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The Impact of Cochlear Implant Experience on Music Perception: Systematic Review and Meta-analysis

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Abstract

Purpose of Review The goal of this paper is to analyze previously published literature to evaluate whether there is a relationship between music perception in cochlear implant users and duration of cochlear implant experience.

Recent Findings There has been little research thus far on this topic. One prospective study done among Korean cochlear implant users has demonstrated passive improvement in timbre and pitch discrimination with time. It is known that speech perception does improve with time, which may point to a similar relationship in music perception as well.

Summary Based on the available data, there is no significant passive improvement in pitch, timbre, or rhythm perception in CI users over time. There was significant heterogeneity in the methodology of music assessment and the patient populations that impacted the results of the current study. In order to improve the quality of music perception research, we advocate for standard reporting guidelines for future music perception studies.

Keywords Music perception · Cochlear implantation · Music enjoyment · Music experience · Hearing loss · Implant experience · Aural rehabilitation

Introduction

Music perception after cochlear implantation (CI) has been a long-studied topic in the hearing-impaired population. Outcomes in music perception lag substantially compared to speech outcomes post-implantation. While the primary outcome of focus in cochlear implantation is speech, prior work in this area has demonstrated that music experience and enjoyment are correlated with patient-reported quality of life outcomes [1].

Numerous studies have attempted to assess music perception in the CI population. Current literature supports the notion that on average, most CI users perceive rhythm similarly to normal hearing people, but struggle with melody, pitch, timbre, and sound quality in varying ways [2••]. Most current cochlear implant studies focus on comparing music perception among CI users to normal hearing people or between CI users who did or did not receive a variety of music training [2••, 3, 4].

An extensive body of literature supports the notion that speech perception improves in CI users over time [5]. By contrast, there is relatively little research as to if and how music perception passively changes with time in CI users. Recently, a 2019 study by Ahn et. al. prospectively evaluated music perception in the CI population as a function of time and found that pitch and timbre discrimination improved with time from implantation, without any changes music-aimed interventions [6]. Gfeller et. al. also noted that greater length of implant experience was associated with increased melody-recognition abilities in CI users. [7•] However, few to no similar studies exist to create a large body of literature exploring this phenomenon.

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There is a lack of consistent correlation between implant experience duration and improved music perception [8]. Gfeller et. al. found that there was no difference in music perception and appraisal scores over a 2-year follow-up period, but the authors noted that given the paucity of literature, it is difficult to know whether two years is enough time or if a longer follow-up is warranted to see any change [9]. The numerous studies indicating that music training can improve music perception in CI users suggest an element of plasticity in music perception that can evolve over time with just day-to-day use, as opposed to formal music training.

This review of the literature aims to assess the currently available data on a study and individual patient level to determine whether increased implant experience correlates with improved music perception, specifically with regard to the broad assessment categories of rhythm, timbre/instrument identification, and melody/pitch. Due to relatively small sample sizes, lack of long-term follow-up, and variable implant experience in existing studies, we sought to evaluate whether the impact of implant experience could be evaluated with meta-analysis of pooled data.

Methods

Literature Search Methodology

A literature search was performed in the PubMed database. The PubMed search criteria used were as follows: (((((music perception) OR (music appreciation)) OR (pitch)) OR (timbre)) OR (rhythm)) AND (cochlear implant). To meet inclusion criteria, studies needed to include either average or individual-level data of CI users and music perception outcomes, specifically including implant experience duration. Any studies that were review studies, written in a foreign language, or did not specifically record outcomes relating to cochlear implant users and aspects of music perception were excluded. Any studies that looked at prelingually deafened populations or did not provide data to individually exclude prelingually deafened patients were also excluded.

Authors A.S. and K.L. reviewed the full abstract list in a blinded manner, while author T.P.H adjudicated discrepancies after the initial review. Any abstract which was not pertaining to music perception in CI users was not reviewed further. The full manuscripts were then reviewed for any abstract that met inclusion. Every manuscript was reviewed by two authors, A.S and K.L, with discrepancies again resolved by author T.P.H. At this stage, any manuscript which did not provide the appropriate variables or numerical values was subsequently excluded. Once all manuscripts were fully reviewed for inclusion, required data was extracted from each study, on an individual level if available, and used in subsequent data analysis.

