Spring 2021

Musicians who use Cochlear Implants Proposal

Leanne Bunnell
lmb223@uakron.edu

Audiology Practices with Musicians who use Cochlear Implants:

A Scoping Review

Leanne Bunnell

School of Speech-Language Pathology and Audiology, The University of Akron

Akron, Ohio, United States

Correspondence concerning this article should be addressed to Leanne Bunnell, University of Akron,

Email: lmb223@uakron.edu

Acronyms: CI = Cochlear Implant; HA = Hearing Aid; NH = Normal Hearing; FSP = Fine-structure processing; HDCIS = High-Definition Continuous Interleaved Sampling; MQRTB = Music Quality Rating Test Battery

Abstract

The purpose of this scoping review was to provide information about the current research related to audiological practices regarding the population of musicians who use cochlear implants technology. This scoping review included studies that investigated post implantation therapy/activities designed to assist users who were also musicians. A scoping review identifies trends and gaps in available evidence. This information can be used to inform on practices currently being used in the audiologic field and identify areas for further research. A scoping review was conducted in April 2021 to identify English-language peer-reviewed journal articles published from 2010 to March 2021. Thematic analysis was used to identify trends among the literature. Six articles were identified that met the inclusion criteria. Four themes related to type of intervention were identified to explore improvements in music skill outcomes in cochlear implant users who were musicians, including: processor, music perception, post implant therapy, and questionnaire. Gaps in the literature were identified regarding the population of cochlear implant users who are musicians. More research in this area is imperative to assist in identifying effective interventions as well as to assist in device choice for the musicians that use or are looking at using cochlear implant technology as well as continuing their lives in the music world post implantation.

Keywords: Cochlear Implants, musicians, audiology

Audiology Practices with Musicians who use Cochlear Implants:

A Scoping Review

Music plays a significant role in societies worldwide and as accessibility of music continues to grow so does the number of people who find joy in it. In defining the characteristics of music Looi (2012) described them as there being "four basic psychological attributes to musical sound – pitch, duration, loudness and timbre." *Pitch* "refers to the low to high ordering of sound" more commonly known as melody, *duration* refers to the length of time a frequency is present for, *loudness* is the decibel level of the sound, and *timbre* is "a multidimensional l attribute related to differences in sound spectra" (Looi, 2012). These four factors combine in infinite ways to create the distinct kinds of music we all know and love, and musicians (whether beginners or experts), need to hear, listen, process, and fully understand these characteristics to perform and appreciate music. Individuals with hearing loss and who use hearing technology often receive benefit from hearing technologies to better understand both spoken communication (Hotton, 2018) and music (Looi et al., 2008); however, a sub-population of cochlear implant users tend to experience additional challenges due to the limitations of their technology such as low pitch accuracy, lower music quality and lower acoustic quality (Roy, 2015; Fulford, 2011).

Music is like speech in the sense that both are complex sound waves with components such as "frequency, temporal, intensity, and timbral" being seen in an organized manner (Looi, 2012). Speech and music also have a lot of differences, two of the major ones being range of fundamental frequencies and accurate perception of the first fundamental frequency (F0). Though it is worth stating that the accuracy of perception of F0 only differs from music in non-tonal languages such as English (Looi, 2012). These two differences are where the problem for individuals with hearing loss, and more specifically, cochlear implant users can occur.

Cochlear Implants are devices that are used to help patients improve their hearing when traditional hearing aids may not be their best option. A cochlear implant is made up of five parts: a

microphone, a speech processor, a transmitter, a receiver, and an electrode array. The microphone, speech processor and transmitter make up the external part of the cochlear implant. Like that of a hearing aid, the microphone picks up sound and sends it to the speech processor so that the information can be processed. Once the information is processed it is sent through the transmitter to the internal portion of the cochlear implant. The internal portion of the cochlear implant is made up of a receiver and an electrode array. The internal portion of the cochlear implant is surgically implanted with the receiver implanted in the mastoid bone of the skull and the electrode array is placed in the cochlea of the inner ear. The cochlear implant device sends the information processed through the receiver to the cochlear array. The cochlear implant completely bypasses the outer, middle, and inner ear and directly stimulates the auditory nerve.

