The Perception of Music in the Deaf and Hard-of-Hearing Community:

A Review of Literature

Emily Hazlett

School of Music, University of Florida

Abstract

Deafness is a broad term that can include many degrees of hearing loss, hearing loss experiences, culture, beliefs, and abilities (National Association of the Deaf, 2023). While Deaf and hard-of-hearing individuals may face certain challenges in regard to music perception, devices and aids can allow individuals to perceive music aurally including rhythm, pitch, melody, and emotion in varying degrees (Looi et al., 2008). Additionally, Deaf and hard-of-hearing individuals may choose to use vibrotactile devices to perceive music through the sense of touch, and this has also shown good results in perceiving various aspects of music (Hopkins et al., 2016; Sharp et al., 2020). Though these individuals may need to overcome certain struggles, research has shown that Deaf and hard-of-hearing individuals have the ability to learn in a music classroom through interacting with and responding to musical stimuli (Chen-Hafteck & Schraer-Joiner, 2011). Music teachers have the responsibility to accommodate these students to give them a meaningful and unrestrictive music education experience (Darrow, 2016). The purpose of this paper is to review research on the perception of music and music learning from the Deaf and hard-of-hearing communities.

The Perception of Music in the Deaf and Hard-of-Hearing Community

Due to a significant number of students in the United States education system having hearing losses in varying degrees, music education systems must adapt to meet the varied needs of these students (Darrow, 2016). Since music is primarily focused upon the sense of hearing in order to listen and respond to music, research is necessary to determine how members of the Deaf and hard-of-hearing communities perceive and experience music. Using this knowledge, music educators must then adapt and modify curriculum to support and be inclusive of students with all degrees of hearing abilities to help them find success (Fulford et al., 2011). In addition to a moral obligation to provide these students with musical experiences, music teachers have a legal obligation to provide differentiated access to education for students with disabilities such as hearing loss (Crockett, 2017). Though music is thought of as a primarily hearing-based art form, Deaf and hard-of-hearing students have shown significant potential and ability to perceive and respond to musical activities (Chen-Hafteck & Schraer-Joiner, 2011). Music educators must be aware of the abilities and needs of Deaf and hard-of-hearing students in order to give these students a meaningful music education (Darrow, 2016).

The purpose of this paper is to analyze and review literature in regard to the perception of music in the Deaf and hard-of-hearing communities. Hearing loss is a spectrum, and individuals across the hearing spectrum refer to themselves in different ways depending on their hearing abilities, age of hearing loss, culture, and other factors (National Association of the Deaf, 2023). Each individual has different hearing circumstances. Therefore, each individual may perceive music in a different way as well. Deaf and hard-of-hearing individuals have shown abilities, though different and diminished in some cases compared to hearing individuals, to identify emotion, pitch, and rhythm in music with varying degrees of accuracy (Darrow, 2006; Looi et

al., 2008). Aids to assist Deaf and hard-of-hearing individuals create varying experiences with music as well; devices that are particularly relevant are hearing aids and cochlear implants (Looi et al., 2008; Stabej et al., 2012; Trehub et al., 2009). Additionally, experiencing music through vibrotactile sensations is possible, instead of or in addition to using the sense of hearing, and various devices exist to assist with perceiving music through touch and vibration (Good et al., 2021; Sharp et al., 2020; Hopkins et al., 2016; Florian et al., 2017). Specific research has also assessed that Deaf and hard-of-hearing students are able to perceive and respond to musical stimuli. Given this knowledge, further research will help to inform music educators how best to teach these students in the classroom (Darrow, 2016).

Defining deafness and hearing loss

Individual hearing abilities and experiences can be very diverse including hearing loss experiences, degree of hearing loss, and culture of hearing loss; all of those components contribute to how individuals may choose to identify within the community of people with hearing losses. According to the National Association of the Deaf (2023), deafness spelled with a lowercase “d” refers simply to a lack of hearing ability, the physical condition. This is more of a medical term and description of hearing abilities. The lowercase word ‘deafness’ does not refer to community, identity, or anything else other than the condition of not hearing. However, individuals may choose to identify with the Deaf community. When referring to Deaf individuals who identify with that community, the capital “D” should be used.

