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## Perception of emotion in music in adults with cochlear implants

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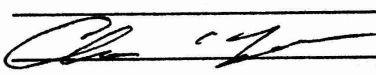
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Applicant Delainey Jaye Spragg  
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Thesis title Perception of emotion in music in adults with cochlear implants

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Read, approved, and signed by:  5/7/2018  
Thesis adviser(s) Dr. Tonya Bergeson-Dana Date

Reader(s)  5/7/2018  
Date  
Dr. Charles Yates Date

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Director, Honors Program Date

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**Perception of emotion in music in adults with cochlear implants**

A Thesis

Presented to the Department of Communication Sciences and Disorders

College of Communications

and

The Honors Program

of

Butler University

In Partial Fulfillment

of the Requirements for Graduation Honors

Delainey Jaye Spragg

May 8th, 2018

**Author Note**

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### **Abstract**

Music is an integral aspect of culture that is uniquely tied to our emotions. Previous studies have shown that hearing loss and cochlear implantation have deleterious effects on music and emotion perception, particularly cues related to pitch, melody, and mode. The purpose of this study is to examine acoustic cues that adults with cochlear implants and adults with normal hearing might use to perceive emotion in music (e.g., tempo and pitch range). One adult (ages 18-50 years) with a cochlear implant and 15 adults who have normal hearing were tested. The participants listened to a series of 40 melodies which varied along tempo and pitch range. Ten melodies conveyed sadness (small pitch range; slow tempo) and 10 conveyed happiness (large pitch range; fast tempo). The remaining 20 presented conflicting cues (small pitch range + fast tempo or large pitch range + slow tempo). We asked participants to rate the emotion of the musical excerpt on a 7-point Likert scale along three dimensions: happy-sad, pleasant-unpleasant, and engaged-unengaged. Results showed that adults with NH and CIs relied on tempo more than pitch range when perceiving emotion in music, but in two instances adults with NH took pitch range into account when rating. The results from this study will help shed light on how effectively cochlear implants convey musical emotions, and could eventually lead to improvements in music perception in listeners with hearing loss.

### **Perception of emotion in music in adults with cochlear implants**

Have you ever been driving in the car and hear a song for the first time that brings a smile to your face, creates movement in your body, and makes it impossible to be anything but happy? Or perhaps you have the complete opposite reaction: The song swells up tears in your eyes, stillness in your extremities, and a somber feeling as you listen. These scenarios highlight the power of music in the lives, and limbic systems, of humans with the ability to hear from a variety of countries around the world.

Music is an integral aspect of culture. Music is a part of everyday rituals including religious ceremonies, education, in the background at the grocery store, and so much more. Music also influences our emotions. We listen to music when we're having a bad day, a good day, when we want to get pumped up for a workout or calmed down for bed. Elements like tempo, rhythm, dynamics, and pitch play a role in composers' portrayal of emotion, and are processed together when those with normal hearing respond emotionally to the music around them.

Balkwill and Thompson (1999) examined the ability of people from one culture (Western) to identify the intended emotion of a piece of music from a culture (Hindustani raga) that is not their own, but instead a "brand-new," unfamiliar tonal system to the listeners. The listeners rated the music on the degree of joy, sadness, anger, and peace as well as provided ratings for tempo, rhythmic complexity, melodic complexity and pitch range. The results showed that listeners were sensitive to emotion in music in a different culture and that is due to the psychophysical cues examined in the study: tempo, rhythmic complexity, melodic complexity, and pitch range. One question addressed in the current

study is whether individuals who have impaired hearing abilities and experience sounds through cochlear implants hear emotion in music the same way?

Cochlear implants (CI) are assistive electrical hearing devices for individuals who have profound hearing loss. The device includes a series of electrodes surgically placed into the cochlea. The electrodes stimulate specific frequencies, which are arranged tonotopically in the cochlea. The original purpose of the device was to aid in lip reading. With the advance of technology, the implant is still now more specialized for the perception of speech than music (Gfeller et al. 2006). Although there have been advancements in the capabilities of the device since its conception, there are still limitations, including a limited number of electrodes available to represent the vast array of frequencies present in typical speech and music.