Cochlear implants (CI) are a common and useful device to help patients who are deaf or severely hard-of hearing. “As of December 2019, approximately 736,900 registered devices have been implanted worldwide. In the United States, roughly 118,100 devices have been implanted in adults and 65,000 in children.” (*Cochlear Implants,* 2018). With the population of individuals who use cochlear implants becoming so large it is important to assure that those that use these devices can continue to participate in their normal day-to-day activities. Today cochlear implant recipients have shown significant improvement in speech and language perception. This has also led a decrease in disputes regarding the effectiveness of CI devices across the lifespan. While most cochlear implant candidates are primarily focused on improving their sense of hearing and in addition improving communication, it is not necessarily the same for those with an interest in music. There is a hesitancy with the musician population because of questions regarding their abilities to hear, appreciate and preform or participate in musical activities post-surgery.

One important thing to remember with CI technology is that a normal hearing person’s “number of outer hair cells in the cochlea has been estimated at 12,000 and the number of inner hair cells at

3,500" ("Human ear - Organ of Corti | Britannica," 2019). This means that the average person without any form of hearing loss has an average of 15,000 functioning hair cells. However, a cochlear implant with today's technology is limited "Up to 22 electrodes" (Enjoying Music with a Cochlear Implant, 2018). These 22 electrodes are tasked with doing the job of thousands of hair cells. This decrease in sensors in the cochlea leads to poor frequency resolution as well as a compromised pitch and timbre recognition (Enjoying Music with a Cochlear Implant, 2018). This is also where inaccurate F0 perception becomes a problem in music recognition as seen on the difference between the current speech and music performance test scores (Looi, 2012). These disadvantages make musicians' music lives harder, especially for those that remember what music used to sound like before their implant and/or hearing loss.

Cochlear implant manufacturers and researchers continue to make several recommendations on which cochlear implants to select, programs to use and interventions post implantations to follow for best musical perception and enjoyment. These recommendations, however, are lacking in number and far between with little to no research backing them up. Thus, the purpose of this scoping review was to analyze and combine information regarding audiological practices for musicians who chose to use cochlear implant technology. The scoping review will be used to clarify key concepts in addition to identifying both gaps and trends in current research. This information can be used to identify further research opportunities and inform current audiological practice regarding musicians who are interested in or have cochlear implants.

Methods

Procedure

A scoping literature was conducted in April 2021 using the PRISMA extension guidelines (*Prisma,* 2021). A scoping review is a type of literature review that identifies and assists with mapping

available research for a specific topic (Munn et al., 2018). The mapping provided by the scoping review is helpful in determining where there are gaps in the research. A scoping review can analyze research while not having a specific question which would need to be answered through a systematic review. The scoping review, however, is still completed following a systematic pattern in which you start with a high amount of research articles and filter cut the amount down at each step until all that remains articles that fit all the criteria.

A scoping review was chosen over a systematic review for a couple of reasons. The first one being the ability to scan over a large amount of researcher easier. With a systematic review you are unable to scan through as much research in the same amount of time due to the difference in levels of analysis whereas with a scoping review you can cast a broad search and look of more research. The other main reason a scoping review was chosen was because there was not a specific question asked in the review, but rather a general topic. The researchers for this review wanted to have the ability to look at all the different methods of assistance that would be available to help the target population and to compile it into one place. This would not have been possible with a systematic review as the question would have needed to be more specific. The last reason a scoping review was a better fit for this study was because of how little the amount of research on the topic is. The types of methods found through this review all differ from each other quite a bit. With a scoping review we can include and review different study designs in one article, whereas, with a systematic review this would be less feasible.

For review, articles in this study needed to address audiological programming/mapping or therapy methods designed to help musicians who use cochlear implant technology with music quality. The restriction to cochlear implants was selected because of how much poorer music enjoyment is for cochlear implant patients than patients with hearing aid technology as well as limited research on other implantable hearing technologies. Articles included in this review were peer – reviewed articles published between 2010 and March 2021, representing a more current sampling of literature that

would include newer programming strategies or information not previously reviewed. Articles were excluded if the population did not use CI technology, the population did not focus on musicians or if the articles were not in English.