Members of the Deaf community typically share a common set of traits and core beliefs that are central to their ideologies as a community. Perhaps the most central of these beliefs and customs is the use of sign language (in most parts of the United States, American Sign Language) as their primary language (Hladek, 2009). Hladek (2009) also discussed the fact that

most members of the Deaf community are born deaf though some members lose their hearing simply at a young age. The Deaf community often chooses to view deafness not as a disability but as a unique and valuable lens through which they live their lives. Value also exists in the community aspects of Deaf culture that provide Deaf individuals with guidance, friendship, and kinship.

People with hearing losses or deafness may also identify with the title of hard of hearing. When used as a noun, hard of hearing appears without dashes, but when used to describe a hard-of-hearing individual, dashes are used between the words. According to the National Association of the Deaf (2023), hard of hearing can be a very diverse term because it can be used to describe an individual with any degree of hearing loss from hearing loss due to old age to total deafness. Oftentimes, individuals with mild or moderate hearing losses will choose to identify as hard of hearing. In other cases, deaf individuals who choose not to identify with the Deaf community for any reason may choose to refer to themselves as hard of hearing. However, members of the Deaf community will almost always refer to themselves as Deaf, not hard of hearing. Deaf and hard-of-hearing individuals are able to choose the term that best fits them based on their experiences and cultural identification.

The term hearing impairment may be used to describe the condition of an individual's hearing. Hearing impairment may be used interchangeably with hearing loss when describing a hearing condition. However, the adjective of 'hearing impaired' is not a widely accepted term for describing a Deaf or hard-of-hearing individual (National Association of the Deaf, 2023). This term used to be widely-used as a descriptor, but it can now be viewed as disrespectful by many people. This is due to the fact that hearing-impaired gives negative implications whereas the terms Deaf and hard-of-hearing can be viewed in a more neutral or positive way. Because of this,

the terms of Deaf, deaf, and hard-of-hearing are the most accepted descriptors of members of this community.

A variety of different aids exist to help Deaf and hard-of-hearing individuals to hear to certain extents. Hearing aids and cochlear implants are perhaps the most widely-known and widely-used, and these are the aids that are most relevant to the study of this topic. The National Institute of Deafness and Other Communication Disorders (2021) describe how these two devices differ from one another and provide different types of assistance. Hearing aids are simply devices to make sounds louder; the amplification of those sounds allow for individuals with remaining hearing abilities to hear sounds. Due to its function, this device is only viable for people with mild to moderate hearing loss.

In contrast, cochlear implants are devices that actually change the way that noises are processed in order for severely damaged ears to still process sound (National Institute of Deafness and Other Communication Disorders, 2021). These devices are oftentimes only for individuals with severe hearing loss or total deafness. Cochlear implants consist of a microphone, speech processor, transmitter, receiver, and electrode array. These components are able to take sounds, noises, and speech from the environment and transmit them to the auditory nerve in the brain for the sounds to be processed. These devices can give severely deaf and hard-of-hearing individuals the ability to hear and process some sounds.

Perception of musical attributes in Deaf and hard-of-hearing individuals

Deaf and hard-of-hearing individuals have the capability to understand many components of music, and much research has been completed to determine the breadth of musical understanding in Deaf and hard-of-hearing attributes. Looi et al. (2008) completed research to study the differences of music perception between hearing aid and cochlear implant users. This

aspect of the study will be discussed in a later section, but this study also reveals important information about the perception of different musical qualities by Deaf and hard-of-hearing individuals. 30 participants (15 with hearing aids and 15 with cochlear implants, all having become deaf post-lingually) were presented with musical examples to test the individuals' ability to identify rhythm, identify pitch, recognize instruments, and recognize melodies. The test was completed twice with about four months in between testing days. The rhythm test revealed an average of 93.5% correct responses between the two groups (hearing aid and cochlear implant). The pitch test revealed an approximate average of 72% correct responses between the groups. The instrument recognition test revealed an approximate average of 53% correct responses between the groups. Finally, the melody recognition test revealed an approximate average of 71.5% correct responses between the groups. It is worth noting that hearing aid users responded with higher averages of correct answers in each category, but both groups did show at least some ability in all categories. This study could show that Deaf and hard-of-hearing individuals may have abilities to recognize all of these musical qualities, but rhythm is by far the most recognizable element and instrument recognition as the least recognizable element.

