Piano Performance and Identification of Melodic Contour and Pitch

of

Prelingually Deaf Children with Cochlear Implants

After Three Months of Formal Music Instruction

Sandra Marković

Thesis submitted to the University of Ottawa
in Partial Fulfillment of the Requirements for the Degree of
Master of Arts

School of Music
Faculty of Arts
University of Ottawa

Table of Contents

List of Tables

List of Figures

Acknowledgments

The completion of this thesis would not have been possible without the support of many people.

First and foremost, I would like to thank my mentor and thesis supervisor, Dr. Gilles Comeau in the Piano Pedagogy Laboratory at the University of Ottawa. His knowledge, guidance, and encouragement inspired me to find my calling in the research field of interdisciplinary studies. I am grateful for the opportunity to improve access to music education for children with cochlear implants.

Thank you to Dr. Giguere and Dr. Koravand who served as my thesis committee whose insightful comments, and helpful suggestions carried me to the end.

In addition, I am thankful to Chen and Mikael for their technical contribution with music excerpts, and data collection. Their patience with my requests is greatly appreciated.

Thank you to Hands and Voices, and Voice, support organizations for deaf and hard of hearing children and parents. Thank you to all the students and their dedicated parents who participated in this study. Their unparalleled commitment to this research has left me forever in debt to them.

Thank you to my friends Erin, Kayko, and Nisreen who have believed in me, and this project since its conception. Our friendly brainstorming sessions kept me positive, engaged, and creative.

Also, thank you to my loving family; my mother and brother whose unwavering support carried me through this process. Thank you to my son Filip whose wisdom and humour helped me cross the finish line. You are my abundance.

Lastly, I would like to dedicate this thesis to my son Andrej, the inspiration for this research. I love you, endlessly.

To Andrej ~ (Mama)

Preface

I certify that the research presented in this thesis is original scholarship. The results represent a distinct contribution to knowledge.

Abstract

Significant developments in cochlear implant design have been made in the past two decades, with clearer speech and music perception serving as the main research foci (Advanced Bionics, 2009). However, poor spectral resolution produces an inadequate representation of the pitch information crucial for music appreciation (Chen, 2012; Galvin, Fu, & Shannon, 2009; Jung et al., 2012). Several studies suggest that daily exposure and practice are positively correlated factors for the effective music instruction of pediatric cochlear implant recipients (children CI users), enhancing their ability to recognize, enjoy, and reproduce music (Comeau, Koravand, & Markovic, 2017; Lo, Looi, Thompson et al., 2020). However, no studies have yet focused on teaching music outcomes and then assessing those taught skills to children CI users. Amid the plethora of research on music therapy for children CI users, no individual formal teaching methods have yet been proposed to investigate the outcomes of teaching classical music on piano. This thesis main goal was a comparative study of children CI users and NH children's piano performances, identification of melody, rhythm, and pitch discrimination after three months of individual formal piano training using a multi-sensory (auditory, visual, and tactile) approach and a customized aural modeling (no notation reading) teaching method with familiar songs. This study included 10 children CI users and 10 NH children aged 4 to 9 with no prior formal music training. The results indicate that in familiar song recognition tests, and MBEMA melody and rhythm tests, children CI users improved on their accuracy after the three months of piano lessons. Also, children CI users have reported enjoyment in practice and music listening overall.

Keywords: **Cochlear Implants; Pediatric Cochlear Implants; Prelingual Deaf Children; Cochlear Implant Users; Pitch; Rhythm; Timbre; Music Education; Music Performance; Music perception; Music Training; Piano teaching.**

Chapter 1

Introduction

The cochlear implant (CI) is a device that helps deaf people hear. Many CI children and adult users, with proper therapy, comprehend and master speech but fail to perceive and recognize music due to its auditory complexity (Petersen, Mortensen, Gjedde, & Vuust, 2009). Many researchers and CI technology developers have recently become interested in improving the ability of CI users to perceive music by experimenting with CI program strategies and trying different learning and listening strategies (Surma, 2024; Cheng, Hsiao & Gfeller, 2012). Many studies have explored music perception with pediatric cochlear implant users, and adult CI users with generally encouraging results. Furthermore, some studies have focused on emotional mechanisms of music processing in CI users in comparison to normal hearing NH groups (Calvino, 2023). CI children users perceive rhythm with an accuracy almost equal to that of their NH peers but perceive pitch and timbre less accurately (Gfeller et al., 2002; Looi, McDermott, McKay, & Hickson, 2008; Vongpaisal, Trehub, & Schellenberg, 2006). In melody recognition tasks, the best results occurred in studies using songs with lyrics that were familiar to the participants, followed by instrumental pieces that were similarly familiar (Gfeller, Olszewski, Turner, Gantz, & Oleson, 2006; Mitani et al., 2007; Nakata et al., 2005; Nakata, Trehub, & Kanda, 2012; Stordahl, 2002; Trehub, Schellenberg, & Vongpaisal, 2009; Vongpaisal, 2004; Vongpaisal et al., 2006). Also, several research studies have developed online music programs for CI users (Calvino, 2023; Firestone, 2020; Fuller, 2018; Looi, 2012). However, very few researchers have instructed children with no prior musical training on an instrument (Surma, 2024; Good, Gordon, Papsin et al., 2017) for the purpose of identification of melodic contour, pitch, and singing abilities and/or piano performance.

Key concepts and terms

Prior to the literature review, it is important to explain some of the salient terms and concepts that will be referred to regularly. First, the c*ochlear implant* (CI) is a neurological prosthesis that simulates hearing for people with severe to profound hearing loss. The CI operates by stimulating the auditory nerve, bypassing damaged hair cells in the cochlea. It does not restore recipients' hearing but rather allows them to perceive sound (Gfeller, 2009; Gfeller, Driscoll, Kenworthy, & Van Voorst, 2011a). Ideal CI candidates are those who have experienced some form of severe to profound sensorineural hearing loss, defined as any deficiency of the auditory nerve or inner ear that inhibits electrical signal transfers to the auditory centers in the brain (Chen, 2012; Rauschecker & Shannon, 2002).

The device itself is comprised of external and internal components. The external device consists of a microphone, processor, and transmitter powered by a small battery. Sound is picked up by the microphone, analyzed, filtered, and digitally encoded by the processor and then sent to the internal components via the transmitting coil. The surgically implanted internal component consists of the receiver, stimulator, and electrode array. The receiver and stimulator, located under the skin just behind and above the ear, receive the electrical signal and send it along to a 22 mm electrode array housed in the cochlea, which activates the auditory nerves, sending auditory information to the brain (Zhou, 2010). The number of electrodes varies from 12 to 22 (Jiam, & Limb, 2020) depending on the brand, model, and era. Current devices are multi-channeled and use anywhere from 16 to 22 channels of stimulation of the hearing neurons and optimized frequency coverage. (Kasturi, 2006). These internal components are "future ready," meaning that they are expected to be adequate for the foreseeable future. Developments in technology happen more rapidly for the external devices.

There are four types of cochlear implantation: *unilateral*, in which only one cochlea receives implantation; *bilateral*, in which both cochleae receives implantation; *bimodal*, in which one cochlea receives implantation while the other uses an assistive hearing device such as a hearing aid; and *hybrid*, an experimental type of implantation used in combination with a hearing aid in an attempt to exploit any residual hearing, usually at lower frequency ranges – below 1000Hz (Cullington & Zeng, 2011). Many research studies suggest that in cases of profoundly deaf individuals, the early (as early as six months of age) and bilateral implantation result in better speech understanding, and production (Zhou, 2010; Kasturu, 2006; Chen, 2012)). Also, research suggests that music perception for bilateral CI users is significantly better than for unilateral CI users (Veekmans, Ressel, Mueller, Vischer & Brockmeier, 2009). Furthermore, research indicates that the young CI users benefit from early implantation due to greater neural plasticity resulting in more efficient use of new information (Gfeller et al., 2011, Hsiao & Gfeller, 2012). Bilateral implantation also provides better sound localization and speech perception amidst noise (Zhou, 2010). Unfortunately, many CI users struggle in noisy environments and with music (Carroll, 2008; Deroche, Lu, Limb, Lin, & Chatterjee, 2014; Nakata et al., 2005). The main population of interest of this proposal will be the bilateral pediatric cochlear implant recipients (children CI users).

Prelingual deafness refers to individuals with no previous experience of or reference to sound, and who rely completely on new auditory experiences occurring through the CI (Gfeller, Driscoll, Kenworthy, & Van Voorst, 2011b; Gfeller et al., 2012; Houston et al., 2012; Hsiao, 2008; Jung et al., 2012; Nakata et al., 2005). Conversely, *postlingual deafness* refers to individuals who lost their hearing *after* language acquisition (Fujita & Ito, 1999; Gfeller, Christ, Knutson, Witt, & et al, 2000). Generally, they are adults and are not the focus of this research. Some research studies suggest that prelingually deaf children underperform postlingually deaf adults in music (Jung et

al., 2012; Olszewski, Gfeller, Froman, Stordahl, & Tomblin, 2005). As many researchers have investigated differences between unilateral and bilateral implantees as well as prelingually and postlingually deaf individuals and concluded that bilateral prelingually deaf individuals are in advantage, this study will choose bilateral children CI users as its main population of interest.

In line with the focus of this research, the literature review examined one hundred and eleven academic papers and research studies with following criteria:

1. Participant selection, in particular children CI users who are bilateral implantees.
2. Topics with a focus on music perception and music recognition for children CI users; and
3. Music instruction and reproduction (music playing).

Chapter 2

Music perception of children CI users

Music pervades human culture, and growing evidence shows it is beneficial in brain functions in many ways (Patel, 2024). Darwin argued that humans have evolved to be musical. Many psychologists since have developed theories on music evolution in humans as a survival value *e.g.,* enhancing social bonds and a role in parent-infant communication (Patel, 2024). Music exists in every culture and society and therefore is universal. The vastness and variety of musical expression indicates the importance it takes in human lives (Levitin, 2024). Nietzche once famously exclaimed: "Without music, life would be a mistake."

Overall, it is agreed that CI users can perceive and recognize music but with some difficulties. Those difficulties in music perception for the CI users can be attributed to the fundamental limitations in complex sound processing (Jiam & Limb, 2020). For example, it is reported that CI users of all ages experience poor transmission of important structural music features such as pitch, melody, and timbre (Calvino, Zuazua, Sanchez-Cuadrado, Gavilan, Mancheno, Arroyo, & Lassaletta, 2023; Gfeller, Jiang, Oleson, Driscoll, & Knutson, 2010; Lu, Huang, & Zeng, 2014; Olszewski et al., 2005; Driscoll, Gfeller, Kliethermes, & Oleson, 2013; Volkova, Trehub, Schellenberg, Papsin, & Gordon, 2014; Vongpaisal et al., 2006; Zhang, Benson, & Cahn, 2013). This section focuses on studies of children CI users' perception of rhythm, pitch, and timbre.

Rhythm

Of all the structural features of music, rhythm is most accessible to all CI users (Abdi et al., 2001; Kosaner et al., 2012; Mortensen, Hansen, Vuust, & Petersen, 2012; Nakata et al., 2005; Yucel, Sennaroglu, & Belgin, 2009). In a comparative review analysis involving normal hearing children, Gfeller and colleagues (2011) reported that deaf children with cochlear implants perceive and play

rhythmic patterns with accuracy similar to that of normal hearing listeners. Also, children CI users are technically well suited for transmitting a basic beat or melodic rhythm (Abdi et al., 2001; Kosaner et al., 2012; Mortensen et al., 2012; Nakata et al., 2005; Yucel et al., 2009). Because of this rhythmic affinity, children CI users often rely on rhythmic cues to identify simple melodies such as *Happy Birthday* and *Twinkle Twinkle* (Hsiao & Gfeller, 2012). Abdi and colleagues (2001) investigated the effects of music training by teaching songs to 23 participants aged 2.5 to 12.5. As a rhythm accuracy test, participants were asked to identify the number of notes played (by the researcher), to play the pattern on one note, and to keep the value of (i.e., reproduce) the notes. The study reported its best accuracy results for these rhythm assessments. Several other studies report that CI users—both adult and children—have scored nearly as high as NH subjects in rhythm testing (Drennan & Rubinstein, 2008; El Fata, James, Laborde, & Fraysse, 2009; Gfeller, 2009; Gfeller et al., 2010; Gfeller et al., 2011b; Looi et al., 2008; Mortensen et al., 2012; Vongpaisal et al., 2006). Gfeller and colleagues (2002) tested 17 adult listeners using the Adopted Primary Measures of Musical Audiation (PMMA) test to evaluate rhythmic pattern discrimination between NH and CI users. The tasks included differentiating two rhythmic patterns, where listeners had to identify a change in the short interval among four long intervals, with the tempo progressively increasing until the listener could no longer hear the short interval. Both groups scored 84% correct, the difference being that NH participants could identify it within a shorter duration (607 ms vs. 1070 ms respectively). Jiam and Limb (2019) summarized current research on music perception with CI children. They suggest that even though with advancement in technology and many music training programs offered with the device manufacturers there are still difficulties with timbre and pitch recognition whereas rhythm continues to be the primary cue for melody recognition for CI children.

In summary, many CI users have similar accuracy in rhythm and tempo discrimination as normal hearing listeners.