Definition and Categorization of Tasks

During the qualitative analysis, tasks were grouped based on the musical outcomes reported in the study. Even if the original study classified it otherwise, for the purposes of this study, tasks were classified as follows:

1. Pitch: Tasks that required differentiating between changes in frequency of individual tones or short musical phrases
2. Melody: Tasks that required identification of musical genre or those that required differentiating between musical phrases of greater duration
3. Timbre: Tasks that required differentiating between sound quality or required identification of instruments
4. Rhythm: Tasks that required differentiating between different rhythms were classified under rhythm

Statistical Methods

The Newcastle–Ottawa Assessment was performed to determine the quality of the studies included in the current review [10].

A meta-analysis was conducted at the study level for studies that had normal hearing controls in each of the four aspects of music perception. Studies that did not report normal hearing data but were based on tests with previously published normal hearing data were included [11, 12]. Due to significant heterogeneity in the tests utilized, CI performance was normalized to the mean normal hearing performance for each test and each metric of music perception. Due to variation in the direction of tests utilized, only those tests where normal hearing listeners were expected to perform better than CI users were included. A performance ratio between cochlear implant users versus normal hearing users evaluated in the study was calculated. A random-effects model with Hartung-Knapp adjustment was used to account for study heterogeneity [13]. A summary normalized performance outcome with 95% confidence intervals using the inverse variance method was performed in R using the meta package [14]. Meta-analyses are graphically represented as forest plots. Heterogeneity of the meta-analyses was calculated and reported as I^2. The Paule-Mandel procedure was used to estimate τ^2 [15, 16].

Evaluating the relationship between CI user music perception and years of implant experience was performed at the study level and the individual level. At the study level, univariate linear regression analysis was performed between mean CI performance ratio and mean years of CI experience for each aspect of music perception. Where possible, this analysis was also performed for individuals. Given the low number of available data, additional individual analysis was undertaken. CI user performance within each reported study and test was converted into z-scores to allow for comparisons across studies. Reverse scoring was performed as necessary. Multivariate linear regression analysis was performed among all individual data from CI users that was available via the literature to evaluate music perception performance, reported as a z-score, as a function of cochlear implant experience in years. Variables analyzed included sex, age at implantation, etiology of deafness, duration of deafness, implant company, and prior musical experience as a binary variable. Pairwise deletion was utilized for missing data. Residual plots were visually inspected for normality and homoscedasticity. Analysis was performed in R, and data was visualized with the ggplot2 and patchwork packages.

Results

There were initially 68 articles that resulted from this search spanning from the years 1996 to 2022. After abstract review, 17 studies were chosen for inclusion. During the process of data extraction,1 study did not have required data available in the full text, resulting in 16 studies included in the final review (Table 1). A Newcastle–Ottawa Assessment was performed to determine the quality of the studies included in the current review. The total average score was 5.6 ± 1.5. The average score from the "Selection" subcategory was 2.9/4, "Comparability" was 1/2, and "Exposure" was 1.8/3 (Supplemental Table 1).

Performance ratios between cochlear implant users and normal hearing subjects were calculated for the measures of timbre/instrument (−0.38, CI [−0.58, −0.19], chi-squared value 82.36, $p < 0.001$, I^2 94%), melody/genre (−0.38, CI [−0.77, 0.00], chi-squared value 598.52, $p < 0.001$, I^2 99%), and rhythm (0.03, CI [−0.06, 0.13], chi-squared value 4.10, $p < 0.13$, I^2 951%) (Supplemental Fig. 1). They failed to demonstrate any significant increase in music perception performance as a function of time (Table 2).

Linear regression analysis was performed between studies as well as with individual subject data as available (Fig. 1). The R^2 values on a study level were 0.022 for rhythm, 0.37 for melody, and 0.69 for timbre. On an individual data point level, the R^2 value was 0.037 for pitch, 0.023 for melody, and 0.027 for timbre. No linear regression analysis demonstrated a strong correlation between implant experience duration and music perception.