Perception of emotion in music amongst Deaf and hard-of-hearing individuals has also been a point of focus in research. Mangelsdorf et al. (2021) studied specifically how Deaf individuals perceive emotion in signed songs when compared with regular signing with no musical components. 64 participants for the study were selected from a participant email list and online database, and the participants were diverse in hearing abilities (24 hearing, 26 Deaf of hard-of-hearing, and 14 preferred not to identify). A Deaf ASL (American Sign Language) translator, Jason Listman, created two sets of videos for each of the eight selected songs. The first set of videos, Listman merely signed the lyrics with no musical influence. The second set of

videos, Listman listened to the songs and interpreted them with musical rhythm, intent, and facial expressions. The participants then viewed both types of videos, rating their view of the musicality of each video. The hearing participants consistently rated the signed songs with musical influence as being more musical rather than the signed lyrics without musical influence. In contrast, Deaf and hard-of-hearing participants rated both types of videos as having high musicality. This could suggest that Deaf and hard-of-hearing individuals have a different perception as to what makes something musical. In addition, both groups of participants were able to identify correct emotions within the signed songs.

Darrow (2006) researched similar topics regarding musical understanding in Deaf and hard-of-hearing students through music listening. A school for the Deaf in the Midwest and nearby elementary and junior high school were used to choose 62 students as participants (some with full hearing abilities and some Deaf students with moderate to severe hearing losses) for this study. The participants were given 12 songs to listen to that were scores from films, and they were asked to assign one of three emotions to each song: happiness, sadness, or fear. Darrow's results showed that hearing students were more likely to identify the correct emotion of the song at a statistically significant difference. The results may suggest that elements such as timbre and texture could be important identifying factors for emotion in music, and those elements may be difficult for Deaf and hard-of-hearing students to perceive. Darrow suggested additional study on strategies and aids for these students to help them identify emotion in music more confidently.

Music perception of individuals with cochlear implants

Cochlear implants are common devices that may be used by Deaf and hard-of-hearing individuals with more severe hearing loss or total deafness. Due to the technology of the device, individuals may be able to hear certain sounds or speech through directly stimulating the

auditory cortex in the brain (National Institute of Deafness and Other Communication Disorders, 2021). As previously discussed, Looi et al. (2008) designed a study to test the differences in perception of music amongst Deaf and hard-of-hearing cochlear implant users compared to hearing aid users. The study used 30 Deaf and hard-of-hearing participants (half cochlear implant users and half hearing aid users) to compare their abilities to identify rhythm, identify pitch, recognize instruments, and recognize melodies. While most participants showed an ability to perceive each category, there was a significant difference between the perception abilities of cochlear implant users and hearing aid users in most categories. Results in the rhythm category were almost exactly the same for both groups of participants. However, for all other categories, the hearing aid participants showed significantly higher scores of music perception when compared to the cochlear implant users. This study could show that certain supports and modifications could be needed for cochlear implant users in order to perceive certain elements of music.