Pitch

Postlingually deaf individuals consistently report dislike of or indifference to music due, it is believed, to their lack of appreciation of the nuances in melodies (Gfeller et al., 2010; Saindon, 2013). For prelingually deaf children, the concept of higher and lower interval size is problematic, as their entire hearing history has occurred through the CI, and they have therefore never heard normal pitch representation (Gfeller et al., 2010; Hsiao, 2008; Olszewski et al., 2005; Stordahl, 2002). A large part of the problem lies in the technical limitations of the CI itself. The perception of low frequencies is 20 Hz for normal hearing; for the CI, however, it is about 300 Hz, resulting in the absence of lower pitches (Drennan & Rubinstein, 2008). Depending on the type and brand of device, the CI electrode array contains 4 to 22 electrodes that can transmit frequencies ranging from 120 to 8000Hz (Saindon, 2010). This is adequate for speech processing but much narrower than the needed frequencies associated with music, which range from 27 to 16744Hz (Gfeller et al., 2011). The pitch patterning (sounds raising, falling, or staying the same) CI users receive is so limited that they ignore it, focusing on timing cues, allowing them to synchronize their dancing, tapping, and clapping with others (Vongpaisal et al., 2006, Kosaner et al., 2012). However, there have been surprising successes in proper identification of familiar tunes with original cues, instrumental and vocal in one-semitone pitch variations amongst prelingually deaf children ages 5 to 11 years old, with a minimum of 2 years of hearing experience (Vongpaisal, 2006, 2009; Volkova et al., 2014; Roy et al., 2014; Crew et al., 2012; Drennan et al., 2008). Galvin and colleagues (2009) conducted a study with 11 adult CI users (M = 56.3) and 9 NH participants with a focus on the determination of melodic contour discrimination using nine different contours where average performance accuracy increased from one to five semitones from 32 to 64% accuracy. In the same study, familiar melody recognition tests decreased from 60 (with rhythmic cues) to 28% without rhythmic cues. However, they also reported that the accuracy of melodic recognition increased to 71% correct, with training (weekly listening

tasks, a half hour per day, five days per week) on their computers at home for two months. Yitao and Li (2013) summarized research results on pitch difficulties and vocal singing as a training tool to a better pitch perception with children CI users. They hypothesized that poor music perception could be also due to poor lexical tone perception especially in noisy environments. They concluded that music training indeed helps with music perception.

In summary, pitch recognition and melodic contour identification is difficult for CI users; however, with training and exposure, accuracy is increased, and positive results have been reported.

Some studies have reported a profound deficiency in the ability of children CI users to recognize and identify melodies compared to their NH peers (Drennan & Rubinstein, 2008; Hsiao & Gfeller, 2012; Gfeller, 2014; Wright, 2012). However, other studies that have made use of songs that are popular and/or familiar to the study participants reported positive results that are generally on par or only slightly lower than NH participants (Mortensen, 2012; Hsiao, 2008; Olszewski et al., 2005). Furthermore, some studies have used instrumental versions of popular/familiar songs, which yielded poorer accuracy rates from the CI group (Mitani et al., 2007, Nakata et al., 2005, 2006, 2012; Vongpaisal et al., 2004, 2006; Gfeller et al., 2006; Stordahl, 2002). A third procedure used melodic contour processing to assess recognition accuracy. These test conditions tended to yield the most negative results, indicating that children CI users have the greatest difficulty with melodic information devoid of lyrical and rhythmic cues (Petersen et al., 2012; Yucel et al., 2009; Trehub et al., 2009; Gfeller, 2014; Falcon-Gonzalez et al., 2014; Volkova, 2012; Omran et al., 2011; Vongpaisal, 2011). However, it is noted that a CI users' ability to recognize melodies improves with the more cues (e.g., lyrical, rhythmic) are received (Gfeller et al., 2006; Nakata et al., 2005; Stordahl, 2002; Vongpaisal et al., 2006), and the more familiar they are with the song (Hsiao, 2008; Olszewski et al., 2005).

In summary, there is a pervasive use of familiar melodies in the existing research, suggesting that

CI users are more reliant on the identification of markers in popular songs (Gfeller et al., 2007, 2008).

Timbre

While NH infants are able to recognize changes in musical timbres as early as 12 months old, the discrimination and recognition of instrumental timbre is quite problematic for CI users (Jung et al., 2012; Stabej et al., 2012; Drennan et al., 2008; Ogordnikova et al., 2008; Roy et al., 2014). The technical limitations of children CI users result in a lack of spectral resolution for the recipient (Kasturi, 2006; Wilson & Dorman, 2008; Wright, 2012; Zhang, Benson & Cahn, 2013; Zhou, 2010). This can increase difficulty in perceiving timbre or distinguishing among types of sounds (Omran et al., 2011; Ogordnikova et al., 2008; Drennan et al., 2008; Stabej et al., 2012; Jung et al., 2012). Timbre perception contributes to auditory spectrum analysis when one listens to complex musical groups such as an orchestra (Zhang et al. 2013; Stabej et al., 2012; Roy et al., 2014; Ogordnikova et al., 2008; Drennan et al., 2008; Jung et al., 2012). For children CI users, instrument timbre recognition is of the greatest challenge compared to adult CI users. Children CI users' most recognizable instrument is the guitar, and the least recognizable is the flute (Stabej et al., 2012; Jung et al., 2012). However, CI users can improve their recognition of different instruments through training, and a direct and focused exposure to musical instruments (Gfeller et al., 2011, 2014; Kosaner et al., 2012; Patel, 2013; Yucel et al., 2009; Pressnitzer et al., 2005; Fujita & Ito, 1999). In addition, Driscoll and colleagues (2009) have researched music instrument recognition with 66 NH adults who have been exposed to a series of training sessions in which they listened to eight different musical instruments through CI simulations. The greatest improvements were noted in a group with direct training sessions over the five-week period, whereas the least improved group was with the repeated exposure, presenting practical implications for the auditory rehabilitation of cochlear implant users in improving their recognition of musical instruments.

In summary, timbre is the most difficult music element to identify for most CI users due to limitations in how CI users process and transmit complex auditory information. Children CI users do not transmit all the fine-grained auditory information that is crucial for timbre perception.

In conclusion, CI users react differently to sounds and music than do their NH peers. The children CI users' stimulation might be initially perceived as tactile rather than auditory (Gfeller et al., 2011; Kosaner et al., 2012). With the proper training and processor programming, however, they have the ability to improve their perception of pitch and timbre (Gfeller et al. 2011; Roy et al., 2014; Crew et al., 2012; Galvin et al., 2009; Drennan et al., 2008; Gonzalez et al., 2014; Omran et al., 2011).

Music learning and reproduction

Despite a plethora of recent studies in the field of music and CI users, very few studies focus on instrumental instruction for children CI users. A notable exception includes an early musical intervention-training program using the Orff method (Abdi et al., 2001). In this study, twenty-three children aged 2.5 to 12.5 years, bilaterally implanted, prelingually deaf children were taught music as a mean of rehabilitation. In addition, children older than 8 years were taught se-tar, a traditional instrument. The study's measuring methods were playing skills, number of melodies played correctly (simple and short melodies from Orff book), number of mistakes made playing familiar melodies, understanding rhythm, repeating rhythm patterns on one tone played by the researcher, differentiating rhythm patterns, and differentiating a tone between two played melodies. The results indicated that both groups (older – 6.5-12.5; and younger group - 3-6) made a notable progress on playing and understanding of rhythm and tunes (Abdi et al., 2001). In addition, a custom designed method called "Music Ears" was developed that combined singing, recognizing songs, tunes, and timbre, with the use of percussion responses (Kosaner et al., 2012). In that study, 25 participants, unilaterally implanted were divided in three groups by: age, duration of CI use, and general ability to follow directions and engage in conversation situations. The study consisted of group and

individual lessons where parental involvement was strongly advised. Group sessions consisted singing chants, one-word songs, and action songs. Also, the teaching was focused on short pieces and their timbre, pitch, dynamic and rhythmic change identifications. Each participant's progress was charted using checklists, questionnaires, and formal testing of auditory perception; EARS for older group and LittlEARS Auditory Questionnaire for the younger. The study was executed over an 18-month period, including one weekly group sessions of 45 minutes and one individual session of 20-30 minutes. The researcher reported significant increase in scores over time for all groups of children. Furthermore, the researcher suggested that the program is easily adaptable to all age groups as none of the subjects performed badly. It is important to mention that all participants, however, least progressed on singing tasks. The researcher suggested that this might be the case due to a longer period needed making a parallel to required longer time even for speech acquisition with children CI users (Kosaner et al., 2012). However, the study, most significantly, made a correlation between music skills and length of listening experience, supporting the idea that the longer children receive music training, the better they score.

Another study by Petersen and colleagues (2009) used basic music ear training by playing the keyboard, singing the individually preferred Danish tunes and by listening exercises using the prerecorded CD with Danish tunes with the aim to improve melodic contour identification, pitch, and rhythm. The subjects were divided in three groups by age, and duration of deafness, and test results (PET tests on speech and music perception). First group received pitch training, second group received rhythm training and third postponed training. After three months, first and second group alternated. The study aimed to view the difference between a rhythmic and melodic strategy as well as between training and no training effects. Music perception tests included: perception of melody and rhythm (same or different), perception of pitch (naming the higher note), and timbre recognition (different instruments – same melodic phrases). The study suggests that music training especially

with young children with Children CI users is a beneficial aid in improving music and listening perception. Furthermore, the researchers suggested that their music education program might be beneficial not only to CI users but also to general populace as well.

Barton & McConkey Robbins (2015) have compiled the data on benefits of music therapy as a "jumpstart" to auditory learning. Their recommendations on integrating music as therapy to enhance language are based on four methods: Re-creative method – where a child is engaged in singing precomposed songs like nursery rhymes, Improvisation method – where children freely chose an instrument and express their emotions and ideas while supervised by the therapist, Receptive method – where the child is engaged in active listening, and Compositional method – where the child and the therapist create a video or audio recording to document child's thoughts, feelings and ideas.

Other studies that advocate music training for CI users include Gfeller (2011) whose multi-sensory perceptual input program suggests combining songs with lyrics, dancing, and rhythmic clapping, and a singing approach (Yennari, 2010; Petersen, 2012) where seven children CI users underage of three were monitored playing with sound making materials, and musical instruments, listening to live and recorded music, and singing alone and with a group. Yennari and Petersen's study (2012) included in their sessions a hello song, singing a new or a favourite song, free use of percussion instruments including electronic keyboards and even whistles, toys, and props. The sessions were recorded over a one-year period and later analyzed. The study was conducted in three different settings: at home, specialist nursery and community nursery. The main goal was to track and analyze children's responses to see best practices. The results emphasized the importance of collective music making and parental involvement as a way of engaging children into activities such as singing, playing instruments and socializing. The researchers offered that singing can enhance children's social and emotional lives and as such should be viewed holistically (p. 294). Also, Lo and colleagues (2020) exposed fourteen 6-9 y prelingually deaf CI users to 12 weeks music therapy

training program and a take home music apps three times a week. Their results report that even a modest amount of music training is beneficial to music and speech outcomes.

It is worth noting research with MELUDIA – the online music training for adult CI users. Boyer & Stohl (2022) have used MELUDIA – an online music program for children and adults with varying musical abilities and skills - to view how suitable MELUDIA is for CI users. Thirty-eight adult CI users, implanted with MED-EL CI devices, participated in music training program where participants underwent 800 exercises with exposure to melody, harmony, spatialization, rhythm and form. The results indicated that using MELUDIA for music training was successful regardless of music background, age, or duration of CI use (p. 265).

Similarly, Calvino and colleagues (2023) used MELUDIA – online music program - for prelingually deaf CI users in their study on music perception. The participants in this study were divided in two groups (6-10, and 11-16 y). The adult NH group served as a control group. The total of 138 participants were tested for this research project where each group was assessed in five different tasks (rhythm, spatialization, melody, density and stable/unstable). Each task contained five levels of difficulty. The MuQPP (music questionnaire for pediatric population) was created by the researchers for this study. The MuRQoL (impact of music on quality of life) – frequency of music perception and engagement, and musical importance questionnaire was also used for this research. The results reported indicate similar results of CI users and NH group with NH group reporting higher level of music exposure than CI users. All groups reported similar level of importance of music with pediatric CI users scoring high on music perception and questionnaire scores. This study concludes positively on use of MELUDIA as a training tool for music training in CI users of all ages.

Another aspect that is important addition to the musical puzzle of children CI users is family involvement. Driscoll, Gfeller, Tan, See, Cheng &Kanemitsu (2015) investigated 32 families with CI

children and NH siblings who were asked to fill questionnaires about music involvement. Results indicated that families who ranked music education high in importance had both children involved in music lessons and no significant difference between CI children and NH siblings in music involvement. On the other hand, parents who ranked music importance low had children who were less involved in music activities (p. 137).

Another project worth mentioning is by Nagathil and Martin (2019) where they customized music compositions, music processing methods, improved sound coding strategies for the CI users. The concerts such as "Noise Carriers", "Interior Design", and MusIC LO, 2.0, and 3.0" was a collaboration between Australia, UK, Spain, and Germany. The goal was to compare and understand the differences between NH and CI users' appreciation and perception of music in live concerts. The project consisted of several seminars where musicians composed electroacoustic music. The concerts featured also pop and acoustic compositions. The questionnaire was design to track the CI user's enjoyment and then compared to the NH listeners. The concerts were considered a success with CI users rating percussion pieces most favoured and melody, and timbre pieces less favoured.

Another study recruited twelve adult CI users for home-based music training that focused on attentive listening of music materials emphasizing melody structure (Firestone et al., 2020). The participants were asked to take 40 minutes music listening sessions for five days. The participants had a choice of 4 weeks or 8 weeks study. The researchers used Speech, Spatial and Hearing Scale questionnaires and tests. The EEG tests revealed a significant improvement in seven participants. They concluded that music listening can be improved with focused music listening.

Yüksel and colleagues (2023) investigated music-evoked emotions, and related mechanisms in CI users. The research included 50 prelingually deaf CI users and 50 age matched NH control group. Both groups' participants completed the same questionnaires on 28 emotions and 10 mechanisms (brainstem reflex, rhythmic entertainment, evaluative conditioning, contagion, visual imagery,

episodic memory, musical expectancy, aesthetic judgment, cognitive appraisal, and lyrics). The results reported positive emotions such as happiness, joy, tranquility, love, and trust equally high in both groups, and negative emotions such as envy, anger, fear, guilt, anxiety ranked the lowest between both groups as well. The CI group ranked lyrics and rhythm entertainment the highest in the emotion mechanism, and lowest in the episodic memory mechanism.

