-Cultural Adaptation and Validation of the Nijmegen Cochlear Implant Questionnaire into Italian. *Eur. Arch. Otorhinolaryngol.* **2016**, *273*, 2001–2007, doi:10.1007/s00405-015-3765-8.

11. The Jamovi Project (2021). Jamovi (Version 1.6) [Computer Software]. Retrieved from Https://Www.Jamovi.Org.
12. Hammond-Kenny, A.; Borsetto, D.; Manjaly, J.G.; Panova, T.; Vijendren, A.; Bance, M.; Tysome, J.R.; Axon, P.R.; Donnelly, N.P. Cochlear Implantation in Elderly Patients: Survival Duration, Hearing Outcomes, Complication Rates, and Cost Utility. *Audiol. Neurotol.* **2022**, *27*, 156–165, doi:10.1159/000517315.
13. Gfeller, K.; Mallalieu, R.M.; Mansouri, A.; McCormick, G.; O'Connell, R.B.; Spinowitz, J.; Gellinek Turner, B. Practices and Attitudes That Enhance Music Engagement of Adult Cochlear Implant Users. *Front. Neurosci.* **2019**, *13*, 1368, doi:10.3389/fnins.2019.01368.
14. Di Nardo, W.; Schinaia, L.; Anzivino, R.; De Corso, E.; Ciacciarelli, A.; Paludetti, G. Musical Training Software for Children with Cochlear Implants. *Acta Otorhinolaryngol. Ital. Organo Uff. Della Soc. Ital. Otorinolaringol. E Chir. Cerv.-facc.* **2015**, *35*, 249–257.
15. Paquette, S.; Ahmed, G.D.; Goffi-Gomez, M.V.; Hoshino, A.C.H.; Peretz, I.; Lehmann, A. Musical and Vocal Emotion Perception for Cochlear Implants Users. *Hear. Res.* **2018**, *370*, 272–282, doi:10.1016/j.heares.2018.08.009.
16. Ferreri, L.; Singer, N.; McPhee, M.; Ripollés, P.; Zatorre, R.J.; Mas-Herrero, E. Engagement in Music-Related Activities During the COVID-19 Pandemic as a Mirror of Individual Differences in Musical Reward and Coping Strategies. *Front. Psychol.* **2021**, *12*, 673772, doi:10.3389/fpsyg.2021.673772.

Tables and Figure

Table 1. Clinical features, audiological outcome and PRO measures of included participants. (a) Descriptives; (b) Frequencies of Gender, Onset and Rehabilitation.

Descriptives	N	Missing	Mean	Median	SD	IQR	Minimum	Maximum
Age (years)	73	0	47.1	49.0	23.1	46.0	11.0	89.0
CI use (years)	73	0	9.75	10.0	6.32	10.00	1.00	27.00
Auditory deprivation (years)	73	0	7.32	0.00	11.8	13.00	0.00	65.00
PTA (dB)	73	0	104	115	22.6	23.8	35.0	120
CI-PTA (dB)	73	0	29.8	30.0	5.84	8.75	20.0	50.0
SRT (dB)	69	4	40.6	40.0	9.27	10.0	22.0	63.0
SIT (dB)	42	31	51.9	50.0	9.94	17.5	40.0	70.0
F MUSQUAV	73	0	3.00	3.11	0.864	1.46	1.50	4.65
I MUSQUAV	73	0	3.34	3.44	0.798	0.83	1.50	5.00
REHAB	46	27	0.791	0.514	0.675	0.903	0.033	2.44
NCIQ1	73	0	3.59	3.60	0.770	1.20	1.60	5.00
NCIQ2	73	0	4.04	4.10	0.675	1.00	2.29	5.00
NCIQ3	73	0	3.44	3.50	0.664	1.10	1.70	4.60
NCIQ4	73	0	3.35	3.30	0.563	0.700	2.20	4.60
NCIQ5	73	0	3.66	3.70	0.861	1.30	1.30	5.00
NCIQ6	73	0	3.47	3.57	0.658	1.00	1.78	4.71
NCIQ-T	73	0	3.59	3.60	0.524	0.733	2.05	4.66

(a)