Discussion

Overall Findings

No meaningful relationships were found between cochlear implant experience and music perception on a study or individual level using meta-analysis of pooled data. This was true both when comparing cochlear implant users to normal hearing patients, as well as when comparing CI users within the CI population. The results of this study suggest that passive, unstructured music listening is not enough to improve music perception over time in CI users. There is substantial existing evidence that active music-listening and music training can improve music perception in CI users over time [32]. Combined with the findings of this study, this may point to a loss in plasticity over time if music perception is not actively focused on. It is important to note that many of the included studies did not specifically ask for subjects' daily music listening habits, which makes it difficult to ascertain how much music subjects listened to day-to-day.

Heterogeneity in the Literature

Some studies suggest that there is a significant improvement in speech perception in CI users between 1 and 5 years post-implantation just as a function of time [33]. Although the reasons for this may be unclear, it remains possible that such a relationship does exist with regards to music perception but was not ascertained by this study given significant heterogeneity in study designs, outcome metrics, and individual patients. Among the individual CI data included in this study, there were some CI users on the higher end of music perception abilities when compared to the average on the linear regression models. An important topic to further study is what differentiates these high performers from other CI users. The current literature has failed to demonstrate any relationship between pre-implant musical experience and post-implant music perception [7•], but there is little else known about what does have an impact on post-implantation music perception.

Music perception studies in CI users employ a variety of metrics to measure aspects of music perceptions, while also typically having small sample sizes. Some studies do include individual patient data points, though many do not. We were able to pool and analyze individual data points using the validated WebPlot Digitizer tool, but these points were unable to be evaluated against many important variables such as duration of deafness and history of music training. Variability in the results could be explained in part by a lack of individual level data, but also

Table 1 Summary of studies included in review [17–31]

Study	Publication Year	No. of CI users	Average age in years (SD, Range)	Average Implant Duration in years (SD, range)	Individual hearing data available	Individual outcomes data available	Normal hearing control group available	Musical outcomes noted in study
Caldwell et al. [17]	2016	10	56.0 (5.81, 50-65)	6.7 (4.16, 2-16)	Yes	No	Yes	Pitch and frequency
Gfeller et al. [18]	2012	87	61.5 (14.1, N/A)	6.87 (5.05, NA)	No	No	Yes	Melody, timbre, rhythm
Cooper et al. [19]	2008	12	49.5 (11.84, 35-71)	4.67 (2.35, 3-10)	Yes	Yes	Yes	Pitch, melody, rhythm
Jiam et al. [20]	2019	15*	63.93 (13.42, 31-84)	7.61 (6.86, 0.75-28)	Yes	Yes	Yes	Pitch, timbre
Gfeller et al. [9]	2010	209	60.2 (15.4, 23.7-92.5)	3.53 (3.78, NA)	No	No	No[a]	Melody, timbre, enjoyment
Smith et al. [21]	2017	21	56.7 (13.7, 32-82)	2.05 (NA, 0.25-13)	Yes	No	No[a]	Timbre, music enjoyment
Vandali et al. [22]	2015	10	67 (12.26, 50-85)	6.65 (3.77, 2-11)	Yes	Yes	No	Pitch, melody
Neben et al. [23]	2013	9	53.78 (16.31, 36-73)	3.67 (1.87, 2-7)	Yes	Yes	No	Pitch melody
Filipo et al. [24]	2008	12	47.6 (N/A, N/A)	3.17 (NA, NA)	No	No	No	Pitch, timbre, general music appraisal
Gfeller et al. [25]	2002	51	55.1 (N/A, 24-81)	6.73 (NA, 1-12.67)	No	No	Yes	Timbre, general music appraisal
Rahne et al. [26]	2011	10**	53.86 (14.75, 36-77)	3.57 (3.36, 0-10)	Yes	Yes	Yes	Timbre
Arnoldner et al. [27]	2007	14	52.20 (13.24, 18.79 - 71.45)	0.98 (0.67, 0.28-2.29)	Yes	No	Yes[b]	Melody, timbre, rhythm
Looi et al. [28]	2008	9	64.7 (8.64, 49-80)	20.07 (10.28, 8-41)	No	Yes	No[c]	Pitch, melody, timbre, rhythm
Kang et al. [29]	2009	42	58 (N/A, 35-81)	4 (NA, 0-15)	No	Yes	Yes	Pitch, melody, timbre
Gfeller et al. [30]	2002	11	56.6 (13.98, 38-75)	NA (NA, 1-1.25)	No	No	No	Timbre
Müller et al. [31]	2018	14	59.9 (9.2, 46-77)	2.3 (1.5, 0.9 - 6.2)	Yes	Yes	Yes[b]	Timbre