Good et al. (2017) research focused on comparing effects of music training and visual arts for prelingually deaf CI users where after six months of training, CI users who underwent the music training, improved on musical skills and emotional prosody processing. Torppa et al., (2018) also reported that informal singing experience (at least once a week) with the group of 4-13 CI users improved speech perception.

In summary, many studies indicated promising results with music learning and reproduction abilities of children CI users. More specifically, they suggested strong correlation between duration of music education and music perception accuracy as well as incorporation of all music aspects (rhythm, pitch, timbre) in music curriculum.

Concluding remarks

From the review of the literature containing one hundred and twenty studies, it is evident that the researchers are interested and invested in exploring the possibilities for music and cochlear implantees. Most studies have focused on music perception (Jiam & Limb, 2020; Brunsk, Murbe &Hahne, 2016; Yitao & Li, 2013; Ogordnikova et al., 2008; Yung et al, 2012; Roy et al., 2014; Chen 2012; Stabej et al., 2012; Hsiao & Gfeller, 2012), music recognition – melodic contour, rhythm, pitch and timbre, and some have focused on suggestive music teaching strategies for children CI users. Most of the studies have concluded that children CI users struggle to some degree with music pitch and timbre in comparison to the NH children (Gfeller 2002). Furthermore, because many children CI users use rhythm as a music cues (Jiam & Limb, 2019), several researchers have

mapped methods of teaching children CI users using percussion and singing as an instrument of choice (Hidalgo, Falk, &Schon, 2017; Kosaner et al., 2012; Yucel et al., 2009; Abdi et al., 2001; Gfeller, 2014). Some researchers report positive outcomes with multisensory activities such as training that combined auditory and motor components rather than just auditory training (Vongpaisal et al., 2016). Previous research in the areas of music perception, melody recognition, and music learning indicates that children CI users have the capacity to perceive music, recognize melodies under certain conditions, and learn music (Looi et al., 2012). Furthermore, importance of parental involvement, especially maternal musicality and exposure of children CI users post implantation has positive effects on language development, social acquisition, and continuous music engagement (Persici et al., 2024; Driscoll et al., 2015). Lastly, many studies have recommended some form of music training for CI users as complimentary therapy to their auditory verbal therapy (Abdi et al., 2001; Chen et al., 2010; Petersen at al., 2015). Current research on CI users suggests computer-based pitch training and face-to-face lessons, and wide range of activities to develop diverse skills (Fuller et al., 2018).

Research problem

Many researchers have been interested in postlingually deaf adults for the main purpose of obtaining information on how music sound after the cochlear implantation. However, even more have researched young implanted children who did not have any previous knowledge and experience with music (prelingually deaf) and their progress in understanding and recognition of music (Nakata et al., 2005, 2006, 2012; Olszewski et al., 2005; Petersen et al., 2009, 2012; Trehub et al., 2009; Veekmans et al., 2009; Chen et al., 2012; Gfeller, 2012; van Besouw et al., 2011; Wright & Uchanski, 2012; Vongpaisal et al., 2006; Stabej et al., 2012; Stordahl, 2002). This ongoing interest in young deaf children with cochlear implants and music understanding and performance abilities is a result of the general awareness and importance of music participation in one's life (Gfeller, 1997).

Bruns and colleagues (2016) reported that classical music was least favourite genre to prelingual CI users, while second favourite to post lingual CI users. To date, the piano has primarily been used for modeling or as a measuring instrument only, not as a means of rehabilitation for children CI users (Abdi, 2001; Galvin et al., 2009; Volkova, 2012; Hopyan et al., 2011; Gfeller et al., 2011; Patel, 2013; Yucel et al., 2009; Petersen et al., 2009). The possible benefits of using piano include the tonal stability of the instrument, as no frequent tuning is necessary, and proper intonation is not reliant on proper technique. In addition, piano hand position provides visual and tactile cues as part of a multi-sensory approach (Gfeller, 2011; van Besouw et al., 2011). Galvin and colleagues (2007) reported the children CI users' ability to successfully recognize rising-falling and falling-rising patterns modeled on the piano. With these positive results, they emphasized the importance of piano training and exposure with children CI users. Galvin and colleagues (2009) concluded that music experience and instruction improve melodic perception and pitch recognition (as a main focus) using piano as a modeling instrument and as a stimulus. The results indicated significant improvement in nine different five-note melodic contour identifications. Furthermore, Galvin and colleagues (2007) suggested that the effects of formal piano training with simple and complex stimuli are an unexplored but promising field of future research. Based on previous research and complex issues of music perception for children CI users, this study would target these deficiencies by exposure and specific training methods.

The focus of this study was possibilities of teaching young children CI users' three familiar and three unfamiliar music pieces over a three-month period to explore and analyze if their music playing reproduction abilities presented any possible improvements in pitch, melodic contour and rhythm discrimination.

Research questions

Previous research on music perception with children CI users indicates that rhythm cues are most

common and easiest to use for the melodic recognition. Also, research indicates that lyrics in tunes give additional structure and help in recognition of the melodies. Furthermore, it is well documented that children CI users struggle with timbre and pitch. Based on evidence that children CI users enjoy music and are eager to participate in music making, this study focused on exposing children CI users to eight familiar melodies with focus on pitch and timbre by using different pedagogical strategies. The effects of the exposure to pre-recorded tunes of eight familiar melodies, and piano playing and singing of the melodies to children CI users was the primary goal of this study. Lastly, all the strategies used were with familiar children's songs by including easy and difficult to identify conditions and compare. The aim of the study was to collect evidence if the training and exposure in a different context would replicate these new learned skills and improve children CI users' music cognition and recognition.

Given the scope of previous research, this research study posed following questions:

1a) How do children CI users differ before and after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented though five different conditions (original, piano, voice, flute, octave higher flute)?

1b) How do children CI users differ to NH children before and after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented though five different conditions (original, piano, voice, flute, octave higher flute)?

1c) How do children CI users differ before and after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented though five different conditions (original, piano, voice, flute, octave higher flute) to CI users who do not?

2a) How do children CI users differ in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from the Montreal Battery Evaluation (MBEMA) test?

2b) How do children CI users differ to NH children in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from the Montreal Battery Evaluation (MBEMA) test?

2c) How do children CI users differ in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from the Montreal Battery Evaluation (MBEMA) test to CI users who do not?

3a) How do children CI users differ in accuracy scores before and after the three months of formal piano training in rhythm discrimination task conducted over 20 pairs of rhythm excerpts from the Montreal Battery Evaluation (MBEMA) test?

3b) How do children CI users differ to NH children in accuracy scores before and after the three months of formal piano training in rhythm discrimination task conducted over 20 pairs of rhythm excerpts from the Montreal Battery Evaluation (MBEMA) test?

3c) How do children CI users differ in in accuracy scores before and after the three months of formal piano training in rhythm discrimination task conducted over 20 pairs of rhythm excerpts from the Montreal Battery Evaluation (MBEMA) test to CI users who do not?

4a) How do children CI users differ to NH children in practice time?

4b) How do children CI users differ to NH children in quality of practice?

4c) How does teacher's assessment of children CI users differ to NH children in enjoyment of piano lessons and music learning?

Hypothesis

The current evidence suggests that children CI users could improve their music abilities with music training and regular practice (Trehub et al., 2009; Mitani et al., 2007; Gfeller, 2011; Chen,

Chuang, McMahon, et al., 2010; Comeau, Koravand, & Markovic, 2017). Based on previous research studies, it is hypothesized that after three months of formal piano training children CI users' experimental group will be able to:

1a) Recognize eight familiar melodies presented through five different conditions with greater accuracy.

1b) Recognize comparably to NH children experimental group at eight familiar melodies presented through five different conditions.

1c) Outperform the children CI users control group on their capacity to recognize and name eight familiar melodies presented though five different conditions.

2a) Perform at the greater accuracy on the MBEMA melody discrimination task.

2b) Perform comparably to NH children on the MBEMA melody discrimination task.

2c) Outperform the children CI users control group on the MBEMA melody discrimination task.

3a) Perform at the greater accuracy on the MBEMA rhythm discrimination task.

3b) Perform comparably to NH children on the MBEMA rhythm discrimination task.

3c) Outperform the children CI users control group on the MBEMA rhythm discrimination task.

4a) Demonstrate that children CI users practice time will be comparable to NH children.

4b) Demonstrate that children CI users' quality of practice will be comparable to NH children.

4c) Lastly, the teacher's assessment of children CI users' enjoyment of piano lessons and music learning would be comparable to NH children.

Chapter 3

Methodology

This research study investigated the effects of a three-month, individualized formal piano lesson plan on children CI users, using a multi-sensory approach and a customized aural modeling (listening and imitating sounds) teaching strategy. This research study has been approved by Ethics Committee of University of Ottawa from Social Sciences and Humanities, REB file number 12-15-02.

Design

This study falls under the category of between-participants (experimental and control groups) which is a common way of measuring differences (and similarities if any) in music perception, and recognition between children CI users and NH children. In addition, the children CI users' experimental group will be compared and measured within-participant to assess their progress before and after the lessons period. Study participants were 10 children CI users and 10 NH children. They were divided into wo groups of experimental, and two control groups. Participants from the experimental groups received piano training for three months. Measures of Familiar Song recognition and MBEMA discrimination tests were obtained pre and post training. Many research studies that focus on detection of music abilities with the pediatric cochlear implant recipients' use this model of study as a comparative analysis to hearing counterparts, validating their findings (Gfeller et al., 2002, 2007, 2009, 2012; Roy et al., 2014; Stordahl, 2002; Stabej et al., 2012; Vongpaisal et al., 2006; van Besouw et al., 2011; Wright & Uchanski, 2012; Zang et al., 2013). Also, it is a quasi-experimental design, as many variables are controlled but not always entirely. Mean values were calculated for each test and results were presented in bar graphs for visual comparison of the four groups.

Sampling

The research study was presented to public schools and itinerary teachers for the deaf, support organizations (Voice, Hands and Voices) in Ottawa. The children CI users' participants were recruited from these two organizations, and NH group from Rockcliffe Park Public School in Ottawa. The researcher attended the Rockcliffe Park Public School parents' meetings, and Voice, and Hands and Voices meetings where the description of the study pamphlets and a short presentation was delivered. The parents of the control group were offered piano lessons after the completion of the study. All the participants were representative sample with its similarities in age (4 to 9), bilaterally implanted with no prior formal music training, and prelingually deaf with minimum two years of hearing experience. Also, in this study we included only neurotypical children CI users. All participants selected for this research fit the requested criteria. A Non-Probability Sampling - Purposive Sampling was applied; everyone had equal opportunity of participating based on previously mentioned criteria. For validation of the study, all participants were matched closely to their age. Though, it is recommended to have 30 participants per group for this kind of study, for the purpose of this research study, and maintainability of the project, we recruited 5 participants per group (5 children CI users and 5 NH children). There were four groups: two experimental groups of children CI users and NH children, and two control groups of children CI users and NH children. The experimental groups received piano training while the control groups did not. Replication might be possible with different conditions and different focus such as motivation and behavior analysis.

Participants

For the purposes of this study, the participant pool was equally divided as follows:

- An experimental group of 5 Pre-lingual Cochlear Implant Recipients (children CI users).
- An experimental group of 5 Normal Hearing (NH) children.
- A control group of 5 Pre-lingual Cochlear Implant Recipients (children CI users).

- A control group of 5 Normal Hearing (NH) children.

Table 1

Overview of Participant Demographics

Groups	Hearing status	Participant ID	Age (years)	Sex	Hearing age (years)
Experiment groups	CI	CI 1	5	F	4
		CI 2	5	F	4
		CI 3	5	M	4
		CI 4	8	M	7
		CI 5	4	M	2
	Normal Hearing	NH 1	5	F	
		NH 2	5	F	
		NH 3	5	M	
		NH 4	8	M	
		NH 5	4	M	
Control groups	CI	CI 1	4	F	3
		CI 2	5	M	4
		CI 3	5	M	4
		CI 4	8	M	7
		CI 5	4	F	4
	Normal Hearing	NH 1	5	F	
		NH 2	6	M	
		NH 3	6	M	
		NH 4	8	M	
		NH 5	5	F	

The experimental groups received the formal music training on the piano for three months or 12 individual lessons on the piano. The control groups did not receive any music training. Participants in the groups were age and gender matched. Aside from the deafness in the children CI users' groups, each candidate had no other pervasive medical issues that would affect their music ability or their learning. Also, the children CI users were all prelingually deaf, and bilaterally implanted with a minimum of 2 years of CI experience. Furthermore, all participants had access to a piano and were able to practice designated tasks.

When teaching piano to both experimental groups – children CI users and NH children – the researcher would communicate each lesson plan. This way the children would get excited and familiar with the task before they would even start to play. That was a way of controlling the independent variable and lay down the foundation as well as lesson and practice predictability. The language used was familiar to all children. The researcher avoided Italian terms for tempo, dynamics, and phrasing, and kept English language as a primary tool and therefore kept their comfort in understanding the task. All children when learning high and low tones, loud and soft sounds were shown how to apply pressure on the keyboards differently to produce different tones. The researcher often used allegory to make impactful images to the music concepts they were being taught. This strategy seems to be helpful to children CI users when identifying melodies through different conditions as timbre recognition seemed the most difficult for them all. When learning a new song, the researcher would always use the same strategies: sing the song with words and clap quarter notes, then touch and sing the finger numbers of the hand we were trying to learn while bopping the head in proper time, then the researcher would play it while singing the finger numbers and bopping in rhythm, and finally give a child a chance to try while we are both singing the finger numbers and bopping in rhythm. Important notice: while teaching melody and playing the piano, the researcher would use only two bars at the time of the material set to be covered. The researcher found it useful strategy when teaching a difficult concept. For the first three songs, the children were taught to play with both hands the same melody and rhythm structure, and both groups got the concepts with ease. The melodic cues were used where finger numbers, and then words of the song were sung. Another useful strategy entailed the researcher asking the child to play once again separate hands and then try together smaller “chunks”.