Variables	N	% of Total	Cumulative %
Gender			
Female	46	63.0 %	63.0 %
Male	27	37.0 %	100.0 %
Onset			
Pre-verbal	33	45.2 %	45.2 %
Post-verbal	40	54.8 %	100.0 %
Rehabilitation			
Unilateral CI	29	39.7 %	39.7 %
Bilateral CI	21	28.8 %	68.5 %
Bimodal	23	31.5 %	100.0 %

(b)

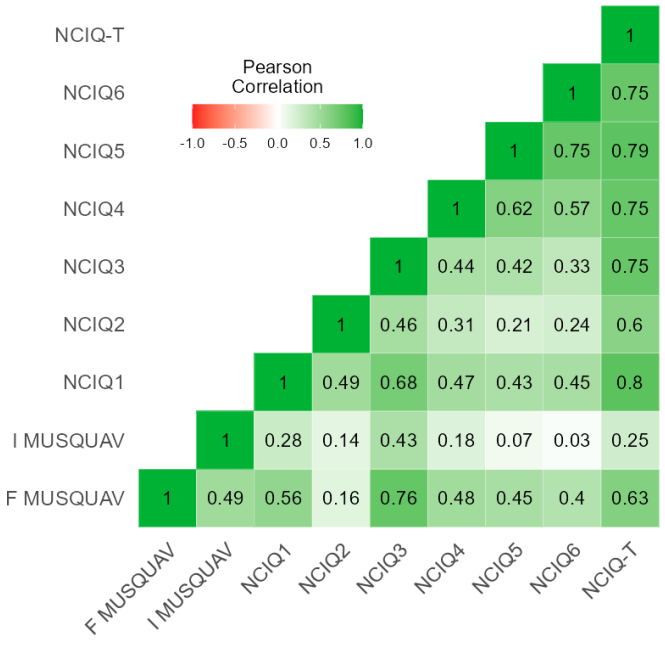
Abbreviations: F MUSQUAV (Frequency questionnaire of Music and Quality of Life questionnaire); I MUSQUAV (Importance section of Music and Quality of Life questionnaire); N (Number of Subjects); NCIQ-T (Nijmegen Cochlear Implant Questionnaire Total); NCIQ 1,2,3,4,5,6 (Subsections of Nijmegen Cochlear Implant Questionnaire); SRT (Speech Recognition Threshold); SIT (Speech Intelligibility Threshold); CI-PTA (Pure Tone Average with Cochlear Implant); PTA (Pure Tone Average); CI (Cochlear Implant).

Table 2. Reliability analysis of different PRO measures: NCIQ and MUSQUAV. (a) Scale Reliability Statistics; (b) Item Reliability Statistics.

Scale Reliability Statistic	Mean	SD	Cronbach's α	(a)
scale	3.500	0.505	0.873	

Item Reliability Statistics	If item dropped Cronbach's α	(b)
F MUSQUAV	0.852	
I MUSQUAV	0.888	
NCIQ1	0.849	
NCIQ2	0.875	
NCIQ3	0.847	
NCIQ4	0.857	
NCIQ5	0.860	
NCIQ6	0.860	
NCIQ-T	0.838	

Figure 1. Correlation Heat map of different PRO measures: NCIQ and MUSQUAV.



Abbreviations: F MUSQUAV (Frequency questionnaire of Music and Quality of Life questionnaire); I MUSQUAV (Importance section of Music and Quality of Life questionnaire); NCIQ-T (Nijmegen Cochlear Implant Questionnaire Total); NCIQ 1,2,3,4,5,6 (Subsections of Nijmegen Cochlear Implant Questionnaire).

Table 3. Correlation and partial correlation matrix for PRO measures and both clinical characteristics and audiological outcome. (a) Correlation Matrix; (b) Partial Correlation.