Despite the advantages of cochlear implants, some challenges certainly exist for users of the device (Trehub, 2009). Vongpaisal et al. (2006) performed research to assess the ways that Deaf and hard-of-hearing individuals with cochlear implants are able to perceive music, specifically to recognize familiar songs. Groups of about 10 cochlear implant users and similar size groups of hearing individuals were selected for the study. Each group was assigned one of three different tasks: identifying familiar songs, identifying pitch changes in isolation, and identifying pitch changes in melodies. In each category, the hearing participants recorded higher accuracy. However, cochlear implant users did show an ability to aurally identify songs and pitch changes in isolation. The melodic context specifically was where the cochlear implant users struggled to perceive the music. When pitches were in isolation, the Deaf and hard-of-hearing

individuals could identify the changes. When the melodic context was added, the Deaf and hard-of-hearing participants really struggled to perceive the changes. This study helps to show that cochlear implant users have a good deal of music perception, but melodic perception could be a particular area of struggle.

Stabej et al. (2012) also studied the music perception abilities of Deaf and hard-of-hearing individuals who use cochlear implant devices. This study used a group of 39 Deaf and hard-of-hearing children who lost their hearing prelingually along with a group of 39 hearing children. The study compared results of the two groups from assessments given on rhythm discrimination, melody discrimination, instrument identification, emotion identification, and dissonance identification. Results of the cochlear implant users were significantly diminished in three categories including rhythm discrimination, instrument identification, and emotion identification. However, no statistically significant difference was shown between the two groups for melody discrimination or dissonance identification. This study may help to reveal strengths and weaknesses of cochlear implants in music perception. However, the results of this study do seem to somewhat contrast the Vongpaisal et al. (2006) study and Looi et al. (2008) study. These studies revealed rhythm discrimination as a strength of cochlear implant users and revealed melodic discrimination as a weakness. However, this Stabej et al. (2012) study found rhythm discrimination to be a weakness of cochlear implant users and melodic discrimination to be a strength. This may show that music perception is an individualized experience amongst cochlear implant users and may present different results depending on a wide variety of factors.

Tactile music perception in Deaf and hard-of-hearing individuals

Deaf and hard-of-hearing individuals have shown abilities to perceive rhythm, pitch, and emotion of music to varying degrees through vibration and tactile sensation (Hopkins et al.,

2016; Sharp et al., 2020). In fact, Good et al. (2021) studied research literature on the ability of the brain to change and adapt how it functions, and their study concluded that the brain has the ability to enhance vibrotactile senses in Deaf and hard-of-hearing individuals. Auer et al. (2007) performed research to study imaging of the brains of both deaf and hearing individuals to determine the parts of the brain that were active for the participants. Six hearing and six deaf individuals were presented with speech vibrational sensations through a device in the right hand. Participants were then assigned to detect when the target vibration was felt. Deaf participants in the study presented with more activation of the auditory cortical regions of the brain in response to the vibration stimulus than the hearing participants did. Auer et al. (2007) concluded that the deaf individuals had expanded regions of tactile response in the brain when compared to normal hearing individuals. This could confirm that the brain has the ability to adapt to an individual's needs, and synaptic connections can be dependent upon the development of the individual. The brains of Deaf and hard-of-hearing individuals may be uniquely suited to perceive music through the sense of touch as compared to hearing individuals.

Various devices have been created and studied to provide vibrotactile musical experiences (Florian et al., 2017; Hopkins et al., 2016). Florian et al. (2017) designed a prototype of such a device and a related software. The effectiveness of the protype was studied amongst Deaf and hard-of-hearing students at the Special Technological High School for Hearing Impaired. Their device output both vibrational stimuli and visual stimuli for the participants, and the participants then answered questions regarding their experience with the device. The participants rated the effectiveness of the device and their musical experience on a scale from 1 to 5 with 5 being the highest effectiveness. 65% of participants rated the device a 5, 23% of participants rated the device a 4, 12% of participants rated the device a 3, and none of the

participants rated the device a 1 or 2. The study concluded that this particular device that output visual and vibrational stimuli was a positive musical experience for Deaf and hard-of-hearing individuals. The research completed by Florian et al. could suggest that alternative opportunities to experience music, such as vibrational and visual sensations, could be meaningful ways for Deaf and hard-of-hearing individuals to experience music.