Measurement

Testing

The children CI users were evaluated on their music perception abilities using melodic contour and rhythm identification tasks. The tests used were:

1) Familiar Song Recognition Test: A list of 8 of the most familiar English children's songs

a) Old McDonald

b) Itsy Bitsy Spider

c) Happy Birthday

d) Wheels on the Bus

e) London Bridge

f) Twinkle, Twinkle

g) If You Are Happy and You Know it

h) Mary Had a Little Lamb

…were presented to identify to each participant under five different conditions each…

I. Original – voice with lyrics and accompaniment

II. Piano only (Accomp)

III. Voice only

IV. Flute

V. Octave higher flute (Fl 8va)

All excerpts were pre-recorded by the lab technician at the Piano Pedagogy at the University of Ottawa. The equipment used were the personal iMac computer laptop and Bose speakers for the music excerpts presentation. Every participant was presented with a sheet of paper with the pictural and written representation of eight familiar songs as a helping tool. They were asked to either point to the picture in front of them or say out loud the name of the song they think is the excerpt they were listening to. Participants were allowed to ask the repeat of the excerpts. The researcher was recording

all the answers by audio and video as well as on answering sheet that was stored in individual file. This test was repeated twice; before the experiment and three months after the experimental groups completed their piano lessons.

2) Montreal Battery of Evaluation (MBEMA) – adapted, short version where 20 sets of melody and 20 sets of rhythm, 2 x 3 seconds excerpts at the time were presented to be discriminated as same or different.

Pre-recorded 20 sets of melody and 20 sets of rhythm excerpts were presented through iMac personal laptop and Bose speakers to each participant on the same day as the Familiar Song Test, also twice – before the experiment and three months after the experimental groups completed their piano lessons. Participants were allowed to ask the repeat of the excerpt. Participants had a choice of voicing the answer – same or different – or circling the answer on the presented sheet. Participants could take as long time as they needed to answer the task.

Independent variables

The research study lasted 3 months (12 lessons) and contained weekly piano lessons at the researcher's home studio, and using a multi-sensory (auditory, visual, and tactile) teaching method. Each class was 30 minutes in duration. Participants were also asked to practice a minimum of 5 sessions per week at a minimum of 15 minutes per session at their home. Tracking of data on requested tasks was done by the parents of the participants after each practice (Appendix I, J).

Dependent variables

The dependent variables in this study are the skills being evaluated:

1. Music contour perception: As many research studies point great difficulties with children CI users' perception of music contour, the researcher investigated whether music contour perception can be improved with exposure and training. Evaluation of the lesson, quality of practice and teacher's rating of the learning process was done after each lesson (Appendix H).

2. Pitch perception: Also investigated as another difficulty for the children CI users, the researcher investigated whether pitch perception can be improved with exposure and training. Evaluation of the lesson, quality of practice and teacher's rating of the learning process were done after each lesson (Appendix H).

Scores for both, independent and dependent variables, were calculated for each participant and each test as per scoring protocol for each test. Mean values were calculated for each test and results were presented in bar graphs for visual comparison of the groups.

Procedure

Recruitment Plan

Following the approval of the Ethics Committee, participants were recruited for both groups (children CI users and NH children's groups) by providing a copy of the advertisement (detailed description of the research study: where, how, who, purpose of the study) to The Voice for Hearing Impaired Children Ottawa Chapter, Hands and Voices Ottawa Chapter and Children's Hospital of Eastern Ontario (CHEO) Cochlear Implant Department. The copies of the advertisement and other recruitment strategies are labelled under the Appendix B of this thesis. The presentation of the study was given to the two groups and local elementary public school for the parents of the participants of this study on two separate dates.

Parents were asked to fill in A Parental Consent Form to allow their child to participate in the study (Appendix C). Each participant was asked to sign the approval of the video recording of the lesson that was used for the analysis of the best practices on multi-sensory approach and the research purposes only (Appendix D). All the participants were asked to fill the Personal Data Form (Appendix E).

Pre-test

The first meeting was set up at the Piano Pedagogy Research Laboratory at the University of Ottawa where the testing that took place were explained in detail to experimental and control groups,

and the participants' parents. All test stimuli were presented from a laptop computer through external BOSE speakers that were calibrated between 60-65 dBA. The pre-tests: Familiar Song recognition where eight most popular children's songs were presented under the five different playing conditions (original, piano, voice, flute, octave higher flute), and MBEMA – 20 sets of melody and 20 sets of rhythm excerpts were presented as a discrimination test (same – different). The samples were made and tested by the Piano Laboratory technician who also set up the optimal hearing environment with two speakers *(Bose*). Each participant arrived with their parent at the designated time and were placed in the room with the explanation of the test that followed. First test was of a Familiar Song Recognition. Every participant was given an option on volume needs adjustment. No participant asked volume to be adjusted. The researcher ran a quick test run of two samples to make sure that the participant understands the task. Since some children are visual learners, the researcher decided to place pictures of the representation of the song to optimize non-confusion and least possible risk of misreading resulting in a wrong choice of the song. Each participant had an option of the repeating the excerpt of the familiar song test. The test duration was thirty to forty-five minutes. The researcher would circle all the answers on the prepared sheets for each participant. After the competition of the first test, every participant had a 15-minute break and would return to the testing room for the second – MBEMA- test. The participants would again be explained the task ahead: they would be hearing the short two excerpts, and that needed task was to discriminate if they are the same or different. All participants were asked to verbalize the answer and the researcher would notify it in the answering sheets. This was also in attempt to minimize possible mistakes but also less tasking on the child. After the competition of the tests, the researcher set up the dates for piano lessons with exchanged information of address and phone number of the piano teacher.

After collecting Personal Data Form, A Parental Consent Form, and the tour of the Piano Pedagogy Research Laboratory and all the experimental participants (CI and NH) were assigned to

the main researcher of the study and the lessons begin a week after.

The lesson plan

The same method of teaching was applied to both children CI users and NH children in experimental groups for all six (three familiar and three unfamiliar) pieces (one at a time) with emphasis on aural modeling (listening and imitating, and no note-reading), supported with additional material (pre-recorded CD containing the learning repertoire) and using multi-sensory approach (visual, aural and tactile). All participants from both experimental groups (Children CI users and NH) were following the same lesson plan every week. The researcher designated twelve weeks to teach six songs which translated to two weeks per song. Each participant from the experimental groups (Children CI users and NH) completed the six songs planned for this research. Teacher used weekly practicing charts to clearly communicate expectations on weekly tasks to each participant. This eliminated any confusion and provided tangible data for each of the participants' growth. Also, parents' and teachers' (two separate) weekly charts were competed expressing detailed impressions of the weekly lessons (Appendix I, J, K).

The Weekly Lessons Plan was predetermined by the researcher with assigned time for a) repertoire (20 min.), b) music games, singing pieces, finger numbers and notes (10 min.). The repertoire was focusing on the note accuracy, rhythm, tempo, and dynamic accuracy and singing of the assigned piece.

Treatment

The repertoire consisted of three familiar pieces (Twinkle, Twinkle, London Bridge, Mary Had a Little Lamb) for each participant. The teacher used Suzuki Book 1 for the repertoire piano pieces. All participants were asked to listen to accompanied CD of the music they would be learning. The speed of learning pieces was individually anticipated and accordingly accommodated. Every participant had equal time to learn the material and the same strategies were used (visual, aural,

tactile), however if the participant responded better with a particular strategy, the teacher would use that one primarily and add others as a supplementing/exposure strategy. If the participant did not complete the song both hands in two weeks, the teacher would still go on to the next song and ask the participant to keep practicing the previous piece.

Also, the repertoire consisted of three non-familiar melodies (Cuckoo, Honeybee, French Children Song) based on previous studies by Trehub (2009) and Vongpaisal (2004, 2006, 2009) in which anywhere from 3 to 10 melodies were utilized. The first six melodies form Suzuki 1 are composed for two hands in the key of C Major and written in an optimal speech frequency range (Kasturi, 2006; Hsiao, 2008).

The reason for three familiar melodies chosen was the ease and accessibility of popular children's songs. The goal was assessment of differences (if any) between children CI users in experimental and children CI users in control group with the hypothesis that piano training will make a positive impact on experimental group resulting in better accuracy in singing, melodic contour and pitch identification. On the other hand, the reason for the unfamiliar three songs was giving an opportunity to children CI users to learn completely new material along with NH children. The goal was assessment of differences (if any) in piano performance abilities between children CI users and NH children in experimental group.

The participants were instructed at the piano studio of the main researcher. The prerecorded CD of familiar and unfamiliar songs was given on a pre-test day.

During the three-month learning period, the researcher collected formative assessments, checklists (Appendix I, J, K), indicating progress and detailed development plans and executions. This included a logbook indicating CD listening task in minutes executed and practice time for each day. The breakdown of each lesson was as follows: 5 min short welcome and catch up about the practice week and introduction to what will be covered in the lesson, 20 minutes for the repertoire

(correct notes, finger numbers, rhythm, tempo, dynamics and technique), 5 min for the melodic contour exercises (figure 1).

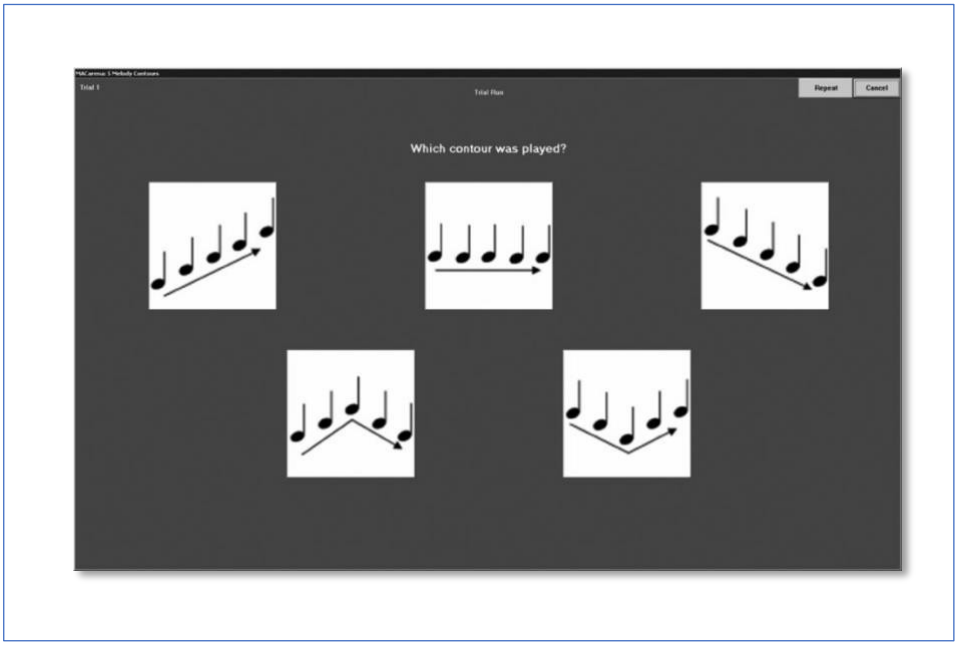


Figure 1. The representation of melodic contour

Also, the practice timeframe breakdown of the lesson plan as follows: 15 minutes for the repertoire (correct notes, finger numbers, rhythm, tempo, dynamics and technique), 15 -30 min of listening to the prerecorded CD.

The music lessons took place in a private studio of a piano teacher's home for the children CI users' experimental group, and at the University of Ottawa Piano Pedagogy Laboratory for the NH experimental group. A parent accompanied their child to each lesson. The lessons at the researcher's studio were conducted on the researcher's instrument, a Yamaha U-1 upright acoustic piano. The teachers used a multi-sensory approach to teach six designated pieces, using visual cues such as looking at the piano keyboard while naming fingers numbers, aural approach such as learning the music pieces by auditory cues and singing the melody, notes, finger numbers and words, and tactile approach such as touching the fingers while naming the notes and finger numbers of the music piece. The teacher used a 'listen-play' method of learning, with two bars 'chunks' of information so that

the participant does not get overwhelmed with the information given. The teacher clearly communicated practicing expectations – number of repeats of the task, 2 bars of melody practice, singing notes or finger numbers while playing - verbally and visually (on a practicing sheet with an area for a student to check of the box after a completed task) to the student as well as to a parent. Each of 12 lessons (per participant) was weekly monitored with supported material such as: parent observation sheet, teacher observation sheet, practicing sheet (for a participant to fill in) that were collected at the end of the study. If the young beginners needed help with recording the answers, parents were instructed to help and fill in the answers for them. These information data sheets were used for assessment on correlation between duration of musical exposure and music accuracy, and included detailed information on willingness to practice, enjoyment of practice and overall quality of practice during the study.

Post-test

After completion of three months of piano training, each participant (experimental and control groups) received a phone call from the researcher asking to meet again at the University of Ottawa Piano Pedagogy Laboratory for the purpose of the post-test. These tests were scheduled one week after the completion of all 12 lessons for both experimental and control groups. All participants were tested again at the Piano Laboratory. The same procedure from pre-test was followed in post-test with all the same designated tests. The same researcher collected the data from the computer program results. The participants were thanked in person and the thank you card was sent to all four groups. The control groups were offered piano lessons three months after.

Weekly forms

A third set of measurements used in this research study were three sets of weekly forms. While the participants were undergoing their 3 months of piano lessons, parents, participants, and teacher forms were used weekly as a measuring instrument of quality of practice and lessons. While the

participants were undergoing their 3 months of piano lessons, parents, participants, and teacher forms were used weekly as a measuring instrument of quality of practice and lessons. 3 and 5 Likert scale was used as a measuring instrument to each of the forms.

The researcher provided all the correspondence emails with participants' parents. All the data was collected at the Piano Pedagogy Research Laboratory at the University of Ottawa. The Personal Data Form was collected before the start of the lessons as well as the pre-tests: Familiar Song Recognition test and MBEMA (melody and rhythm) discrimination test. The weekly (practicing, parent and teacher) charts were collected upon the completion of the 12 formal piano lessons and stored at the Piano Pedagogy Research Laboratory at the University of Ottawa.