		F MUSQUAV	I MUSQUAV	NCIQ-T	Gender	Age	Onset	Rehabil.	CI use	Aud. depr.	PTA	CI-PTA	SRT	SI
F MUSQUAV	ϱ	—												
	adj. p-v.	—												
I MUSQUAV	ϱ	**0.488**	—											
	adj. p-v.	**0.008***	—											
NCIQ-T	ϱ	**0.609**	0.209	—										
	adj. p-v.	**0.039***	0.132	—										
Gender	ϱ	0.197	0.049	0.083	—									
	adj. p-v.	0.143	0.717	0.557	—									
Age	ϱ	**-0.399**	**-0.300**	-0.223	-0.131	—								
	adj. p-v.	**0.020***	**0.029***	0.103	0.334	—								
Onset	ϱ	**-0.367**	-0.204	-0.133	-0.045	**0.601**	—							
	adj. p-v.	**0.016***	0.137	0.328	0.732	**0.005***	—							
Rehabil.	ϱ	-0.128	-0.204	0.001	-0.201	**0.293**	0.270	—						
	adj. p-v.	0.342	0.138	0.990	0.142	**0.032***	0.051	—						
CI use	ϱ	0.261	0.112	0.127	0.151	-0.247	**-0.421**	**-0.598**	—					
	adj. p-v.	0.058	0.403	0.342	0.274	0.072	**0.007***	**0.006***	—					
Aud. depr.	ϱ	0.178	0.148	0.050	0.242	-0.160	-0.249	**-0.845**	**0.630**	—				
	adj. p-v.	0.198	0.273	0.718	0.076	0.239	0.074	**0.009***	**0.010***	—				
PTA	ϱ	-0.162	0.040	-0.065	-0.077	-0.178	-0.043	**-0.417**	**0.277**	0.074	—			
	adj. p-v.	0.243	0.750	0.633	0.579	0.192	0.740	**0.004***	**0.045***	0.586	—			
CI-PTA	ϱ	**-0.292**	-0.178	**-0.352**	-0.370	**0.428**	0.137	**0.270**	-0.233	-0.197	-0.117	—		
	adj. p-v.	**0.033***	0.194	**0.009***	0.078	**0.005***	0.315	**0.049***	0.089	0.147	0.385	—		
SRT	ϱ	**-0.365**	-0.166	-0.270	-0.255	**0.659**	**0.384**	**0.372**	**-0.314**	-0.233	-0.250	**0.682**	—	
	adj. p-v.	**0.007***	0.240	0.057	0.072	**0.006***	**0.013***	**0.007***	**0.027***	0.098	0.076	**0.004***	—	
SIT	ϱ	**-0.427**	-0.106	-0.199	**-0.377**	**0.731**	**0.476**	**0.447**	**-0.448**	-0.306	-0.276	**0.728**	**0.844**	—
	adj. p-v.	**0.016***	0.572	0.272	**0.036***	**0.007***	**0.016***	**0.010***	**0.010***	0.091	0.131	**0.010***	**0.005***	—

(a)

		F MUSQUAV	I MUSQUAV	NCIQ-T	CI-PTA	SRT	SIT
F MUSQUAV	ϱ	—					
	adj. p-v.	—					
I MUSQUAV	ϱ	**0.447**	—				
	adj. p-v.	**0.015***	—				
NCIQ-T	ϱ	**0.582**	0.171	—			
	adj. p-v.	**0.008***	0.364	—			
CI-PTA	ϱ	-0.124	-0.051	**-0.304**	—		
	adj. p-v.	0.401	0.687	**0.039***	—		
SRT	ϱ	-0.084	0.125	-0.146	**0.520**	—	
	adj. p-v.	0.555	0.385	0.387	**0.005***	—	
SIT	ϱ	-0.180	0.225	-0.224	**0.403**	**0.540**	—
	adj. p-v.	0.412	0.362	0.327	**0.040***	**0.004***	—

(b)

Note: controlling for 'Gender', 'Age', 'Onset', 'Rehabilitation', 'CI use', 'Auditory deprivation', and 'PTA'.
*= Significant using a False Discovery Rate of 0.05
Abbreviations: adj. p-v. (adjusted p-value); aud. depr. (auditory deprivation); F MUSQUAV (Frequency questionnaire of Music and Quality of Life questionnaire); I MUSQUAV (Importance section of Music and Quality of Life questionnaire); N (Number of

Subjects); NCIQ-T (Nijmegen Cochlear Implant Questionnaire Total); Rehabil. (Rehabilitation); SRT (Speech Recognition Threshold); SIT (Speech Intelligibility Threshold); CI-PTA (Pure Tone Average with Cochlear Implant); PTA (Pure Tone Average); CI (Cochlear Implant); ϱ (Spearman's rho).