Music is comprised of a variety of frequencies, but it is the perceived pitch of lower notes in musical pieces that truly round out the sound and help create the entire emotional experience. Unfortunately, due to the tonotopic arrangement of the cochlea and the electrodes not reaching the apical end, the lower frequencies are not encompassed in the electronic sound produced by the cochlear implant and not at the same location of the perception. The cochlea is comprised of hair cells that are stimulated and essentially send signals to the brain that interpret the frequency based on where the hair cells are stimulated. There are thousands of these hair cells that create the complex sounds that are heard and it is nearly impossible, at this point, for the 23 electrodes in the CI to duplicate the intricacies of the cells. For these reasons, among others, tasks like pitch discrimination are difficult for people with CIs (Kong, et al. 2004). Moreover, pitch along with rhythm and tempo are important factors not only for the general perception of

music, but also the perception of emotion in music. This potentially makes perceiving emotion in music much more difficult for people with CIs compared to those who have normal hearing (NH).

There have been many comparisons between adults with CIs and adults with adults NH in terms of overall music perception. In one such study, Gfeller, K. E., Olszewski, C., Turner, C., Gantz, B., & Oleson, J. (2006) looked at varying types and combinations of assistive hearing devices and how they affected music perception. They compared adults with CI Hybrids (devices that spare some residual hearing) and conventional long electrode devices to adults with NH. They measured real world song recognition and instrument recognition and found that the hybrid group was closer in accuracy to the NH group than the others. This indicated that the presence of some residual hearing (i.e., low frequency perception) is important in the perception of musical stimuli.

Although previous studies suggest that adults with CIs will experience challenges when perceiving emotion in music because of a lack of low-frequency perception, it is still possible that they might use other acoustic cues to perceive some emotion in music. In an experiment conducted by Caldwell, M., Rankin, S., Jiradejvong, P., Carver, C., & Limb C. (2015), the researchers hypothesized that CI users would rely more on tempo rather than pitch when interpreting emotion in music. They used novel melodies with choral accompaniment with permutations for each, including positive valence (major mode, fast tempo), negative valence (minor mode, slow tempo), and ambiguous valences (major mode, slow tempo and minor mode, fast tempo). Each participant rated whether they sounded happy or sad on a 7-point Likert scale after the stimuli were presented.

They found that adults with NH tended to rate all four stimuli very differently while adults with CI did not rate the major-slow and minor-slow differently. That was also true for the major-fast and minor-fast conditions. That is, the CI users did not distinguish between the major and minor modes, but did distinguish across tempo. They also found that participants who were musicians did better overall than those who were non-musicians. They concluded that adults with CIs use tempo more than pitch when determining emotion in music.

Shirvani, S., Jafari, Z., Zarandi, M., Jalaie, S., Mohagheghi, H., & Tale, M. (2016) explored the effects of unilateral and bimodal implantation on music perception in children with hearing loss. They hypothesized that a bimodal fitting would be more effective than a unilateral CI because it can improve spectral transmission of low frequency information through the provision of acoustic signals in perception of emotion in music. They played musical pieces to evoke the emotions of happy or sad. Then, they asked the children to point to a picture corresponding with the emotion that they perceived. They found that children with bimodal fittings had higher scores than children with unilateral cochlear implants. However, children with normal hearing had a higher mean score than the two CI groups. They concluded that bimodal fitting with CIs are better for the perception of emotion in music and could aid in the increase of joy while listening to music, as well as assist in the social and personal lives of children with CIs.

Volkova, A., Trehub, S., Schellenberg, G., Papsin, B., & Gordon, K. (2013) conducted two experiments that examined the ability of children with bilateral CIs to identify emotion in speech and music. The children judged whether piano excerpts sounded happy or sad. They found that children with CIs misunderstood happy speech for

sad speech more often than children with NH. They established that children with CIs tested above chance levels on identifying emotion in music (happy and sad), but still tested significantly below children with NH. The children with CIs had more variability in their results as compared to children with NH. They concluded that children with CIs could discern emotion from music, but not at the same level of children with NH showing that more information is needed on the cues utilized by those with CIs to discern emotion.