Once all the data had been collected, the data analysis begin. All the data analysis were performed by the main researcher at the Piano Pedagogy Research Laboratory at the University of Ottawa (Appendix N, O, P). The access to the personal information data forms and the results are available only to the Director of the Piano Pedagogy Research Laboratory and the main researcher.

Chapter 4

Results

This chapter is divided in four sections for each of the research questions. For each research question, the analysis test will be described first, and results will follow. Furthermore, the findings will be discussed, and each research question will have its own conclusion. Lastly, there will be a general conclusion to the whole chapter.

Song Recognition Test

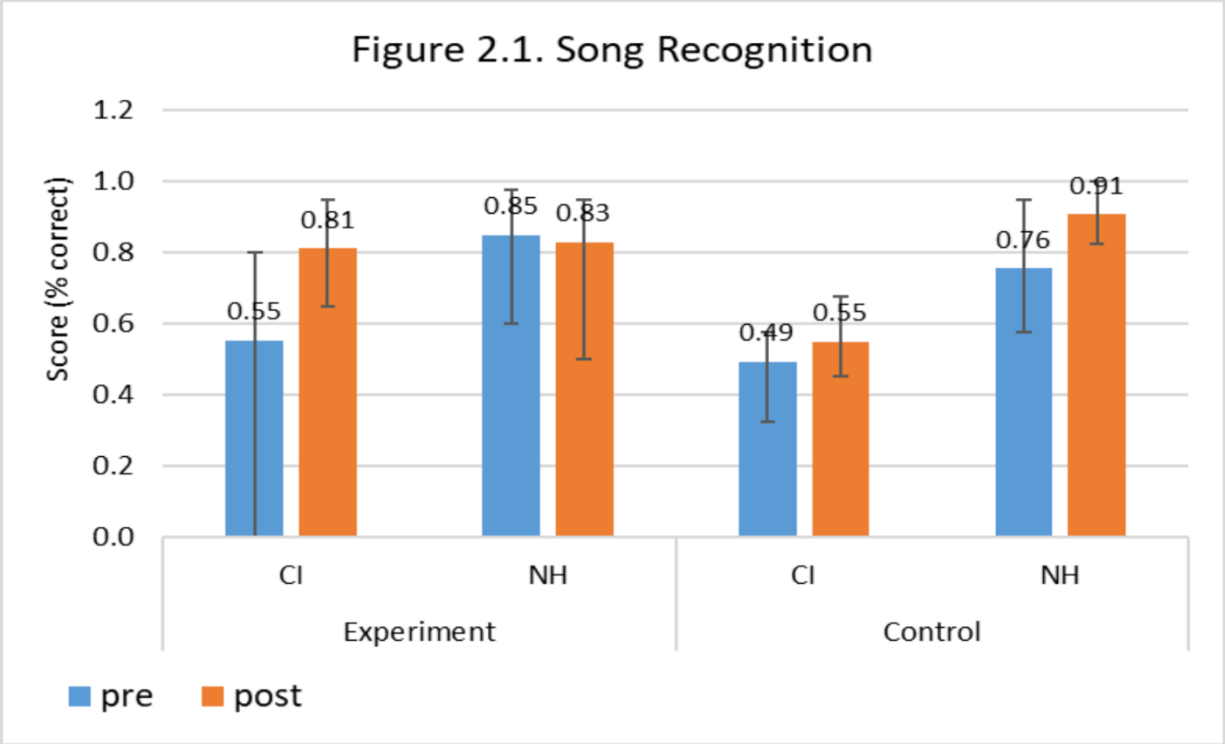


Figure 2.1. Results for the Song Recognition Test for all participants (mean and range).

First test administered to all participants was the Familiar Song Recognition test. Eight popular children's songs through five different playing conditions were presented to each participant. Total of 40 excerpts were 10 seconds long (each), and participants could ask for the excerpts to be repeated. As seen from the figure 2.1 the overall accuracy of the children CI users in experimental

group was 55% accurate pre and 81% post three months of piano lessons. Overall, children CI users experimental group performance increased 33% post piano lessons in their song recognition test. NH children in experimental group scored 85% accurate pre and 83% post piano training. NH children in experimental group decreased their accuracy for 2%.

Meanwhile, children CI users from control group scored 49% pre and 55% post three months – 6% increase, while NH children from control group measured 76% pre and 91% - 15% increase post three months as seen in Figure 2.1.

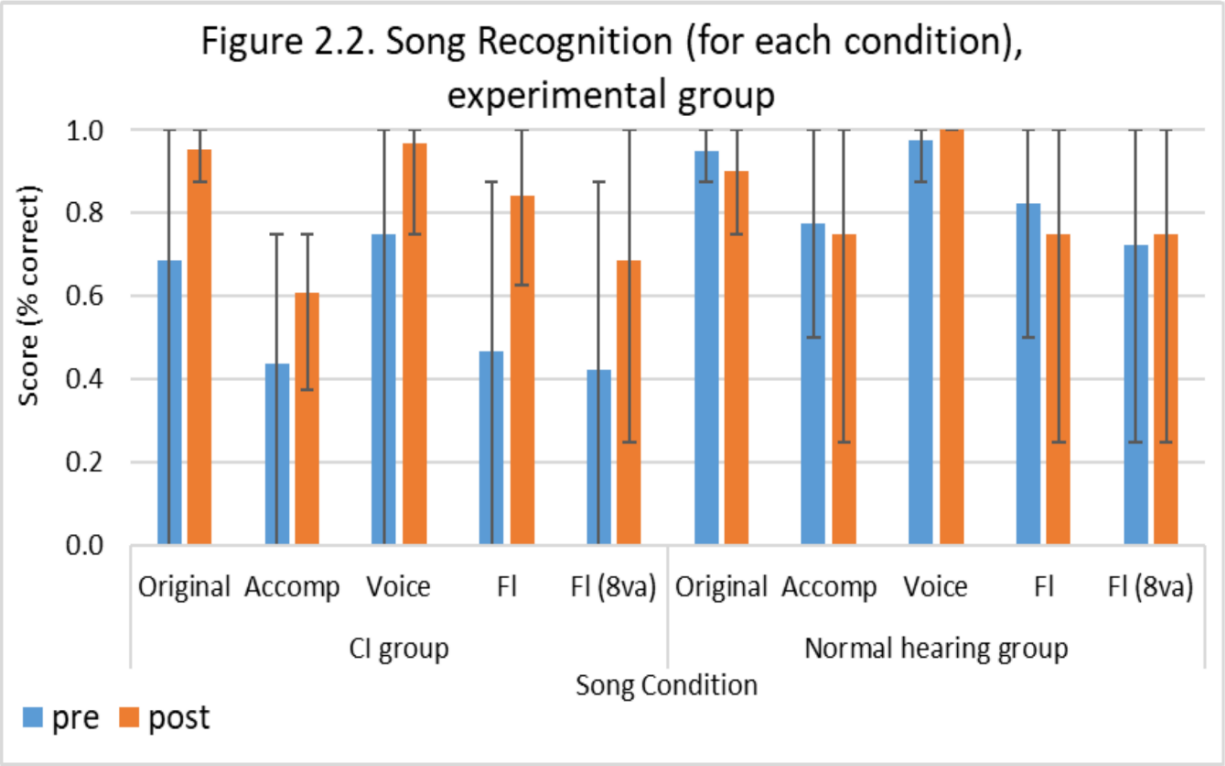


Figure 2.2. Song Recognition Test for all the participants through different conditions (mean and range).

Unsurprisingly, excerpts with original condition (accompaniment and voice with lyrics) were among the highest at 69% pre, and 94% post three months of lessons, as well as voice (excerpts with lyrics) at 74% pre and 98% post lessons. Furthermore, detection time was the fastest in original condition with 2.2 seconds averaging for the children CI users and 1.5 seconds for the NH children

group in pre lessons and 1.9 seconds for children CI users' group and 1.2 for NH children group post piano lessons. A great challenge for the children CI users' group was immediately present with a drop from lyrics and voice representation of the melody – in accompaniment condition - with 42% accuracy pre lessons. The improvement in this condition is evident as results improved to 60% accuracy post lessons for the children CI users' group.

The most challenging identifying for children CI users was octave higher flute condition in both pre and post lesson. However, the increase in accuracy in this condition was visible; children CI users' group went from 41% to 69% accuracy. Flute condition was also challenging pre lessons with 47% pre and 86% accuracy post lessons, resulting the biggest improvement for all conditions for children CI users' group.

The NH children experimental group did not increase drastically on any conditions pre and post piano lessons as their accuracy was high in all conditions. NH children group accuracy results were as follows: The most favoured was voice (with lyrics) with 97% pre and 100% post piano lessons. A slight decrease in accuracy is noted in flute excerpts from 82% pre and 73% post piano lessons for the NH children group. Also, a slight decrease is noted in original - from 96% pre to 90% post -, and accompaniment - from 78% pre to 76% post - condition.

When comparing two groups pre lessons results the data indicates that NH experimental group increased in only two conditions by 3% in already favoured and high accurately voice with lyrics condition, and 2% in octave higher flute condition. The other three conditions decreased: original 5%, accompaniment 2%, and flute 7%. We could hypothesize that overconfidence, impulsive and rushed answers, but also simply a tired brain occurred for the NH children group. For the children CI users' group, on the other hand, the increase was present in all five conditions after piano lessons: original 25%, accompaniment 18%, voice 24%, flute 39%, and octave higher flute 28%.

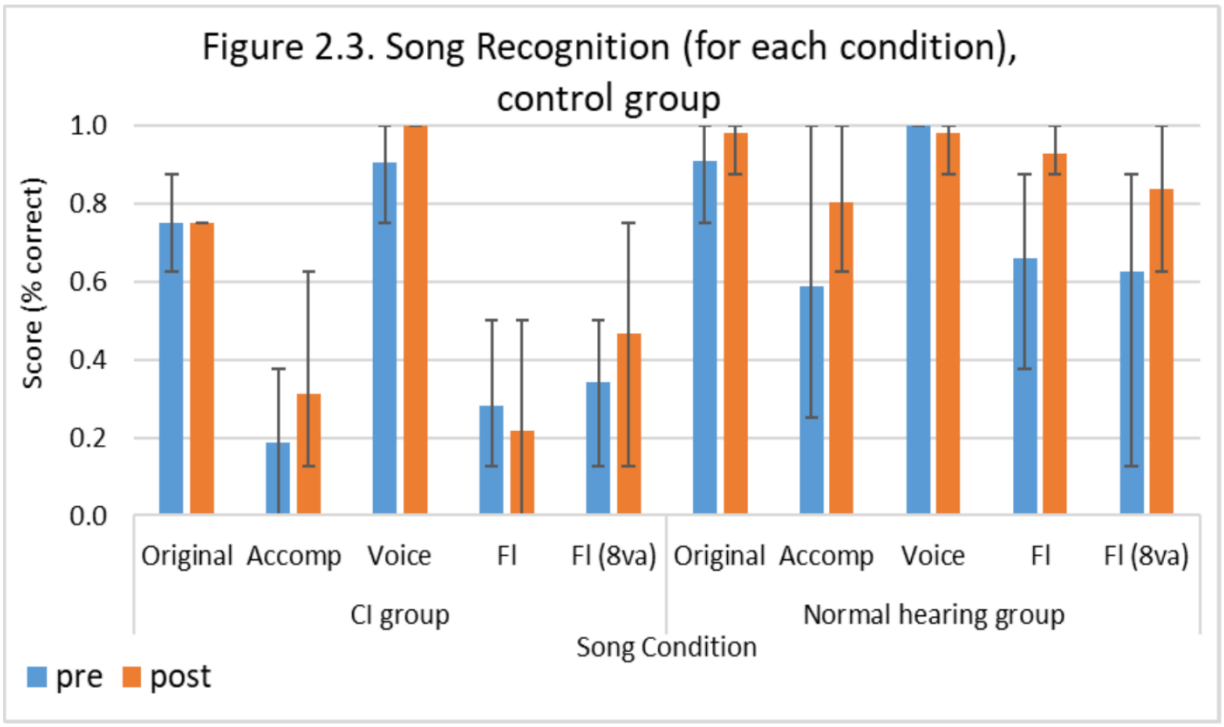


Figure 2.3. Results of the Song Recognition Test for all the participants in the control group for each condition (mean and range).

The children CI users' control group was surprising as they outperformed some conditions even of NH children experimental group. Breakdown of 5 different conditions from graph 2.3 indicate that children CI users' control group had the most accuracy in voice with lyrics condition with 90% pre and 100% post three months. Their second-best condition was original excerpts with 73% pre and same 73% post three months. The natural maturation takes place with all children and some increase in accuracy is always expected. The expected difficulties with flute and octave flute were present with children CI users' control group as well testing 29% pre and 21% post three months for flute, and 33% pre and 47% post for octave flute. Surprisingly, the most challenging condition for children CI users' control group - octave higher flute – was still increased for 14% after three months of maturation. The only decreased condition for children CI users' control group was flute 8%. The original condition for the children CI users' control group stayed the same, and the increase in accompaniment 12%, voice 10%, and octave flute 14% was noted.

In contrast, NH children control group outperformed NH children experimental group in every condition except voice (-1% difference) post three months. Their results are as follows: original 91% pre and 99% post, accompaniment 59% pre and 80% post, voice 100% pre and 99% post, flute 64% pre and 92% post, and lastly octave flute 62% pre and 82% post three months.

It is evident that the NH children control group performed the best in post three months conditions, however the biggest increase in accuracy was for the children CI users' experimental group. Their increased accuracy is as follows: original was 25% increase vs. children CI users' control group that tested the same (73%). In accompaniment condition children CI users' experimental group increased 18% the same as children CI users' control group. The voice condition for children CI users' experimental group was an increase of 24% while the children CI users' control group scored 5% increase to perfect 100% score. The flute condition was the biggest increase for children CI users' experimental group with 39% while children CI users' control group decreased 8%. Another big increase for children CI users' experimental group was octave higher flute with 28% while children CI users' control group had an increase of 14%.