*20 total, but pre-lingual deaf patients excluded for total included our study of 12 subjects; **10 total, but pre-lingual deaf patients excluded for total included our study of 7 subjects

[a]Normal hearing control group data published but not available

[b]Normal hearing control group data available in prior publications

[c]Only aided control group data available

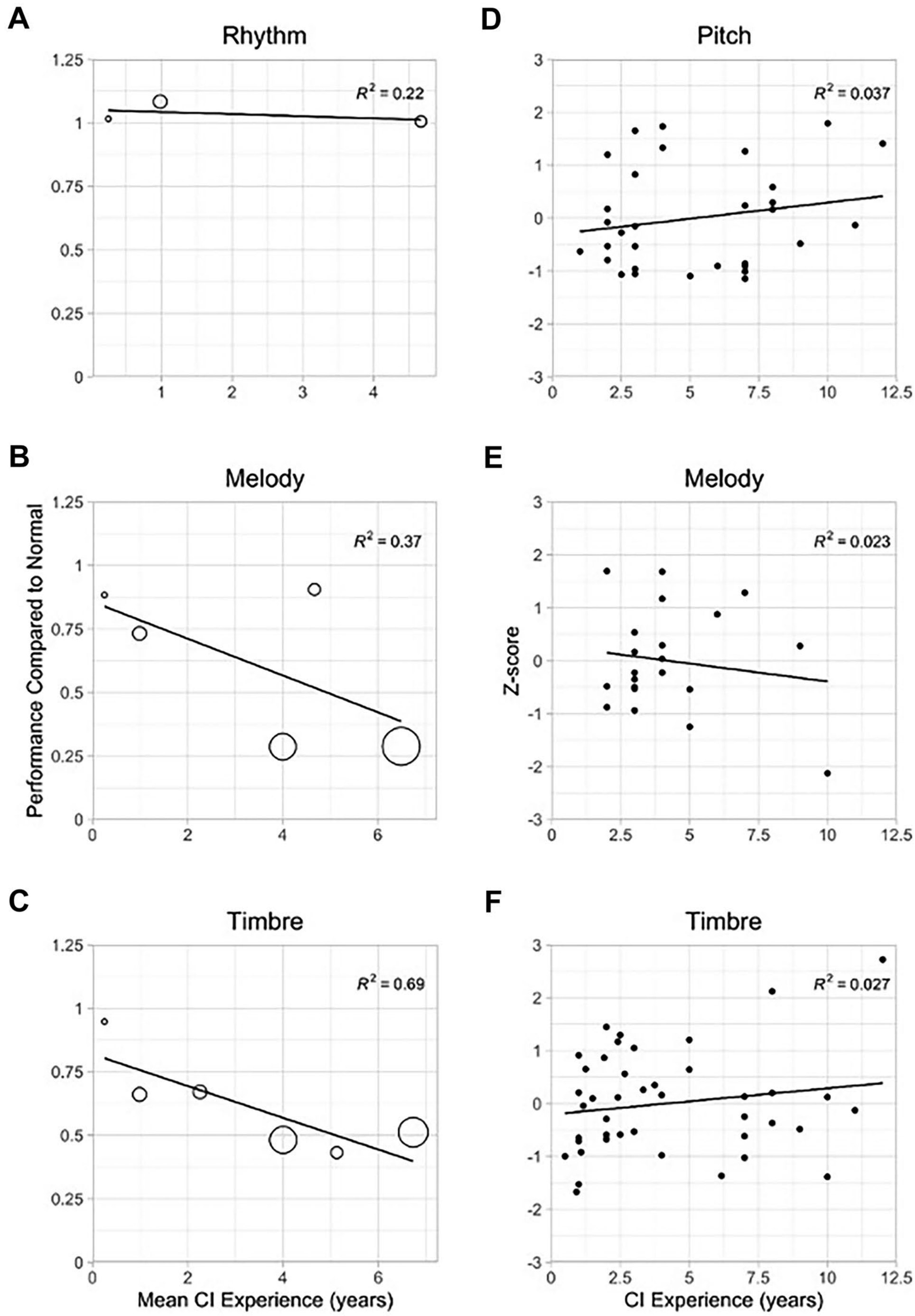

Fig. 1 Linear regression models of **A** rhythm at a study level, **B** melody at a study level, **C** timbre at a study level, **D** pitch using individual subject data, **E** melody using individual subject data, and **F** timbre using individual subject data

in the variety of metrics used to evaluate music perception. [34•] In our review, studies used tests ranging from study-specific audiologic evaluations, to validated evaluations such as the Montreal Battery of Evaluation of Amusia.

Another important aspect in assessing the heterogeneity of the current studies included is the individual quality of these studies. Based on the average scores of the Newcastle–Ottawa Scale (NOS) of included studies, the overall bias risk in the included studies is high. When this data is pooled as in our systematic review, these biases can be further compounded thus reducing the quality of conclusions that may be drawn. Many of the categories evaluated by the NOS are difficult to control in cochlear implant studies. Specifically, controlling and matching patients can be difficult as there may already be a low population of CI users in a given locale. It can also be hard to blind audiologists and evaluators who help assess outcomes in these studies, as different methods need to be used in normal hearing control subjects versus cochlear implant subjects.

Table 2 Performance ratios of cochlear implant user data versus normal-hearing subjects

	Rhythm	Timbre/Instrument	Melody
No. of studies	3	6	5
Random effects model			
Performance ratio (CI)	0.03 [−0.06, −0.13]	0.38 [−0.58, −0.19]	0.38 [−0.77,0.00]
p-value	−0.2665	0.0042	0.0515
Tau^2	0.0946	0.0348	0.0946
I^2	51%	94%	99%
Heterogeneity test			
Q	4.1	82.36	598.52
df	2	5	4
p-value	0.13	< 0.0001	< 0.0001