Given previous findings about the cues used by children to perceive emotion in music, additional studies focused on perception of emotional cues in the adult population. In an experiment conducted by Kong, Y., Cruz, R., Ackland Jones, J., & Zeng, F. (2004). they looked at the effects of hearing loss and CIs on tempo discrimination, rhythmic pattern identification, and melody identification. They found that when it came to tempo discrimination, people with CIs had similar results to people with NH. In rhythmic pattern identification people with NH did better overall as compared to people with CI, but one CI participant showed similar results to the NH group. In melody identification people with NH made no mistakes, whereas people with CIs performed significantly worse in this task. They concluded that rhythmic cues are vital to people with CIs when listening to music, and that a CI does not adequately support music perception.

The research mentioned above focuses on the background of CIs and their current abilities, as well as comparisons in music listening between people with CIs and people with NH. They highlight the perception of emotion in music and the cues used to do so. The current information gives insight into the ability for adults with CIs to perceive emotion in music through tempo rather than pitch and the understanding that adults with NH rely more on pitch cues to delineate the emotions in a musical piece. However,

questions arise as to what other musical elements are used to perceive emotion in music. For example, large versus small pitch range could play a role in the perception of the intended feeling or emotion from the piece. Understanding the contribution of pitch range to perception of emotion in music would be novel not only when comparing adults with CIs and NH, but within the category of NH adults alone. Cochlear implants have improved greatly over the years, but they need further improvements to better the quality of life of the people using them. More information on potential acoustic cues for perception of emotion in music for adults with NH and adults with CIs could bring more insight into how CI technology can be updated to make users feel more connected to their culture.

To examine these questions, I followed the general methods of the Hunter, Schellenberg, and Schimmack (2008) study, in which they tested whether mixed happy and sad feelings would be elevated in NH adults in conditions with mixed cues of happiness and sadness compared to conditions with consistent cues. They took excerpts of music with contrasting mode and asked participants to rate them on happiness, sadness, pleasantness, and unpleasantness on a 7-point Likert scale. The research showed that opposite feelings can be co-activated by the same piece of music. They also found that music can be used to elicit mixed happy and sad emotions in predictable ways. Finally, they found that although opposite feelings can be triggered at the same time, they are not completely independent.

## **Methods**

The overall design of the study was modeled after the Hunter et al. (2008) research study considered in the introduction. The data were collected at Butler

University in Indianapolis, IN as well as a private home in Attica, IN for the convenience of the participants. The experiment was conducted in a quiet, distraction-free room, and all but two participants were in the room individually. Consent forms were completed by all participants before commencement of research began. Background forms and basic audiometric screening were also completed to gain information about music background, demographic information, family hearing health, and current hearing health to ensure inclusion criteria were achieved.

### *Participants*

Participants were recruited via the Butler University Communication Sciences and Disorder Facebook page, the Indiana University ENT Facebook page, and through word of mouth. Electronic flyers were posted on these pages and distributed to adults on campus. All individuals voluntarily chose to participate and they could stop experimentation at any time throughout the process. They also received monetary compensation for time and travel equal to \$10 cash. Inclusion criteria included adults between the ages of 18-50 years old, hearing within normal limits defined by dB for 500, 1000, 2000, 4000, and 8000 frequencies spatially less than 20 dB (for NH group) or adults within the above age criteria with unilateral or bilateral CIs. Participants were excluded if there were self-reports of early onset dementia or other cognitive dysfunctions. There were sixteen individuals who participated in the experiment. Fifteen were adults between the ages of 18-30 (10 female, 5 male) with NH and one adult male 28 years old with a postlingual CI. No prelingual adults with CI were tested. One participant was excluded from analysis due to self-reported hearing loss.

### *Stimuli*

All the musical pieces were created via GarageBand using the Grand Piano or Classical Piano timbre in the Butler University Multisensory Learning Facility managed by Dr. Tim Brimmer. The stimuli were 30 ms in duration. Fast and slow versions were created for each musical tune. The fast stimuli averaged 125 bpm and the slow stimuli averaged 80 bpm. Half of the tunes had a large pitch range (average = 8.5 st) and the other half had a small pitch range (average = 4 st).

### *Procedure*

Participants except for the adult with a CI were first screened with a GSI portable audiometer.