Montreal Battery Evaluation (MBEMA) – Melody Discrimination Test

The first MBEMA tests that we measured was melody discrimination. 20 sets of 3-5 seconds melody contour excerpts were given to participants to identify if same or different.

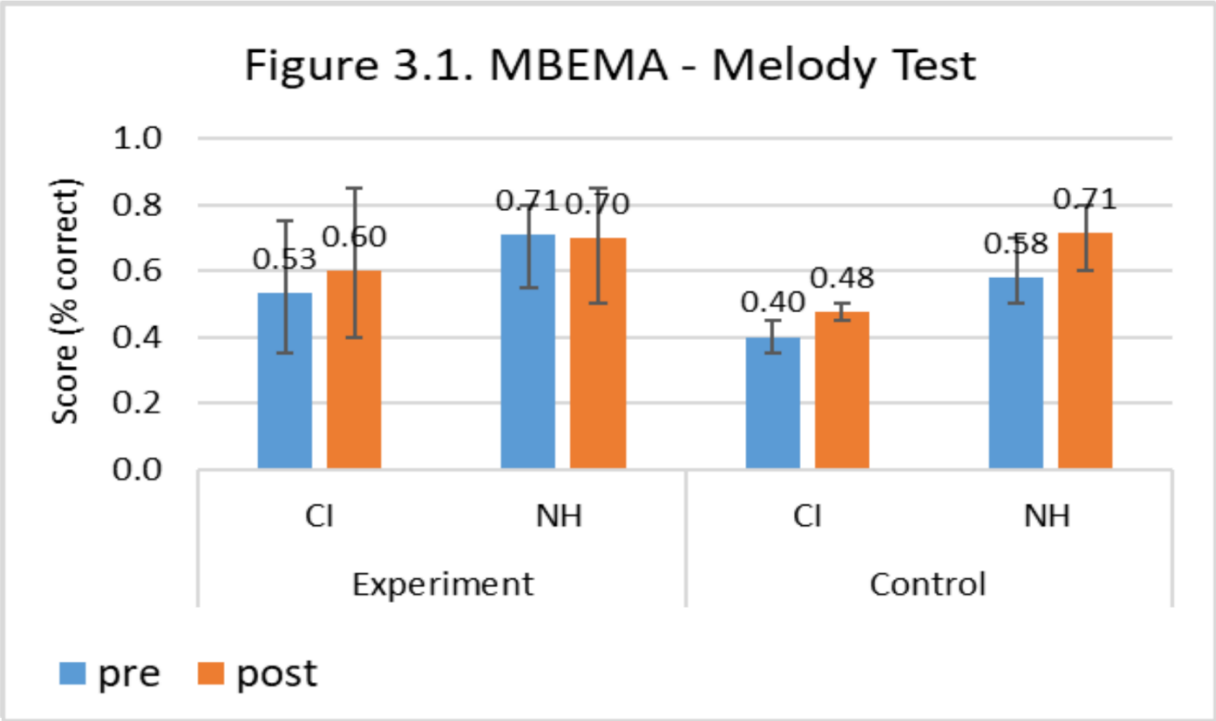


Figure 3.1. Results of the MBEMA - Melody Discrimination Test for all the participants (mean and range).

As seen from the figure 3.1, the experimental group of CI participants were 53% accurate pre piano training, and 60% accurate after – 7% increase. NH children were testing better but not significantly with average of 71% accuracy pre and 70% after piano training – decrease of 1%. The children CI users' control group scored only 40% accurate pre and 48% accurate - 8% increase - after three months. Meanwhile NH children control group tested 58% pre and 71% after three months – 13% increase.

The children CI users' control group was more accurate post three months by 1%, however, they tested lower in their pre three months piano lessons by 13%. The 60% accuracy for children CI users' experimental and 48% for children CI users' control group post three months is worth noting as that difference is 12% greater in favour of children CI users' experimental group. Because of non-equal start between children CI users' experimental and control groups as experimental increased by 7% while control increased 8% it appears that the piano lessons did not play a significant part. We could

hypothesize that the increase presented was due to a natural maturation. Interestingly, NH children control group increase was larger – 13% increase, while NH children experimental group decreased by 1%.

Montreal Battery Evaluation (MBEMA) – Rhythm Discrimination Test

On MBEMA rhythm discrimination test, as seen in Figure 3.2, 20 sets of 3-5 seconds rhythm contour excerpts were given to participants to identify if same or different.

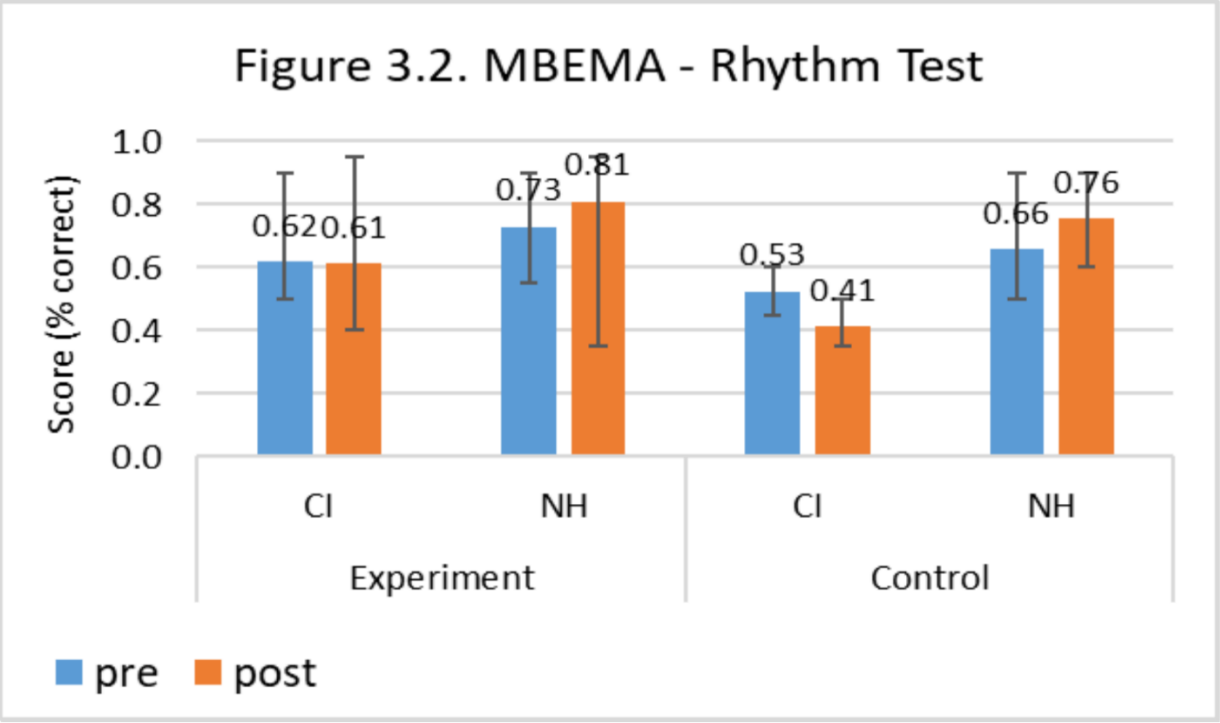


Figure 3.2. Results of the MBEMA - Rhythm Discrimination Test for all the participants (mean and range).

The children CI users experimental group tested 62% accurate pre, and 61% post three months of piano lessons (1% decrease). NH children experimental group scored higher with 73% accuracy pre, and 81% post three months of piano training (8% increase). The children CI users control group scored 53% accurate pre and 41% post three months (12% decrease), while NH children control group tested 66% accurate pre, and 76% post three months (10% increase).

The children CI users experimental group decreased less (1%) than children CI users control group (12%) and performed better overall. NH children experimental, however performed less accurately

with a slight decrease (1%), after three months of piano training, while NH children control outperformed everyone and improved the most - (10%). Here too, it appears that piano lessons did not impact on developing rhythm test.

Practice Quality

The figure 4.1 presents the results of the weekly quality of practice charts from both student and the parents. 3-point Likert scale was used as measuring instrument for this data collection.

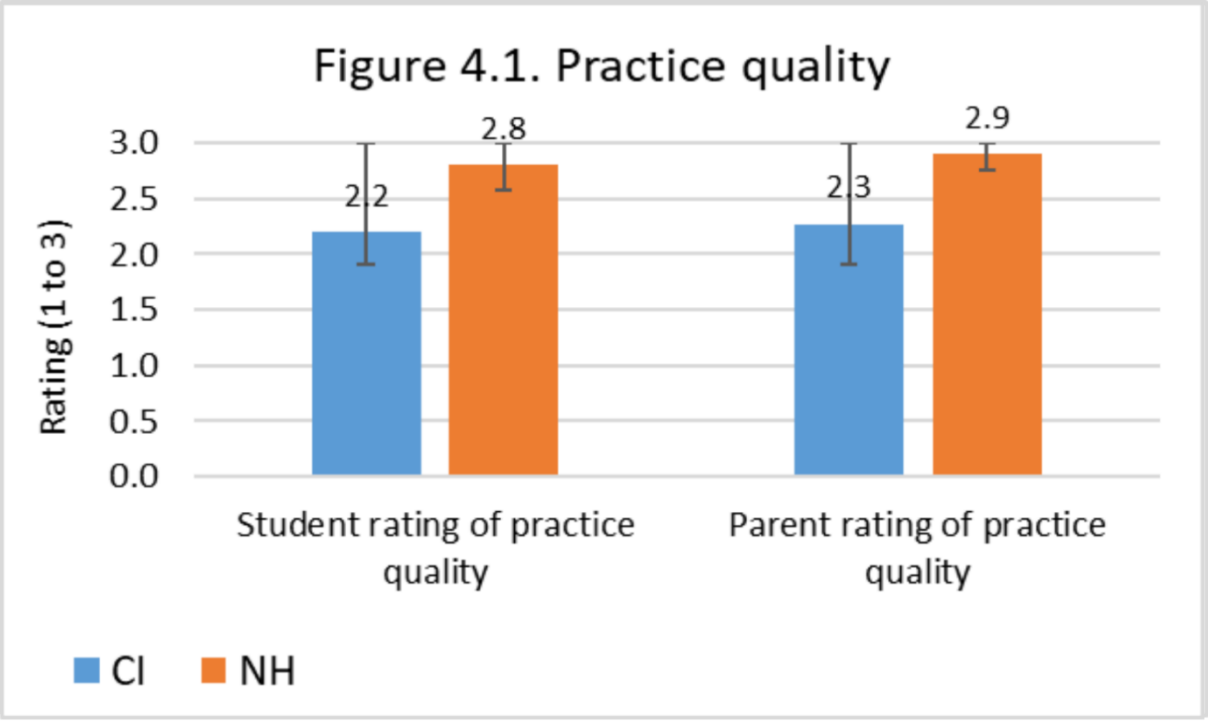


Figure 4.1. Results of the teacher and parent ratings on practice quality for experimental groups (mean and range).

When it comes to practice quality, children CI users rated themselves at 2.2 average while their NH children group at 2.8.

The parents of the children CI users rated the practice quality at 2.3 (1 higher than students), while NH children parents rated the quality of their children's practice at 2.9 – practically the same as their children. Students from both groups (CI and NH) rated themselves closely with only 0.1 difference.

Similarly, both sets of parents (CI and NH group) rated their children's quality of practice

slightly better than their children, with also 0.1 difference.

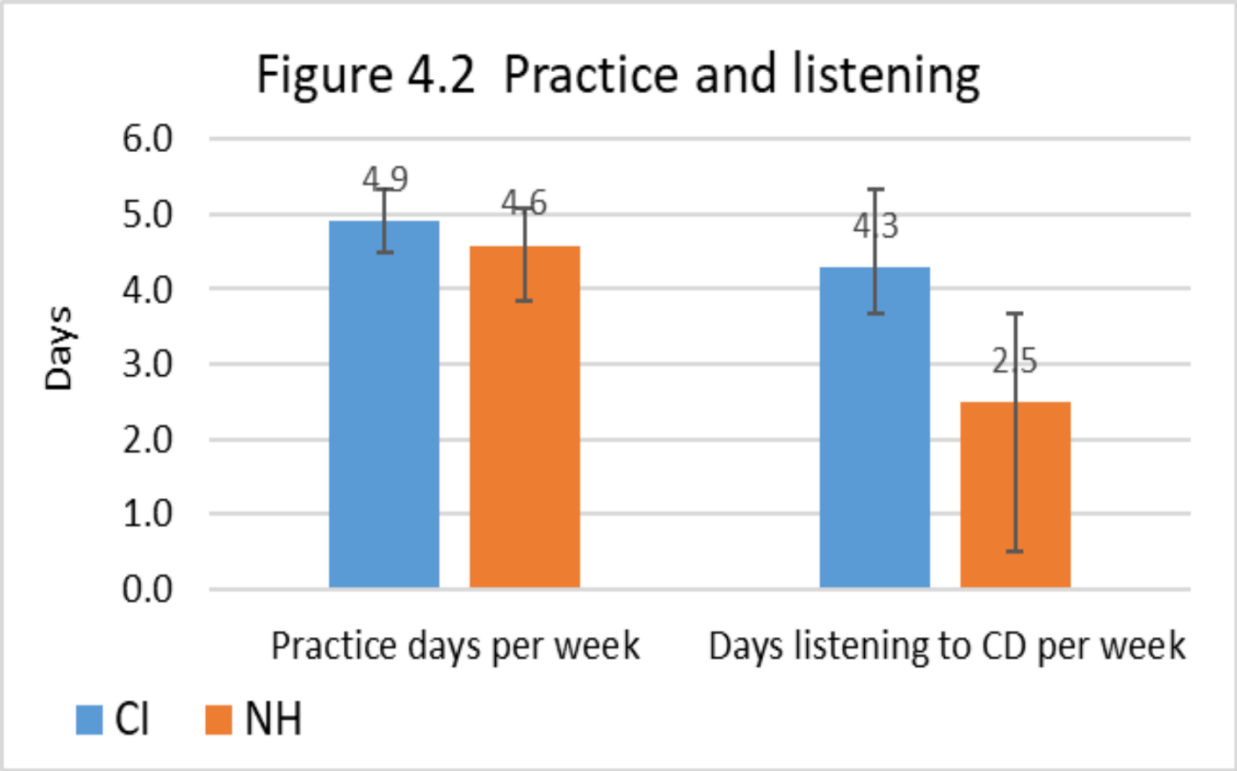


Figure 4.2. Results of practicing days and listening to the pre-recorded assigned music for experimental groups (mean and range).