Future Directions

Significant heterogeneity in the methodology of music assessment and the patient populations impacted the results of the current study. We postulate that standard reporting guidelines would improve data quality for future music perception studies, and we offer some suggestions for future work. First, we advocate for the inclusion of individual-level outcomes data in future studies, linked to pertinent demographic variables. A standard reporting guideline in music perception research would further allow for standardization of research pertaining to this topic. This should include implant experience at the time of study, a quantified metric to demonstrate prior music experience and music training (for example, weekly hours), duration of deafness, and implant device. Given that no gold standard or clear "front-runner" exists at this time with respect to either objective or subjective assessment of music perception, researchers may consider z-score reporting, as done in the current study, as a strategy for comparing results across assessment types.

Conclusions

Music perception in CI users does not appear to improve as a function of passive listening and implant experience time, although these conclusions of this review are impacted by significant heterogeneity in the current data. Further research is needed to truly ascertain whether a relationship exists, especially given that there are prior studies that do support an increase in music perception abilities with increased implant experience. We strongly advocate for the inclusion of individual-level patient data linked to pertinent demographic variables, a standardized set of reported variables, and consideration of a standardized metric by which to evaluate music perception in CI users to be incorporated in future studies.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s40136-022-00418-1.

Declarations

Conflict of Interest The authors declare no competing interests.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

References

Papers of particular interest, published recently, have been highlighted as:
• Of importance
•• Of major importance