The participants listened to familiar melodies in randomized order that had either a wide pitch range (e.g., Joy to the World) or a small pitch range (e.g., Mary Had a Little Lamb), and either fast or slow tempo. The excerpts were 30 seconds in duration. They listened to 40 excerpts in total. Music was played on a Macintosh computer by the researcher through Bose Companion Two Series Three Multimedia speakers.

There were no vocals, to avoid influence from the lyrics. Ten of the excerpts conveyed sadness (small pitch range; slow tempo) and ten conveyed happiness (wide pitch range; fast tempo). The remaining twenty presented conflicting cues (small pitch range + fast tempo or wide pitch range + slow tempo).

When the participant finished the excerpt, they gave three ratings. They were instructed by the researcher to rate the music on how it made them feel. A Microsoft Excel document was displayed on a Macintosh 2017 Macbook Pro computer to gather

data. Using the Mac and a Microsoft Excel spreadsheet, the participant rated each piece on three Likert scales, “How did the music make you feel?” The first was sad (1) to happy (7). The second was unpleasant (1) to pleasant (7). Finally, the third was unengaged (1) to engaged (7). When they completed the excerpt the researcher continued to the next piece until all 40 excerpts were rated.

### *Statistical analysis*

The raw data were evaluated through SPSS software system. A series of Repeated Measures ANOVAs were run to look at the differences in rating across the different types of stimuli for the NH test group. This data analysis tested the significance of the data that was collected and assisted in the rejection or non-rejection of the null hypothesis. There was also a descriptive statistical analysis done on the data collected to determine the mean, median, and mode of the data for comparison. In addition, it looked at the range, standard deviation, errors, and variance in the results. It was then examined closely in order to catch any mathematical errors that could affect the number outcomes. Statistics through this software were unable to be performed on the CI subject due to the small sample, but the data gathered for this subject was used for anecdotal or qualitative comparison.

## **Results**

### *Adults with NH*

Correlation analyses did not reveal statistically significant relationships between years of music training and the individual ratings of emotion, engagement, or pleasantness, which suggests that music training did not influence any of the ratings. Figure 1 shows the

ratings across conditions for adults with NH. Repeated-measures ANOVAs were completed to determine whether there were significant differences among the ratings of happy and sad, engagement, and pleasantness across the tempo and pitch characteristics (descriptive statistics are shown in Table 1). Emotion (happy vs. sad) ratings were significantly different across the tempo and pitch conditions,  $F(3,42) = 21.04, p < .001$ . Post-hoc paired 2-tailed t-tests showed that all the ratings for the four tempo and pitch conditions were significantly different from each other,  $ps < .02$ .

Engagement ratings were also significantly different across conditions,  $F(3,42) = 7.74, p < .001$ . Post-hoc t-tests showed that engagement ratings for fast-large and fast-small ratings were higher than slow-small ratings, and fast-small ratings were also higher than slow-large ratings,  $ps < .02$ . These findings suggest that engagement ratings were influenced more by tempo than by pitch range.

Finally, pleasantness ratings were significantly different from each other,  $F(3,42) = 9.08, p < .001$ . Post-hoc t-tests again revealed that fast-large and fast-small ratings were higher than those for slow-small ( $ps < .01$ ), suggesting a similar tempo effect as in the engagement ratings. However, adult listeners also rated slow-small greater than slow-large ( $p < .001$ ), which suggests that pitch range also influenced pleasantness ratings.

#### *Adult with CIs:*

Figure 2 shows the ratings across conditions for the adult with a CI. Due to the small sample we were unable to complete analytical statistics for the participant with a CI. Descriptive statistics revealed that this participant rated fast-small the most happy, pleasant, and engaging with average ratings of 5.6, 5.4, and 5.3, respectively (see Table 2). In contrast, slow-large was perceived as the most sad, unpleasant, and unengaging

with average ratings of 3.0, 4.0, and 3.9, respectively. These results suggest that this participant's ratings of the musical excerpts were more closely tied to tempo than pitch range.