Articles were searched using a multi-database platform tool, ZipSearch, available through the University of Akron. The search was completed using the following key words/phrases; “cochlear*”, “music*” and “hearing loss or deafness or hearing impairment or deaf or hard of hearing”. These phrases were used to cast a wide net of varying research articles to scan for this scoping review to find all articles that may have different methods to assist the target population. An additional article was added outside of the database search from a journal website’s similar article posting, and both the author and honors project sponsor decided to include it in the study.

Both the author and honors project sponsor developed a data charting form prior to the search being conducted, the search was then completed by the author independently. The first step in the review was having the articles reviewed by title and abstracts to see if both matched criteria. After that, a full text review was completed by both parties. The articles were then discussed to finalize selection for the review. Eleven articles were deemed to most closely meet the inclusion criteria from ZipSearch with one article being was added from the same journal as a previously selected article (see Figure 1 for article inclusion flowchart). Five articles were subsequently excluded due to one article not being published in English, two were abstracts from a conference journal lacking sufficient study details to review, and an additional two articles were previous literature reviews. The remaining six articles were analyzed.

Analysis

Due to multiple research designs used, a meta-analysis could not be completed. A qualitative assessment was completed, and themes related to research that focused on musicians with cochlear implants were synthesized, and a narrative summary was generated.

Results

The scoping review revealed six peer-reviewed research articles that were published between 2010 and March 2021, that studied methods to assist musicians adapting to using cochlear implant technology. Of these, four general study designs were found regarding the target population (see Review Table for study details): Processors (n=1), Music Perception (n=1), Post-Implant Therapy (n=3) and Questionnaire (n=1).