1. Drennan WR, Rubinstein JT. Music perception in cochlear implant users and its relationship with psychophysical capabilities. J Rehabil Res Dev. 2008;45(5):779–89. https://doi.org/10.1682/jrrd.2007.08.0118.
2.•• McDermott HJ. Music perception with cochlear implants: a review. Trends Amplif. 2004;8(2):49–82. https://doi.org/10.1177/108471380400800203. **Review, although from some years ago, laid important groundwork for baseline music perception expectations in cochlear implant users.**
3. Limb CJ, Rubinstein JT. Current research on music perception in cochlear implant users. Otolaryngol Clin North Am. 2012;45(1):129–40. https://doi.org/10.1016/j.otc.2011.08.021.
4. Shukor NFA, Lee J, Seo YJ, Han W. Efficacy of music training in hearing aid and cochlear implant users: a systematic review and meta-analysis. Clin Exp Otorhinolaryngol. 2021;14(1):15–28. https://doi.org/10.21053/ceo.2020.00101.
5. Krueger B, Joseph G, Rost U, Strauss-Schier A, Lenarz T, Buechner A. Performance groups in adult cochlear implant users: speech perception results from 1984 until today. Otol Neurotol. 2008;29(4):509–12. https://doi.org/10.1097/MAO.0b013e318171972f.
6. Ahn J, Ryu G, Cho YS. Long-term changes in musical perception in Korean cochlear implant patients. Otol Neurotol. 2019;40(3):312–20. https://doi.org/10.1097/MAO.0000000000002098.
7.• Gfeller K, Oleson J, Knutson JF, Breheny P, Driscoll V, Olszewski C. Multivariate predictors of music perception and appraisal by adult cochlear implant users. J Am Acad Audiol. 2008;19(2):120–134. https://doi.org/10.3766/jaaa.19.2.3. **This is one of the studies that does provide some evidence that there can be improvement in domains of music perception**

with passive cochlear implant use over time. Studies like this are uncommon as most evaluate changes with music training rather than passive use.