## **Discussion**

This study examined whether adults with a cochlear implant and adults with normal hearing use pitch range, in addition to tempo, to determine emotion in music. The results of this study suggest that NH and CI listeners both relied more heavily on tempo rather than pitch range when making judgments of emotion, engagement, and pleasantness of the musical excerpts. Moreover, the adult with a CI had larger differences between slow and fast tempos on the happy-sad scale as compared to the NH adults. This aligns with past research indicating that tempo is utilized more than pitch cues when perceiving emotion in music via a CI. Therefore, pitch range is not significantly tied to perception of emotion for and this CI user as well as adults with NH.

However, there are two exceptions to the statement above. Adults with NH rated slow-small to be more pleasant than slow-large, suggesting that pitch range did in fact play a role in the emotional perception of pleasantness. Similarly, ratings were judged as happier for musical excerpts with small pitch ranges in both fast and small tempo conditions for adults with NH, suggesting that pitch range had some effect on the emotional perception. This contradicts the predictions made in the hypothesis speculating that fast-large would be the most happy and slow-small would be the saddest excerpts.

When comparing adults with a CI and adults with NH many similarities were noted. Adults with NH and the adult with CI perceived fast-small as the happiest, engaging, and pleasant, slow-large as the saddest, and slow-small as the least pleasant.

Additionally, it should be noted that both adults with NH and CIs had a stronger preference for a small pitch range, rating it happier on the happy-sad scale and the pleasantness scale. This reiterates the suggestion mentioned above that pitch range in part could play a role in the perception of emotion in music not only in adults with NH, but those with CIs as well.

The results showed that on a broad scale, adults with NH and CIs perceive music based on tempo and pitch range similarly overall, but do show differences in average ratings across each condition. This finding could suggest again that tempo, the main musical cue for adults with CIs to perceive emotion in music, was often the indicator for emotional ratings in both participant groups. The effect of pitch range however should not be overlooked as it could play a small role in determining perception of emotion in music.

In the Hunter, et al. (2008) article it was shown that both feelings of happiness and sadness can be activated at the same time for the same piece of music; the present study showed similar effects. In slow-large excerpts CI and NH participants demonstrated feelings of moderate engagement and pleasantness as well as sadness. This shows that songs that are sad can still hold the interest of the listener and give them a pleasant experience with the music as well. This aligns with the results from prior research and expands the knowledge that not only happiness and sadness can be co-activated, but also engagement and pleasantness.

There were excerpts in the study that had subtle differences that were not explored in data collection, but should be considered. In a handful of pieces there was a difference in timbre from Grand Piano to Classical Piano, giving it a different sound

quality. Additionally, a few pieces had more complex rhythms than other musical excerpts that could have influenced ratings of emotion, engagement, and pleasantness. Because the numbers of musical excerpts with these features were not balanced across conditions, we did not conduct statistical analyses on these features. However, future studies are warranted to assess the effects of timbre and rhythmic complexity on ratings of emotion, engagement, and pleasantness for adults with NH and adults with CIs.

An additional limitation is the small sample size of participants who use CIs. A future study should include more CI participants so comparisons can be made within the group as well as across listener groups.

Data were also gathered in two separate locations for the convenience of the participants. Although there is no reason to believe that location affected the ratings, it is possible that the participants could have had a different listening experience based on location. That is, familiar or unfamiliar environments could alter the emotional state of a participant, influencing their ratings of emotion, engagement, and pleasantness of the musical excerpts. Future research should attempt to keep data collection in a more controlled environment so that confounding variables such as this are considered and less likely to interfere with results.

A final major limitation to this study was the adult hearing screening tool used before testing NH participants. There is no agreed upon screening tool in audiology for adults, therefore the researcher had to determine what was a pass and what was a fail. A pass in the current study was defined as hearing thresholds in both ears less than 20 dB on an audiogram. Life circumstances and years of noise exposure endured by adults influences hearing abilities. As age increases the speculated normal hearing thresholds

could be greater than 20 dB, but still classify as NH. A less rigid verification tool along with a validation tool such as a separate questionnaire about hearing abilities, should be utilized together to make a more educated classification for the purposes of this study.