Deaf and hard-of-hearing individuals experience music differently when they experience it through vibrotactile sensations instead of through hearing. Therefore, researchers have begun to study how these individuals perceive music in this manner (Sharp et al., 2020; Hopkins et al., 2016). Sharp et al. (2020) researched how both deaf and hearing participants perceived emotion in vibrotactile musical experiences using a haptic glove. 10 hearing participants and 10 participants with congenital profound bilateral hearing loss were presented with 56 melodies representing different emotions (happiness, sadness, fear, and peace). Deaf individuals were able to better identify emotion in music, specifically the emotion of happiness. The study concluded that more advanced tasks may help to better reveal that deaf individuals have greater tactile senses than normal hearing individuals, in this case specifically relating to emotions in music. This research could suggest not only that Deaf and hard-of-hearing individuals may have meaningful musical experiences through tactile stimuli, but these individuals may have a unique ability to access and perceive music through the sense of touch.

The ability to perceive other musical features in addition to emotion, such as pitch and rhythm, through vibrotactile means has also been researched (Hopkins et al., 2016). Hopkins et al. (2016) performed research to determine a range of pitches that can be perceived through vibration on the glabrous skin of the fingertip, forefoot, and heel. Participants with varied hearing abilities (normal hearing and mild, moderate, severe, and profound hearing loss)

participated in experiencing vibrotactile frequencies and reported their perception of the frequencies. Though each body part studied (fingertip, forefoot, and heel) presented slightly different results, the study was able to conclude that the range of pitches that can be reliably perceived through vibrotactile stimuli to those areas is C1 through G5. This range is significantly more limited than normal hearing abilities, but this does allow access to the range of most instruments common to the United States. This suggests that using vibrotactile devices to experience music may present some challenges, but the individual would still be able to perceive a large majority of important pitches in music.

Music learning in Deaf and hard-of-hearing students

Many students in the American education system identify as Deaf or hard-of-hearing, so research on music perception is important and relevant for music educators (Darrow, 2016). In addition, some research has been conducted about the ways that Deaf and hard-of-hearing students learn music in the classroom (Darrow, 2016; Chen-Hafteck, & Schraer-Joiner, 2011). Chen-Hafteck and Schraer-Joiner (2011) conducted a case study to research the music learning of five Deaf and hard-of-hearing children, ages 3-4, with severe hearing loss. The students were instructed in music classes, and their actions, responses, and music-making were observed. This study specifically focused on a few aspects of music learning: musical engagement, musical knowledge, musical communication, and flow experience. The results of the study showed that the students were highly engaged in the music learning experience and able to complete most of the activities that were conducted in the class. The flow indicator rating was high for most students in most activities which shows that they were focused on the task and engaged throughout. This study shows that Deaf and hard-of-hearing students are able to enjoy and

participate in musical activities and music learning; these students may just need some modifications and adaptations in order to be as successful as possible.

Depending on situations, individuals may have very different experiences with music education throughout their schooling experiences. Fulford et al. (2011) researched the music experiences of several Deaf and hard-of-hearing individuals to learn their perspective on their music education experiences. Interviews of 12 Deaf and hard-of-hearing participants who identify as musicians were conducted, and a thematic network analysis was conducted on the interviews. Certain themes emerged consistently amongst the participants in positive and negative experiences with music. Familial support was shown to be a really important factor in musicians developing confidence and independence in their music-making. Additionally, the learning of listening strategies and skills was essential to musical development. Musicians reported more success when they were taught skills to navigate musical listening with their individual hearing difficulties. Other common themes for success were an intrinsic love of music, self-efficacy, stigmas of hearing loss, and personal strategies. Some common themes for challenges in music were performance anxiety, negative interactions, synchronization struggles, and tuning problems. This study could help reveal themes that may assist Deaf and hard-of-hearing students in learning music in a positive environment and may assist students in avoiding common struggles.