8. Looi V, Gfeller K, Driscoll V. Music appreciation and training for cochlear implant recipients: a review. Semin Hear. 2012;33(4):307–34. https://doi.org/10.1055/s-0032-1329222.
9. Gfeller K, Jiang D, Oleson JJ, Driscoll V, Knutson JF. Temporal stability of music perception and appraisal scores of adult cochlear implant recipients. J Am Acad Audiol. 2010;21(1):28–34. https://doi.org/10.3766/jaaa.21.1.4.
10. Peterson J, Welch V, Losos M, Tugwell P. The Newcastle-Ottawa scale (NOS) for assessing the quality of nonrandomised studies in meta-analyses. Ottawa Ottawa Hospital Research Institute. 2011;2(1):1–12.
11. Looi V, McDermott H, McKay C, Hickson L. Music perception of cochlear implant users compared with that of hearing aid users. Ear Hear. 2008;29(3):421–34. https://doi.org/10.1097/AUD.0b013e31816a0d0b.
12. Brockmeier SJ, Fitzgerald D, Searle O, et al. The MuSIC perception test: a novel battery for testing music perception of cochlear implant users. Cochlear Implants Int. 2011;12(1):10–20. https://doi.org/10.1179/146701010X12677899497236.
13. Knapp G, Hartung J. Improved tests for a random effects meta-regression with a single covariate. Stat Med. 2003;22(17):2693–710. https://doi.org/10.1002/sim.1482.
14. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. 2020.
15. Paule RC, Mandel J. Consensus values and weighting factors. J Res Natl Bur Stand (1977). 1982;87(5):377–85. https://doi.org/10.6028/jres.087.022.
16. Bakbergenuly I, Hoaglin DC, Kulinskaya E. Methods for estimating between-study variance and overall effect in meta-analysis of odds ratios. Res Synth Methods. 2020;11(3):426–42. https://doi.org/10.1002/jrsm.1404.
17. Caldwell MT, Jiradejvong P, Limb CJ. Impaired perception of sensory consonance and dissonance in cochlear implant users. Otol Neurotol. 2016;37(3):229–34. https://doi.org/10.1097/MAO.0000000000000960.
18. Gfeller K, Jiang D, Oleson JJ, et al. The effects of musical and linguistic components in recognition of real-world musical excerpts by cochlear implant recipients and normal-hearing adults. J Music Ther. 2012;49(1):68–101. https://doi.org/10.1093/jmt/49.1.68.
19. Cooper WB, Tobey E, Loizou PC. Music perception by cochlear implant and normal hearing listeners as measured by the Montreal Battery for Evaluation of Amusia. Ear Hear. 2008;29(4):618–26. https://doi.org/10.1097/AUD.0b013e318174e787.
20. Jiam NT, Deroche ML, Jiradejvong P, Limb CJ. A randomized controlled crossover study of the impact of online music training on pitch and timbre perception in cochlear implant users. J Assoc Res Otolaryngol. 2019;20(3):247–62. https://doi.org/10.1007/s10162-018-00704-0.
21. Smith L, Bartel L, Joglekar S, Chen J. Musical rehabilitation in adult cochlear implant recipients with a self-administered software. Otol Neurotol. 2017;38(8):e262–7. https://doi.org/10.1097/MAO.0000000000001447.
22. Vandali A, Sly D, Cowan R, van Hoesel R. Training of cochlear implant users to improve pitch perception in the presence of competing place cues. Ear Hear. 2015;36(2):e1–13. https://doi.org/10.1097/AUD.0000000000000109.
23. Neben N, Lenarz T, Schuessler M, Harpel T, Buechner A. New cochlear implant research coding strategy based on the MP3(000™) strategy to reintroduce the virtual channel effect. Acta Otolaryngol. 2013;133(5):481–90. https://doi.org/10.3109/00016489.2012.753639.
24. Filipo R, Ballantyne D, Mancini P, D'elia C. Music perception in cochlear implant recipients: comparison of findings between HiRes90 and HiRes120. Acta Otolaryngol. 2008;128(4):378–81. https://doi.org/10.1080/00016480701796955.
25. Gfeller K, Witt S, Woodworth G, Mehr MA, Knutson J. Effects of frequency, instrumental family, and cochlear implant type on timbre recognition and appraisal. Ann Otol Rhinol Laryngol. 2002;111(4):349–56. https://doi.org/10.1177/000348940211100412.
26. Rahne T, Böhme L, Götze G. Timbre discrimination in cochlear implant users and normal hearing subjects using cross-faded synthetic tones. J Neurosci Methods. 2011;199(2):290–5. https://doi.org/10.1016/j.jneumeth.2011.05.022.
27. Arnoldner C, Riss D, Brunner M, Durisin M, Baumgartner WD, Hamzavi JS. Speech and music perception with the new fine structure speech coding strategy: preliminary results. Acta Otolaryngol. 2007;127(12):1298–303. https://doi.org/10.1080/00016480701275261.
28. Looi V, McDermott H, McKay C, Hickson L. The effect of cochlear implantation on music perception by adults with usable pre-operative acoustic hearing. Int J Audiol. 2008;47(5):257–68. https://doi.org/10.1080/14992020801955237.
29. Kang R, Nimmons GL, Drennan W, et al. Development and validation of the University of Washington Clinical Assessment of Music Perception test. Ear Hear. 2009;30(4):411–8. https://doi.org/10.1097/AUD.0b013e3181a61bc0.
30. Gfeller K, Witt S, Adamek M, et al. Effects of training on timbre recognition and appraisal by postlingually deafened cochlear implant recipients. J Am Acad Audiol. 2002;13(3):132–45.
31. Müller V, Klünter H, Fürstenberg D, Meister H, Walger M, Lang-Roth R. Examination of prosody and timbre perception in adults with cochlear implants comparing different fine structure coding strategies. Am J Audiol. 2018;27(2):197–207. https://doi.org/10.1044/2017_AJA-17-0046.
32. Shukor NFA, Lee J, Seo YJ, Han W. Efficacy of music training in hearing aid and cochlear implant users: a systematic review and meta-analysis. Clin Exp Otorhinolaryngol. 2021;14(1):15–28. https://doi.org/10.21053/ceo.2020.00101.
33. Dillon MT, Buss E, Adunka MC, et al. Long-term speech perception in elderly cochlear implant users. JAMA Otolaryngol Head Neck Surg. 2013;139(3):279–83. https://doi.org/10.1001/jamaoto.2013.1814.
34. • Hwa TP, Wen CZ, Ruckenstein MJ. Assessment of music experience after cochlear implantation: a review of current tools and their utilization. World J Otorhinolaryngol Head Neck Surg. 2021;7(2):116–125. Published 2021 Apr 3. https://doi.org/10.1016/j.wjorl.2021.02.003. **This is an important paper that goes into detail on the heterogeneity that exists within the music-perception evaluation domain. This also supports the recommendation that standardization of evaluation/data collection can help create stronger future studies.**