Future directions for research in this area should focus on differences in emotional perception in music regarding whether adults with CIs who lost their hearing prior to or following spoken language acquisition, which has not been explored in the literature. A new study could consist of three groups, the first being adults with NH (control group), the second being adults who lost their hearing before learning to speak (pre-lingual group), and the third being adults who lost their hearing after learning to speak (post-lingual group). The question could explore if adults who received CIs before they learned how to speak (pre-lingual) and those who received it after they learned how to speak (post-lingual) perceive not only emotion but music in general differently? With the information that is known about this topic I predict that adults with pre-lingual cochlear implants will perceive emotion in music differently because of their representations of music being built from scratch and better experience with the CI, as opposed to adults who lost their hearing later in life.

A better understanding of additional acoustic cues, if any, used by adults with NH and CIs to perceive emotion in music should also be explored in the future. As discussed above, timbre and rhythmic complexity could influence ratings of emotion, engagement, and pleasantness of music. More research on acoustic cues such as these could be helpful in furthering the understanding of acoustic cues that affect emotional experiences in NH and CI adults. These results would help fill a large gap in current knowledge about the

similarities and differences in the perception of emotion in music between the two groups, as well as having the potential to improve current CI technology.

### **Conclusion**

Although the results for this study were inconsistent with the hypothesis, new information was discovered to enhance our understanding of music listening for adults with NH and CIs. This study has added important knowledge to the literature regarding the cues adults with and without hearing loss use to perceive emotion in music.

Additional studies are necessary to expand knowledge of specifically what cues are utilized for both groups. This information will in turn advance the technology used by those with profound hearing loss to improve their quality of life and thus provide a more authentic music listening experience.

## References

- Balkwill, L., & Thompson, W. (1999). A cross-cultural investigation of the perception of emotion in music: psychophysical and cultural cues. *Music Perception, 17*(1), 43-64. DOI: 10.2307/40285811
- Caldwell, M., Rankin, S., Jiradejvong, P., Carver, C., & Limb C. (2015). Cochlear implant users rely on tempo rather than on pitch information during perception of musical emotion. *Cochlear Implants International, 16*, S114-S120. DOI: 10.1179/1467010015Z
- Gfeller, K. E., Olszewki, C., Turner, C., Gantz, B., & Oleson, J. (2006). Music perception with cochlear implants and residual hearing. *Audiology & Neurology, 11*, 12-15. DOI: 10.1159/000095608
- Hunter, P., Schellenberg, G. & Schimmack, U., (2008). Mixed affective responses to music with conflicting cues. *Cognition and Emotion, 22*, 327-352. DOI: 10.1080/002699930701438145
- Juslin, P., & Vastfjall, D. (2008). Emotional responses to music: the need to consider underlying mechanisms. *Behavioral And Brain Sciences, 31*, 559-621. DOI: 10.1017
- Juslin, P., Barradas, G, Ovsiannikow, M., Limmon, J., (2016). Prevalence of emotions, mechanisms, and motives in music listening: a comparison of individualist and collectivist cultures. *Psychomusicology: Music, Mind, and Brain, 26*, 293-326.

Kong, Y., Cruz, R., Ackland Jones, J., & Zeng, F. (2004). Music perception with temporal cues in acoustic and electric hearing. *Ear & Hearing*, 25(2), 173-185.

DOI: 10.1097/01.AUD

Loizou, P. (1998). Mimicking the human ear: an overview of signal-processing strategies for converting sound into electrical signals in cochlear implants. *IEEE Signal Processing Magazine*, September, 101-130.

Shirvani, S., Jafari, Z., Zarandi, M., Jalaie, S., Mohagheghi, H., & Tale, M. (2016). Emotional perception of music in children with bimodal fitting and unilateral cochlear implant. *Annals of Otology, Rhinology & Laryngology*, 125, 470-477.