All our participants were asked to practice minimum 5 days a week and 15 minutes and listen to the CD daily. We have tracked participants daily and weekly practice as well as their times and duration of listening to the assigned CD. Figure 4.2 indicates that children CI users were slightly more dedicated to practice averaging at 4.9 days a week, in comparison to their NH children group at 4.6 days. However, dedication to listening to the CD was more prevalent with children CI users' group at 4.3 days a week, and 2.5 with NH children group.

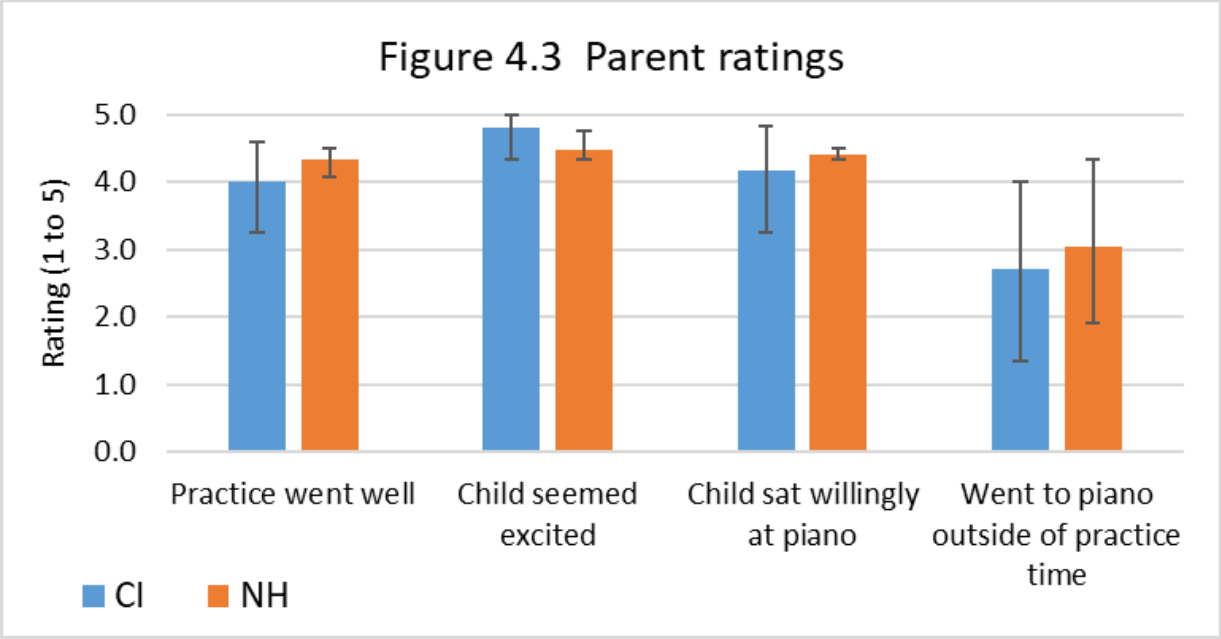


Figure 4.3. Results of parent ratings on their assessment of the practice, excitement about music and practice, and their child's motivation to play outside the assigned and required time for experimental groups (mean and range).

Figure 4.3 explains in more detail the parent rating of weekly practice, and child's excitement to practice. 5-point Likert scale was used as a measuring instrument. The documents were collected after each lesson by the piano teacher.

The children CI users' parents rated their child's excitement to practice the greatest – 4.8, willing to sit at the piano 4.2, rated their practice at 4, and playing piano outside designated practice time at 2.7. Meanwhile, NH children's parents rated their children's excitement to practicing at 4.5, willingness to sit at the piano at 4.4, practice itself at 4, and playing outside the designated practice time at 3.0.

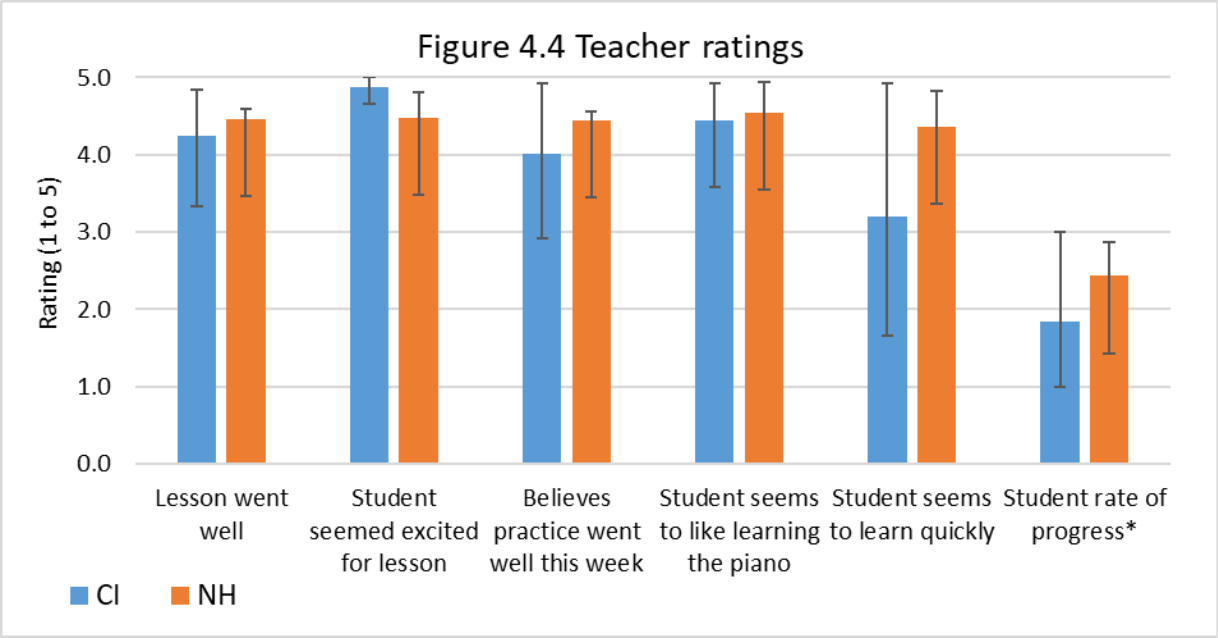


Figure 4.4. Results of teacher's rating on lesson, child's excitement, practice, learning process, and progress for experimental groups. *3-point Likert Scale was used for Student rate of progress (mean and range).

It appears that both groups were comparatively close, and rather excited to be in lessons and to practice. Although, neither group went out of their way to sit outside the practice time and play.

In this last Figure 4.4 teacher's weekly reflections on practice and overall progress were recorded. 5-point Likert scale was used as a measuring instrument for this data analysis, except for Student Rate of Progress where 3-point Likert scale was used as a measuring instrument. Data indicates that children CI users' group was most favoured in excitement for a lesson with 4.9 score vs 4.5 for NH children group. They also scored high 4.4 on enjoyment of learning piano while the NH children group score a bit higher at 4.6. In 12 weeks/lessons children CI users' group score 4.2 assessment on lesson efficacy while the NH children group scored a bit higher at 4.5. However, children CI users' group certainly learned slower than NH children group with 3.2 score while NH scored 4.4. The rate of overall progress for the children CI users' group was slower than the NH children group averaging at 1.4 for children CI users' group and 2.4 for NH children group.

Summary

The aim of this study was to determine whether cochlear implant children could improve their accuracy in melody, rhythm, and pitch identification after three months of formal music instructions. We tested all the children before and after the formal piano lessons. All children from the experimental group – 5 children CI users and 5 NH children – received 12 piano lessons with emphasis on aural modeling based on adapted Suzuki method in addition to visual and tactile cues as a teaching method. Six (three familiar and three unfamiliar) songs were taught, and all children learned with a different level of accuracy to play all six pieces. After the 12 lessons, all children were tested – including the controlled group that did not receive the lessons - and we have concluded that:

- CI experimental group improved on song recognition test through all conditions by 33%.
- CI experimental group improved on MBEMA melody test by 7%
- CI experimental group decreased on MBEMA rhythm test by 1%.

The hypothesized outcome for the experimental group in song recognition test resulted in positive outcomes. The specific and multi-modal approach and strategies, exposure and practice CI children proved to improve children CI users' music recognition. The MBEMA test seemed difficult for all participants. It appears the minimal differences in excerpts made an undesired outcome of children having a hard time keeping focused and "zoning out" and therefore guessing the same/different options.

Also, children CI users rated high on practice quality, listening to the assigned music, and overall enjoyment in music learning. Furthermore, the teacher rating indicated that lessons, practice, and learning process was rated highly as well, although the progress rate was slower than their NH counterparts. Nevertheless, the learning that took place was undeniably positive for all parties involved.

Chapter 5

Discussion

The goal of this research project was to determine if children with cochlear implants would benefit from formal music training and if so, what would be the implications and best practices. We wanted to see whether children who receive three months of piano lessons based on adapted Suzuki method – aural approach with visual and tactile cues - would indeed improve music understanding, recognition of pitch and overall enjoy music learning. This section will synthesize previous research done on the topic, some personal reflection as a teacher to these participants, and suggestions on future practices for teachers and students with children CI users, and lastly the discussion on results of the study.

As mentioned earlier, several research studies with focus on children CI users in music indicate that continuous exposure to music has positive effects on melody recognition, and melody reproduction (Comeau, Koravand, Markovic, 2017; Abdi, Khalessi, Khorsandi, &Gholami, 2001; Kosaner, Kiline, & Deniz, 2012; Chen, Chuang, McMahon et al., 2010). Studies indicate that Children CI users use rhythm as melodic cues (Hsiao &Gfeller, 2012), and have difficulty with pitch and timbre identification (Gfeller et al., 2002; Looi, McDermott, Mckay, &Hickson, 2008; Vongpaisal, Trehub, &Schellenberg, 2006). This research narrowed down several questions with emphasis on teaching children CI users' melody - pitch, timbre, and rhythm – through formal piano lessons. Research indicates that maximized audition take place in therapy sessions where the environment is quiet, the therapist is sitting close to the child, using animated voice, and not looking straight at the child but is using objects for the attention and is providing repetition (Barton & Robbins, 2015). Similarly, the researcher has adapted "input and output" strategies used for speech and music acquisition in my own piano teaching in this research study. In this study we have been able to demonstrate that with formal music lessons and exposure to melody and complexities of music

listening and music making, our CI participants will increase their abilities in identification of melodies through different conditions and improve their abilities to recognize music and rhythm patterns with greater accuracy. We demonstrated that learning a piano indeed can be enjoyed by CI children if provided with optimal conditions, adapted teaching strategies, and parental support.

After completing 12 lessons of piano teaching to children CI users and NH children, the following observations that could be prevalent in some of the conclusions on benefits of teaching piano to children CI users and possible methods that can be further used and developed are:

When teaching piano to both experimental groups – CI and NH children – the researcher would prepare the participants by communicating each the goals and plans of the lesson. This way the participants would get excited and familiar with the task before they would start to play. All children started learning basics of music concepts and were shown where are the high and low tones on the keyboard. Singing, demonstrating on keyboard, and then imitating – aural approach - was a successful approach. Noticeable difference with children CI users in following the instruction was the attention to the teacher's face (particularly lips) while speaking. The demonstration of the task would break the facial fixation and sway attention to the piano or technical movements. Meanwhile, NH children group would listen attentively with a focus on the instrument or technical movements only. This could be explained by children CI users trying to get as many cues as possible during tasks. The children CI users group demonstrated that they need to work harder to complete the music puzzle by adding as many cues as possible by reading the lips, following technical movements, and copying the motor skills necessary to play the piano. Low sounds were preferred with the children CI users' group while NH children group did not show any preferences. When "playing around" on the piano it was noticeable that children CI users' group would often use only one hand in attempts to make sounds – low or high – even when they learned to use both hands. Meanwhile as soon as NH children group learned to use both hands on a first song, they would freely use both hands in a game of "make

your own sounds and music". The teacher often used allegory to make impactful images to the music concepts they were being taught. This seemed to help children CI users when identifying melodies through different conditions as timbre recognition seemed the most difficult for them all. When learning a new song the teacher would always use the same strategies: sing the song with words and clap quarter notes, then touch and sing the finger numbers of the hand we were trying to learn while bopping the head in proper quarter time, then the teacher would play it while singing the finger numbers and bopping in rhythm, and finally give a participant a chance to try while we are both singing the finger numbers and bopping in rhythm. Important notice: while teaching melody and playing the piano, the teacher would use only two bars at the time of the assigned material. It was a useful tool to ease the concepts especially when learning a difficult one. Too much of a material usually creates insecurities or mediocre abilities in music performance. The teacher used Yo-Yo Ma's "two bars a day" strategy worked wonders for all the piano students and especially with children CI users' group. They never got frustrated and even more importantly, they could master concepts in real time along with their NH children group. The teacher used the same strategies with both groups and have seen same level of enjoyment between the groups. Both groups of kids were always eager to come to their lessons and were prepared with their sheets and practiced their repertoire assigned. Both group of participants were having relatively easy time with first three songs: Twinkle Twinkle, Mary Had a Little Lamb, and London Bridge. For the first three songs, both groups were taught both hands same melody and rhythm structure, and both groups got the concepts easily. The teacher used melodic cues and sang finger numbers, and then words of the song. Even when singing and switching the finger numbers - left to right – the concepts were manageable for both groups. When the tasks got harder – French Children Song – there was no noticed difference in enjoyment with children CI users, even when accuracy decreased. It appeared that the children CI users were more focused on the task rather than outcome accuracy. On the contrary, the NH children were visibly

getting more frustrated with more challenging tasks of two hands and different melodies in each as they would hear mistakes easily. During lessons, separate hands melodies were tackled with almost identical accuracy between two groups. Putting hands together is challenging for all children but was evident that children CI users were at the disadvantage. Their motor and rhythmical – timing – accuracy was on point, but the note accuracy was lower than the NH children. Furthermore, children CI users melodic pitch when singing was off as they had difficulty choosing (or hearing) what hand melody they should sing. Sometimes, the melody of the right hand would be sung in a left-hand rhythm and the confusion would further appear. As a strategy, the teacher would ask the child to play once again separate hands and then try together smaller "chunks" and that almost always worked. Again, the enjoyment was always present regardless of correctness and efficacy. All the children CI users immensely enjoyed creating music and making sounds in general. They enjoyed matching their voice sound to the piano key sound; matching the pitch of the voice and piano key in a five-finger scale (C-G) was one of the favourite warm up games.