Teaching strategies are important in order to help Deaf and hard-of-hearing individuals, and differentiating instruction for students with disabilities is also a legal requirement of public-school teachers in America (Crockett, 2017). Jones (2015) studied the Individuals with Disabilities Education Act, current policies, trends in research, and public perception of teaching students with disabilities. The Individuals with Disabilities Education Act describes the rights of

students with disabilities to individualized planning, adaptations, and an education in the least restrictive environment. This led to more students with disabilities being present in full-group classrooms, and teachers had to learn to accommodate their needs. This study found that a significantly larger number of teachers now feel equipped with the tools to succeed in teaching students with disabilities compared to that same statistic at the time of the creation of the law in 1975. This could suggest that teacher education programs are evolving to include necessary information for teachers to be able to assist students with disabilities in any way they may need. This study shows that not only should teachers make accommodations for Deaf and hard-of-hearing students to succeed in their music classrooms, they are also legally required to do so.

Discussion

Music teachers should be aware of the research about the perception of music for Deaf and hard-of-hearing individuals so that they can help to best educate this population of students (Darrow, 2016). Research has shown that Deaf and hard-of-hearing students are able to perceive and respond to music appropriately in music classes (Chen-Hafteck & Schraer-Joiner, 2011). Music teachers have a moral and legal responsibility to make accommodations for Deaf and hard-of-hearing students in the music classroom (Jones, 2015). Each learner is different and may require different learning strategies and accommodations to be successful in the classroom, and this remains true for Deaf and hard-of-hearing students in the music classroom (Darrow, 2016).

A library database search revealed a slight gap in the literature surrounding music learning and teaching theories and strategies for Deaf and hard-of-hearing students. Future research in this area could include specific learning theories and strategies, helpful accommodations, and more clarity on which aspects of music learning may pose the biggest challenge or the most accessibility. Research has clearly shown that Deaf and hard-of-hearing

individuals have potential and aptitude for music, so music teachers should learn strategies to help these students meet that potential (Darrow, 2016).

Conclusions

Deafness is a spectrum that contains many hearing abilities and cultural differences that may lead to different individual experiences with hearing loss (National Association of the Deaf, 2023). Individuals may use a variety of aids to assist them in perceiving the world around them including vibrotactile devices, hearing aids, and cochlear implants (The National Institute of Deafness and Other Communication Disorders, 2021). Due to the spectrum of hearing loss and variety in aids, the perception of music by Deaf and hard-of-hearing individuals is often very dependent on an individual's personal needs, experiences, and situation. Vibrotactile devices can allow Deaf and hard-of-hearing individuals to perceive music through the sense of touch, and this has proved to be a viable option for perceiving many aspects of music (Florian et al., 2017). Additionally, Deaf and hard-of-hearing individuals may use remaining hearing or hearing that is accessed through a cochlear implant to perceive music (Looi, et al., 2008). Some debate exists among researchers as to what elements of music Deaf and hard-of-hearing individuals perceive effectively, but research has shown that many individuals have the ability to perceive rhythm, pitch, melody, and emotion (Mangelsdorf et al., 2021; Darrow, 2006; Looi et al., 2008).

Music learning is an area of research that could use to be expanded upon when considering how Deaf and hard-of-hearing individuals experience music. Music teacher training should address how teachers can best present material and activities to music learners to give them the best music education opportunity. More research on music teacher training in regard to students with disabilities, specifically deafness, would assist music teachers in knowing how to best help these students in their classroom. Deaf and hard-of-hearing students have the ability to

enjoy and make music, and they should have every opportunity to do so (Chen-Hafteck & Schraer-Joiner, 2011).