DOI: 10.1177/0003489415619943

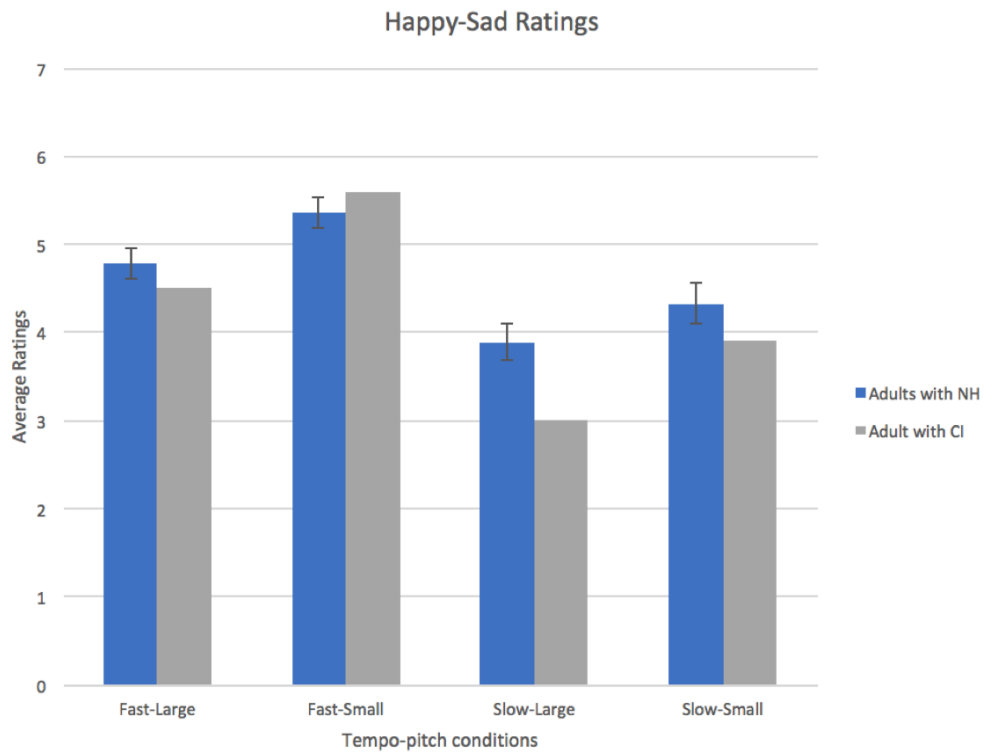
Volkova, A., Trehub, S., Schellenberg, G., Papsin, B., & Gordon, K. (2013). Children with bilateral cochlear implants identify emotion in speech and music. *Cochlear Implants International*, 14, 80-91. DOI: 10.1179/1754762812Y

*Table 1: Adults with Normal Hearing average condition ratings*

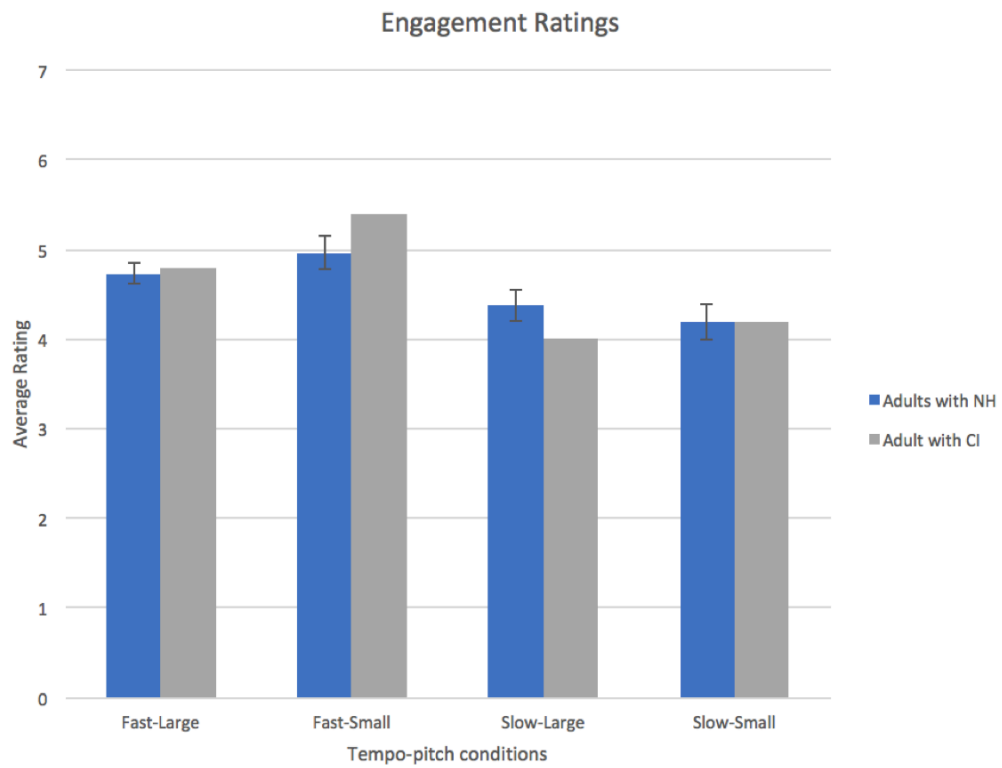
Tempo and Pitch Conditions	Happy-Sad Average Ratings	Engagement Average Ratings	Pleasantness Average Ratings
Fast- Large	4.79	4.73	4.37
Fast- Small	5.36	4.96	4.67
Slow- Large	3.89	4.37	4.34
Slow- Small	4.33	4.19	3.9