Table 4. Demographic, clinical characteristics, audiological outcomes and PRO measures of REHAB group. (a) Descriptives – REHAB group; (b) Frequencies of Gender, Onset and Rehabilitation – REHAB group.

Descriptives	N	Missing	Mean	Median	SD	IQR	Minimum	Maximum
Age (yrs)	46	0	46.9	47.0	21.3	34.3	11.0	79.0
CI use (yrs)	46	0	9.57	9.00	6.59	10.0	1.00	27.0
Auditory depr. (yrs)	46	0	6.96	0.00	10.7	13.0	0.00	48.0
PTA (dB)	46	0	107	116	19.2	19.1	48.8	120
CI-PTA (dB)	46	0	30.3	30.0	5.79	9.69	21.3	50.0
SRT (dB)	44	2	41.0	40.0	6.77	7.50	25.0	57.0
SIT (dB)	23	23	54.3	50.0	8.96	10.0	40.0	70.0
F MUSQUAV	46	0	2.85	2.79	0.75	1.15	1.61	4.39
I MUSQUAV	46	0	3.64	3.56	0.59	0.74	2.50	5.00
REHAB	46	0	0.791	0.514	0.675	0.903	0.033	2.44
NCIQ1	46	0	3.50	3.60	0.703	0.975	1.60	4.56
NCIQ2	46	0	4.05	4.01	0.700	1.09	2.29	5.00
NCIQ3	46	0	3.39	3.40	0.625	1.00	1.70	4.60
NCIQ4	46	0	3.31	3.20	0.564	0.667	2.30	4.60
NCIQ5	46	0	3.50	3.58	0.870	1.28	1.30	4.80
NCIQ6	46	0	3.33	3.40	0.687	1.04	1.78	4.44
NCIQ-T	46	0	3.51	3.55	0.526	0.763	2.05	4.59

(a)

Variables	N	% of Total	Cumulative %
Gender			
Female	33	71.7 %	71.7 %
Male	13	28.3 %	100.0 %
Onset			
Pre-verbal	19	41.3 %	41.3 %
Post-verbal	27	58.7 %	100.0 %
Rehabilitation			
Unilateral CI	18	39.1 %	39.1 %
Bilateral CI	15	32.6 %	71.7 %
Bimodal	13	28.3 %	100.0 %

(b)

Abbreviations: F MUSQUAV (Frequency questionnaire of Music and Quality of Life questionnaire); I MUSQUAV (Importance section of Music and Quality of Life questionnaire); NCIQ-T (Nijmegen Cochlear Implant Questionnaire Total); NCIQ 1,2,3,4,5,6 (Subsections of Nijmegen Cochlear Implant Questionnaire); SRT (Speech Recognition Threshold); SIT (Speech Intelligibility Threshold); CI-PTA (Pure Tone Average with Cochlear Implant); PTA (Pure Tone Average); CI (Cochlear Implant).

Table 5 Partial correlation matrix of REHAB factor with clinical characteristics, audiological outcome and NCIQ.

	CI-PTA	**SRT**	**SIT**	**NCIQ-T**	**NCIQ1**	**NCIQ2**	**NCIQ3**	**NCIQ4**	**NCIQ5**	**NCIQ6**
REHAB										
Spearman's rho	0.221	0.417	0.067	-0.356	-0.185	-0.092	-0.570	-0.344	-0.203	-0.230
Adj. p-value	0.293	0.050*	0.806	0.087	0.325	0.642	0.010*	0.080	0.307	0.318

Note: controlling for 'Gender', 'Age', 'Onset', 'Rehabilitation', 'CI use', 'Auditory deprivation', and 'PTA'.
*= Significant using a False Discovery Rate of 0.05
Abbreviations: F MUSQUAV (Frequency questionnaire of Music and Quality of Life questionnaire); I MUSQUAV (Importance section of Music and Quality of Life questionnaire); NCIQ-T (Nijmegen Cochlear Implant Questionnaire Total); NCIQ 1,2,3,4,5,6 (Subsections of Nijmegen Cochlear Implant Questionnaire); SRT (Speech Recognition Threshold); SIT (Speech Intelligibility Threshold); CI-PTA (Pure Tone Average with Cochlear Implant); PTA (Pure Tone Average); CI (Cochlear Implant).