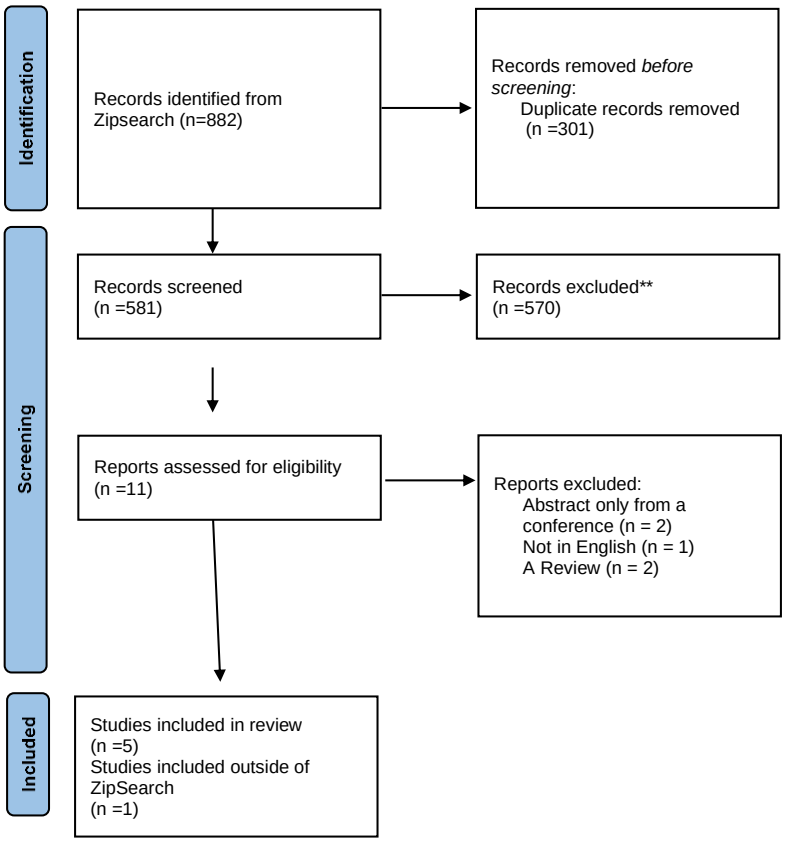

Table 1. Review Table

Year / First Author	Design	Population	CI Music Strategy	Outcome Measures	Overall Conclusions
2011 Looi	Pilot study to compare processing strategies of CI.	1. (n=65) adults. 2. (n=10) normal hearing adults). 3. (n=5) post-lingually deafened CI recipients from NZ and Australia	FSP vs. HDCIS	MQRTB - Music quality rating test battery	FSP (fine-structure processing) is better for music appreciation, MQRTB is effective.
2012 Rocca	Clinical Experience	Children with CIs is a school for Deaf children	Music Therapy	Music-Based Habilitation	The consistent use of music has led to children confidently participating in musical contexts
2012 Plant	Clinical experience	(MFG) The population ranges from 5-25 CI users per group (SC) n = 44 CI users	Music Reintroduction	Music focus groups (MFG), special compositions (SC)	(MFG) Music enjoyment was 6.2 /7 (1 being terrible and 7 being excellent) (SC) 5.6/7
2015 Hutter	Research Experiment	(n=12) unilaterally implanted post-lingually deafened CI users	Individualized Music Therapy	Hearing Implant Sound Quality Index; Multidimensional Self-Concept Scales	Subjective sound quality and the global score on the self-concept questionnaire improved
2015 Vannson	Small group study	(n=30) 11 normal-hearing listeners, 11 bimodal CI and hearing-aid users, and 8 bilaterally implanted CI users	Dichotic vs. Diotic in Music Clarity	Dichotic Listening	No significant differences between diotic and dichotic presentation
2019 Gfeller	Small group study	(n=6) adult Ci users	Music Engagement	Active music making	Reflections of six CI users who successfully engage in active music making

Processors

The first category this review aimed to find information from the literature about was that of making mapping/programming changes, or identifying different manufacturers/processors to see which one was better for the musician population. Only one article fit this category (Looi, Winter, Anderson, & Sucher, 2011). The researchers developed an instrument and test battery in this study to compare the appraisal ratings from CI users called the Music Quality Rating Test Battery (MQRTB). The test battery included a set of ten songs across five distinct categories (Modern, classical, common, country, and western) of music. This resulted in two songs in each category, one obscure song and one familiar. The test battery went through three separate stages. The first was used to select songs to be included in the MQRTB. Then the researchers compared length and complexity of chosen songs on a group of normal hearing individuals. The last stage of the research was a pilot study using the MQRTB.

In the pilot study, the five CI recipients were from New Zealand and Australia and were all post-lingually deafened. The pilot study compared two speech processing strategies, the fine structure processing (FSP) strategy and the high-definition continuous interleaved sampling (HDCIS) strategy. The pilot study discovered two important findings. The first being that the FSP was rated better by study participants than the HDCIS in terms of music appreciation for the sound processor. The second being that the MQRTB is an effective way of comparing speech processing strategies for music with CI recipients.

Music Perception

Music perception is the way an individual perceives enjoyment from music. By changing the way, we perceive music can make for a more enjoyable listening experience. Only one article fell into the music perception category (Vannson, Innes-Brown, and Marozeau, 2015). This is important for CI recipients as music enjoyment is “often reported to be unsatisfactory” (Vannson et al., 2015). To make

music be perceived as more enjoyable, the research team developed a study comparing monophonic listening (both parts in same ear), diotic mode listening (both parts both ears) to dichotic listening (the bass and treble clef parts of short polyphonic piano pieces separately to each ear). The authors had a sample size of 30 persons (n=11 normal-hearing, n=11 Bimodal CI and HA users, n=8 Bilaterally implanted CI users).

The study involved twenty-eight lyric-free piano pieces with the goal to elicit either a happy or sad response. Each piece had a duration of ten to fifteen seconds. The pieces are presented in four different configurations; Monaural (both parts sent to best ear), Diotic (both parts sent to both), Dichotic 1 (Treble sent to best ear, Bass sent to opposite) and Dichotic 2 (Bass sent to best, Treble sent to opposite). The results of the study show that regardless of having normal hearing, bimodal CI, and HA, or two cochlear implants, there were no significant differences in music perception.

Post-Implantation Therapy

More rigorous post implantation music training/intervention methods were found in four articles (Rocca, 2012; Plant 2012; Hutter, 2015; Gfeller, 2019). Both Rocca and Plant's articles were based off clinical cases; whereas Vannson and Gfeller's used an experimental design.

Rocca (2012) highlighted plans and timelines to help expose children with cochlear implants to music in a beneficial manner and based on observations made at the Mary Hare School for Deaf Children. The article described that through consistent use of music, the amount of participation in musical events also increases for the children using CIs.