*Table 2: Adult with Cochlear Implant average condition ratings*

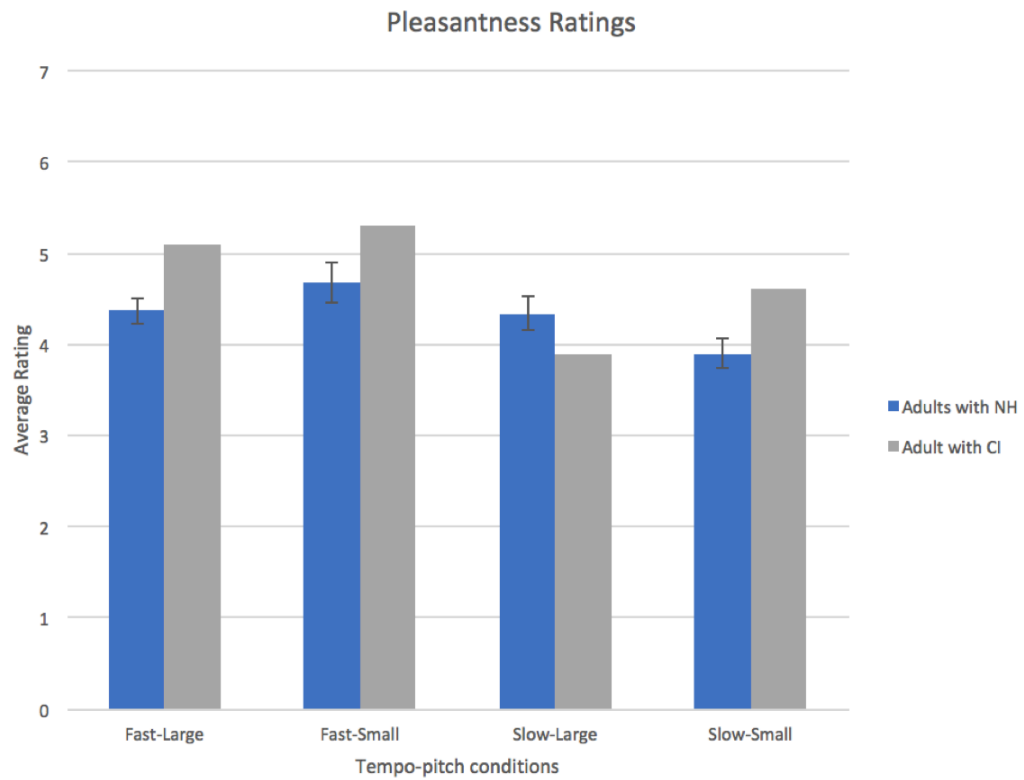
Tempo and Pitch Conditions	Happy-Sad Average Ratings	Engagement Average Ratings	Pleasantness Average Ratings
Fast- Large	4.5	4.8	5.1
Fast- Small	5.6	5.4	5.3
Slow- Large	3	4	3.9
Slow- Small	3.9	4.2	4.6



*Figure 1: This figure illustrates the average ratings for the happy-sad scale between adults with NH and the adult with CI*



*Figure 2: This figure illustrates the average ratings for the engagement scales between adults with NH and the adult with CI*



*Figure 3: This figure illustrates the average ratings for the engagement scales between adults with NH and the adult with CI*