References

Auer, E. T., Bernstein, L. E., Sungkarat, W., & Singh, M. (2007). Vibrotactile activation of the auditory cortices in deaf versus hearing adults. *NeuroReport*, *18*(7), 645–648. https://doi.org/10.1097/wnr.0b013e3280d943b9

Chen-Hafteck, L., & Schraer-Joiner, L. (2011). The engagement in musical activities of young children with varied hearing abilities. *Music Education Research*, *13*(1), 93–106. https://doi.org/10.1080/14613808.2011.553279

Community and culture – frequently asked questions. National Association of the Deaf. Retrieved February 25, 2023, from https://www.nad.org/resources/american-sign-language/community-and-culture-frequently-asked-questions/

Crockett, J. B. (2017). Legal aspects of teaching music students with disabilities. *Music Educators Journal*, *104*(2), 45–50. https://doi.org/10.1177/0027432117712802

Darrow, A.A. (2006). The role of music in deaf culture: Deaf students' perception of emotion in music. *Journal of Music Therapy*, *43*(1), 2–15. https://doi.org/10.1093/jmt/43.1.2

Darrow, A.A. (2016). Teaching students with hearing losses. *General Music Today*, *20*(2), 27–30. https://doi.org/10.1177/10483713070200020107

Florian, H., Mocanu, A., Vlasin, C., Machado, J., Carvalho, V., Soares, F., Astilean, A., & Avram, C. (2017). Deaf people feeling music rhythm by using a sensing and actuating device. *Sensors and Actuators A: Physical*, *267*, 431–442.

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/10.1080/14613808.2011.632086

Good, A., Reed, M. J., & Russo, F. A. (2021). Compensatory plasticity in the deaf brain: Effects on perception of Music. https://doi.org/10.32920/14638263.v1

Hladek, G. (2009). *Cochlear Implants, The Deaf Culture, And Ethics*. Ohio University | The Institute for Applied & Professional Ethics Archives. Retrieved February 25, 2023, from https://www.ohio.edu/ethics/tag/deaf-culture/index.html

Hopkins, C., Maté-Cid, S., Fulford, R., Seiffert, G., & Ginsborg, J. (2016). Vibrotactile presentation of musical notes to the glabrous skin for adults with normal hearing or a hearing impairment: Thresholds, dynamic range and high-frequency perception. *PLOS ONE*, *11*(5). https://doi.org/10.1371/journal.pone.0155807

Jones, S. K. (2015). Teaching students with disabilities. *Update: Applications of Research in Music Education*, *34*(1), 13–23. https://doi.org/10.1177/8755123314548039

Looi, V., McDermott, H., McKay, C., & Hickson, L. (2008). Music perception of cochlear implant users compared with that of hearing aid users. *Ear & Hearing*, *29*(3), 421–434. https://doi.org/10.1097/aud.0b013e31816a0d0b

Mangelsdorf, H. H., Listman, J., & Maler, A. (2021). Perception of musicality and emotion in signed songs. *Music Perception*, *39*(2), 160–180. https://doi.org/10.1525/mp.2021.39.2.160

National Institute of Deafness and Other Communication Disorders. (2021, March 24). *Cochlear implants*. National Institute of Deafness and Other Communication Disorders. Retrieved February 26, 2023, from https://www.nidcd.nih.gov/health/cochlear-implants#:~:text=A%20cochlear%20implant%20is%20very,directly%20stimulate%20the%20auditory%20nerve.

Sharp, A., Bacon, B. A., & Champoux, F. (2020). Enhanced tactile identification of musical emotion in the deaf. *Experimental Brain Research*, *238*(5), 1229–1236. https://doi.org/10.1007/s00221-020-05789-9

Stabej, K. K., Smid, L., Gros, A., Zargi, M., Kosir, A., & Vatovec, J. (2012). The music perception abilities of prelingually deaf children with cochlear implants. *International Journal of Pediatric Otorhinolaryngology*, *76*(10), 1392–1400. https://doi.org/10.1016/j.ijporl.2012.07.004

Trehub, S. E., Vongpaisal, T., & Nakata, T. (2009). Music in the lives of deaf children with cochlear implants. *Annals of the New York Academy of Sciences*, *1169*(1), 534–542. https://doi.org/10.1111/j.1749-6632.2009.04554.x

Vongpaisal, T., Trehub, S. E., & Schellenberg, E. G. (2006). Song recognition by children and adolescents with cochlear implants. *Journal of Speech, Language, and Hearing Research*, *49*(5), 1091–1103. https://doi.org/10.1044/1092-4388(2006/078)