Plant (2012) revealed many of the same ideas as Rocca, however with an adult population. Plant's article has two separate types of therapy, the first was call Music Focus Groups and the second was referred to as Special Compositions for cochlear implant users. In the first group, the size of each group ranged from five to twenty-five. The groups were designed to promote a supportive environment

to listen to music. In the second type of therapy, the creation of special compositions designed for enjoyment for cochlear implant recipients were tested among study participants. The therapies were assessed across 44 CI recipients. Both therapy types were rated by participants on a scale of one to seven, one being terrible and seven being excellent. Special compositions had an average score 5.6 and Music Focus Group had an average score of 6.2. The results implied that the Music Focus Groups were deemed more favorable by the CI recipients than the special compositions.

The third study (Hutter, 2015) created an individualized music therapy method including aspects such as melody recognition, pitch discrimination and timbre identification using a hearing implant sound quality index and a multidimensional self-concept scale to measure improvement. The study had a population of 12 unilaterally implanted post-lingually deafened CI users. After the individualized therapies there was improved scores on subjective sound quality.

Questionnaire

The final study (Gfeller, 2019) focused on music engagement through active music making. The study had a population of n=6 adult CI users with a high-level of musicianship. The study used a questionnaire to investigate the narratives of these six individuals in attempts to find methods that can be generalized to other CI using musicians. The results of the questionnaire show six successfully engaged individuals. Their reflections have shown an importance in “pre-CI music instruction, extensive practice and immersion in music listening and playing, persistence and self-efficacy, and problem-solving skills that optimize music engagement” (Gfeller, 2019).

Discussion

Cochlear implant technology has been showing steady progress in the terms of speech, however, the music aspect is seen as lacking by many CI recipients. For musicians this creates a hesitancy because of questions about their abilities to hear, appreciate and preform or participate in

musical activities post-surgery. The purpose of this scoping review was to provide information regarding what strategies currently exist in research to assist musicians with Cochlear implant devices. This scoping review discovered research gaps as well as opportunities to further research.

To present date, the gaps in research regarding the target population provides many limitations. All research that was used took place with small sample sizes and no acknowledgement to different demographics apart from adult vs. child. This scoping review found no research regarding different brands of CI devices performance in addition to limited research on comparing different programs and processors. Additionally, research is needed to identify which therapies are most beneficial to specifically professional musicians.

Most research reviewed was found to be in music therapy post-implantation, showing that therapy/training can lead to positive results. From Rocca (2012) and Plant (2012), studies show that across children and adults, there are approaches that can be taken to increase music appreciation by merely exposing cochlear implant users to songs, styles, and genres of music that they might be interested in. Hutter (2015) likewise showed that by individualizing therapy to the interests of users can be of support; however, more research regarding an outline of how to set up therapy would be a good next step.

Gfeller (2019) identified even among experienced or successful musicians who use CIs, there are still many gaps to investigate, including differences between pre-CI and post-CI therapies, practice durations of music training that could lead to more/less success, and the need for studies involving personality and attitude coaching to help keep CI recipients in a headspace to work hard for their musical success. The results collectively describe post-implant therapy groups may be more effective than any technological or programming approach for now; however, more research is still needed to determine the implications of CI mapping and musician outcomes.

Scoping Review Limitations

In the little research that was available, there was no indication from the literature regarding which manufacturer, implant, or external sound processors are best for the target population of musicians. A systematic review of additional databases with other existing data available from the manufacturers themselves (e.g., "white papers") could increase the sampling of articles and data to review. This review showed that there is little difference in music perception among cochlear implant users and those with normal hearing (Vannson et al., 2015); suggesting that cochlear implants have improved aspects of musical participation among CI users (e.g., pitch perception among users); however, there is need for additional research to explore other areas/characteristics of music perception, performance, and appreciation.

Conclusion

This scoping review revealed a scarcity in research regarding audiologic practices to help musicians with cochlear implants. More research is needed to identify the best products, programs, and intervention methods for these patients. This review revealed important gaps in research to be explored by future researchers. It is important to fill these gaps in research to improve the musicianship and overall quality of life for this population. The tools identified in some of these studies may lead to effective use of clinical monitoring of outcomes within audiological practices, and referrals to music therapists or music education may be warranted for specific implant recipients desiring to improve in their musical abilities.

References

Cochlear Implants. (2018, June 15). NIDCD. Retrieved from https://www.nidcd.nih.gov/health/cochlear--implants

Enjoying Music with a Cochlear Implant. (2018, December 11). University of Southhampton. Retrieved from Enjoying music with a cochlear implant | University of Southampton

Fulford, R., Ginsborg, J., & Goldbart, J. (2011). Learning not to listen: the experiences of musicians with hearing impairments. Music Education Research, 13(4), 447–464. https://doi-org.ezproxy.uakron.edu:2443/10.1080/14613808.2011.632086

Gfeller, K., Driscoll, V., & Loui, V. (2012). Music Appreciation and Training for Cochlear Implant Recipients: A Review. *Seminars in Hearing*, *33*(04), 307–334. https://doi.org/10.1055/s-0032-1329222

Gfeller, K., Mallalieu, R. M., Mansouri, A., McCormick, G., O'Connell, R. B., Spinowitz, J., & Gellinek Turner, B. (2019). Practices and Attitudes That Enhance Music Engagement of Adult Cochlear Implant Users. *Frontiers in Neuroscience*, *13*. https://doi.org/10.3389/fnins.2019.01368

Granello, D. H., & Wheaton, J. E. (2004). Online Data Collection: Strategies for Research. Journal of Counseling & Development, 82(4), 387–393. https://doi-org.ezproxy.uakron.edu:2443/10.1002/j.1556-6678.2004.tb00325.x

Hotton, M., & Bergeron, F. (2018). A systematic review of the effectiveness of hearing technologies on speech perception outcomes for people with a severe-to-profound high-frequency hearing loss. Canadian Journal of Speech-Language Pathology and Audiology, 42(2), 95–115.

Human ear - Organ of Corti | Britannica. (2019). In Encyclopædia Britannica. https://www.britannica.com/science/ear/Organ-of-Corti

Hutter, E., Argstatter, H., Grapp, M., & Plinkert, P. K. (2015). Music therapy as specific and complementary training for adults after cochlear implantation: A pilot study. *Cochlear Implants International*, *16 Suppl 3*, S13-21. https://doi.org/10.1179/1467010015Z.000000000261

Looi, V., McDermott, H., McKay, C., & Hickson, L. (2008). Music Perception of Cochlear Implant Users Compared with that of Hearing Aid Users. *Ear and Hearing*, *29*(3), 421–434. https://doi.org/10.1097/aud.0b013e31816a0d0b

Looi, V., Winter, P., Anderson, I., & Sucher, C. (2011). A music quality rating test battery for cochlear implant users to compare the FSP and HDCIS strategies for music appreciation. *International Journal of Audiology*, *50*(8), 503–518. https://doi.org/10.3109/14992027.2011.562246

Munn, Z., Peters, M. D. J., Stern, C., Tufanaru, C., McArthur, A., & Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, *18*(1). https://doi.org/10.1186/s12874-018-0611-x

Nogueira, W., Nagathil, A., & Martin, R. (2019). Making Music More Accessible for Cochlear Implant Listeners: Recent Developments. *IEEE Signal Processing Magazine*, *36*(1), 115–127. https://doi.org/10.1109/msp.2018.2874059

Plant, G. (2012). Reintroducing Music to Adults with Cochlear Implants. *Seminars in Hearing*, *33*(04), 419–424. https://doi.org/10.1055/s-0032-1329228

PRISMA. (2021). Www.prisma-Statement.org. http://www.prisma-statement.org/Extensions/ScopingReviews

Rocca, C. (2012). A Different Musical Perspective: Improving Outcomes in Music through Habilitation, Education, and Training for Children with Cochlear Implants. Seminars in Hearing, 33(04), 425–433. https://doi.org/10.1055/s-0032-1329229

Roy, A. T., Vigeant, M., Munjal, T., Carver, C., Jiradejvong, P., & Limb, C. J. (2015). Reverberation negatively impacts musical sound quality for cochlear implant users. Cochlear Implants International: An Interdisciplinary Journal, 16, S105–S113. https://doi-org.ezproxy.uakron.edu:2443/10.1179/1467010015Z.000000000262

Vannson, N., Innes-Brown, H., & Marozeau, J. (2015). Dichotic Listening Can Improve Perceived Clarity of Music in Cochlear Implant Users. *Trends in Hearing*, *19*, 233121651559897. https://doi.org/10.1177/2331216515598971