Research Question 1

1a) How do children CI users differ before and after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented though five different conditions (original, piano, voice, flute, octave higher flute)?

The children CI users experimental group increased their accuracy in melody test recognition >18% <39% in every condition, respectively. We have hypothesized that the increase in melody recognition with piano training would be present. These positive results certainly indicate that there is a positive outcome of piano lessons on increase in music recognition accuracy. However, we must account in natural maturation as a contributor to these results as well. All the children attended public schools where the socialization and singing in classrooms were part of the curriculum. Also, we must account those parents of the children CI users' group were eager to enhance music

experiences for their children and as such were exposing them to music on the radio at home and in the car. All parents reported that due to being participants of the study they have been more aware of the musical input and exposure and that they noticed their own enjoyment and were motivated by their children's positive responses. The parental involvement had played an undeniable influence on the results of this study. Yucel and colleagues (2009) have investigated the impact on music recognition and enjoyment in relation to parental involvement and have reported that the greater the involvement of parents – greater the positive results of enjoyment with CI children. Furthermore, Driscoll and colleagues (2015) investigated relevance of music participation in children CI users and family involvement. They reported that the higher importance music played in family life, the higher chances of children CI users participating in music bands and music activities. The results of our study have aligned with this research where we see positive coloration between involved parents who supplemented the music learning with music listening outside the designated and required time for the purposes of this study.

1b) How do children CI users differ to NH children after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented through five different conditions (original, piano, voice, flute, octave higher flute)?

Much of research has compared children CI users to NH children. Most conclude that children CI users can replicate speech with almost no difficulties as the devices are designed for speech prosody but pose a great difficulty when processing music (Jiam & Limb, 2020; Gfeller, et al., 2002; Jiam et al., 2019; Vonpaisal et al., 2006; Isaiah et al., 2014). When comparing children CI users to NH children researchers agree that access to music sound complexities is not on equal grounds due to pitch and timbre recognition deficiency (Drennan & Rubinstein, 2008; Hsiao & Gfeller, 2012; Gfleer, 2014; Wright, 2012).

We hypothesized that exposure and training to music excerpts – structured piano lessons,

listening to music on pre-recorded CD would improve the accuracy in music recognition. We also hypothesized that it is in fact possible with training to have children CI users be comparable in music accuracy to NH children. For this study, lessons were equally designed with a focus on teaching six songs on piano with both hands. It is important to mention that learning an instrument is difficult for anyone. Hand/eye coordination, listening and following instructions, and creating desired sounds with proper technique and rhythm accuracy is challenging regardless of hearing abilities. Being aware of children CI users' difficulties, the researcher structured piano lessons where the positive outlook on learning experience was monumental and primary focus. The teacher used visual, auditory and tactile strategies to make lessons approachable, manageable, and creatively fun. Having parental support and involvement added positive aspect to children CI users piano learning experience.

It was evident that in lessons NH children would access information easier than children CI users' group. It was also evident that lesson material was covered quicker than in children CI users' group. Furthermore, NH children group needed less time for reproducing the tasks. NH children group needed less repetitions on tasks to achieve the desired outcomes and children CI users' group required more varieties in strategies – repeatedly – to achieve the same.

In conclusion, positive effects of great increase in music recognition test through different conditions for children CI users after the three months of piano lessons are evident. The base line between two groups was of a great difference and the children CI users' group was in a disadvantage position with 55% accuracy whereas the NH children group was at the 85%. We must take in consideration that children CI users must work harder to achieve the NH children base line in accuracy in music recognition test, however they have achieved it after only three months of piano lessons. Also, we must take in consideration that natural maturation could play a part in these positive results as the children CI users were also exposed to social settings in schools, and at home

increased music listening.

1c) How do children CI users differ before and after three months of formal piano training on their capacity to recognize and name eight familiar melodies presented though five different conditions (original, piano, voice, flute, octave higher flute) to CI users who do not?

So far, researchers haven't compared children CI users who are given music instruction to children CI users who do not. In fact, children CI users are mostly compared to NH counterparts (Torppa, Faulkner, Laasonen, et al., 2020; Boyer & Stohl, 2022; Stabej et al., 2012;). Also, their own abilities are documented (independently) after battery of tests on music recognition and specifically on pitch, rhythm and timbre (Hsiao, 2008). Furthermore, Bruns and colleagues (2016) investigated and compared prelingual children CI users and postlingual children CI users. They investigated pitch, rhythm, melody, chord and instrument identification.

The focus of this study was to compare children CI users from experimental group to children CI users in control group and investigate effects of music training. After three months of formal music lessons, children CI users experimental group increased 33% (from 55% to 81%) in accuracy in melody test recognition compared to children CI users in control group who increased only 6% (from 49% to 55%). However, detailed breakdown of each of conditions in melody recognition test indicates that the control group of children CI users scored on lyrics 90% on pretest and 100% on posttest, original stayed the same at 73% pre and posttest, octave flute from 29% pretest to 21% posttest, flute 33% pre and 47% posttest. Children CI users in control group decreased their accuracy only in flute condition excerpts by 8%. They have increased every other condition: accompaniment by 12%, voice by 10%, octave higher flute by 14% and original by 10%. We hypothesize that natural maturation could be one of the causes for the increase even if not as significant as children CI users' experimental group who increased in all five conditions: original by 25%, accompaniment by 18%,

voice by 24%, flute by 39%, octave higher flute by 28%.

Comparing children CI users experimental and children CI users in control group gives a more accurate perspective on melody accuracy increase due to natural maturation (control group), and piano lessons (experimental group). The results indicate that CI control group increased in every condition, >10%<14%, except flute (<8%), meanwhile children CI users experimental group increased in every condition >18%<39%, outperforming accuracy of children CI users in controlled group. Also, worth noting is that children CI users in control group had tested with higher accuracy in pretest than experimental and as such should be accounted as a potential factor for a greater increase in melody test recognition apart from natural maturation. Lastly, we can conclude that music training for children CI users has indeed impacted positively increase in accuracy in melody recognition through different conditions.

Research Question 2

2a) How do children CI users differ in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from Montreal Battery Evaluation (MBEMA) test?

There are variety of test material that have been used in a past decade to measure music perception for the children CI users. For this study, the Montreal Battery Test, MBEMA (Peretz et al., 2003) for both melody and rhythm test was chosen as the participants could use rhythm cues or melody contour in order to differentiate "same or different" samples. Galvin and colleagues ((2007) study identified children CI users' melody recognition with rhythmic cues at 58% accuracy and 29% without rhythmic cues. Similarly, Kong and colleagues (2004) reported results in tested melody recognition with rhythmic cues with 63% and no rhythmic cues at 12% accuracy.

In this study, children CI users in experimental group scored 53% pre and 60% accurate in posttest in music MBEMA. As mentioned earlier, not a large increase has been noted; 7% increase

in melody MBEMA test the children CI users in experimental group. It has been observed that most participants had a hard time focusing after the twelfth excerpt due to the repetition of short and similar excerpts.

2b) How do children CI users differ to NH children in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from Montreal Battery Evaluation (MBEMA) test?

The children CI users in experimental group tested 53% pre and 60% posttest on music MBEMA discrimination test with a not large increase of 7% after three months of formal piano lessons. NH children experimental group tested 71% pre and 70% posttest, a slight decrease of 1% is noted.

It was taken in consideration that MBEMA discrimination tests require a lot more focus to detail and minor differences need to be noticed that even for a NH children group it seemed challenging at times. Similarity of excerpts – repetition of 20 pairs of excerpts in same duration – with minor differences also pose a focus challenge and as such it has been noticed that after the twelfth excerpt presented, most participants seemed as if they were guessing between two choices: same – different. No large increase in both groups is noted.

2c) How do children CI users in accuracy scores before and after the three months of formal piano training in melody discrimination task conducted over 20 pairs of music excerpts from Montreal Battery Evaluation (MBEMA) test to CI users who do not?

The children CI users experimental group scored 53% pre and 60% post on melody MBEMA discrimination test while children CI users control group scored 40% accurate on melody MBEMA discrimination pretest and 48% accurate in posttest. The children CI users experimental group increased 7% in melody while children CI users control group increased 8%.

It appeared that none of the groups improved largely on the MBEMA test in music samples. The MBEMA tests was challenging for all three groups. It is worth noting that NH children group had the

most success, while second best was children CI users' experimental group and lastly, children CI users in control group scored lowest on the music samples accuracy. Research indicates that children CI users often use rhythm as cues to melodic structures. But since these samples were not in context of songs rhythm excerpts it might be worth noting that both children CI users' groups had trouble in identification of same or different patterns.

Research Question 3

3a) How do children CI users differ in accuracy scores before and after the three months of formal piano training in rhythm discrimination task conducted over 20 pairs of rhythm excerpts from Montreal Battery Evaluation (MBEMA) test?

It is well reported that children CI users' ability to process rhythmic cues are nearly equivalent to NH children (Jiam & Limb, 2019). Music and speech both share processing mechanisms, although they differ in rhythm. Rhythm in music is beat based while speech rhythm is not (Jiam & Limb, 2019). Furthermore, children CI users use rhythm pattern for the identification of melodies (Hsiao & Gfeller, 2012).

In this study, children CI users experimental group scored 62% pre and 61% posttest accurate in rhythm MBEMA discrimination test. A slight decrease in accuracy has been noted. These results are slightly higher in accuracy in comparison to melody samples although not a large accuracy is visible. As mentioned earlier, the MBEMA test seems to be difficult for most. We conclude that even in rhythmic test – where accuracy should be noticeably higher - participants had a great difficulty identifying results with accuracy. One of the reasons could be that the rhythm test was applied right after the melody test which was difficult for all participants. The similarities of two tests might be a reason for a brain fatigue. Also, rhythm samples were short and outside of the music context.

3b) How do children CI users differ to NH children in accuracy scores before and after the three months of formal piano training in rhythm task conducted over 20 pairs of rhythm excerpts

from Montreal Battery Evaluation (MBEMA) test?

On rhythm MBEMA test, children CI users experimental group scored 62% pre and 61% posttest, while NH children group scored 73% pre and 81% posttest, an increase of 8%.

In this test, NH children experimental group scored the highest in posttest. Although, their increase in accuracy was not large. Twenty percent of difference in accuracy between two groups post piano lessons in favour of NH participants is reported.

3c) How do children CI users differ in accuracy scores before and after the three months of formal piano training in rhythm task conducted over 20 pairs of rhythm excerpts from Montreal Battery Evaluation (MBEMA) test?

On rhythm MBEMA test, children CI users control group tested 53% accurate pre and 41% posttest, a decrease of 12%. In contrast, children CI users experimental group rhythm MBEMA was 62% pre and 61% posttest accurate. In rhythm MBEMA test children CI users experimental group decreased 1% while children CI users control group decreased 12%. Twenty percent difference in favour of children CI users' experimental group after piano lessons is reported. While children CI users' experimental group did not increase (1% decrease), NH children experimental group increased (20% to Children CI users – experimental), while children CI users control group decreased their accuracy (20% to children CI users – experimental). We conclude that while children CI users use the rhythm as cue to melody recognition, they had a difficult time with decoding MBEMA rhythm samples.

The reasons for the difficulties in recognizing rhythm excerpts with a greater accuracy might be simply due to similarities in excerpts, their short duration, and outside the melody context excerpts.

Research Question 4

4a) How do children CI users differ to NH children in practice time?

When it comes to practice time, children CI users group averaged at 4.9 days compared to NH

children group who averaged at 4.3.

The children CI users group followed instructions with greater dedication than NH children group. They were eager to oblige all the tasks that were weekly communicated in their practicing sheets. Parents reported that there were no difficulties in getting their children sit at the bench and practice. NH children group was a little less inclined to practice five days a week. The children CI users group reported that they were signing while practicing which might have result in more fun and engaging practice and therefore eagerness to do it daily. Also, it is important to mention that all the children CI users have had an experience in formal lesson-like-environment during the auditory verbal therapy and as such used to focused and repetitive tasks. Most of the group has had five years (or more) of AVT (auditory verbal therapy) where the skills learned have been translated to piano lessons and piano home practices.

4b) How do children CI users differ to NH children in quality of practice?

Both parents and children rated their practice quality comparably close; the children CI users at 2.2 and their parents at 2.8 (out of 3 Likert scale). NH children group rated 2.3 for students and 2.9 for parents – 0.1 difference between both, respectively.

Both groups were beginners and were eager to learn basics of playing piano. Their excitement grew with each lesson as Suzuki based method engages young enthusiasts with songs that are recognizable and easy to sing. During the lesson, both groups would receive clearly communicated tasks that needed to be practiced and both groups followed them with great accuracy. Also, both groups would arrive to their lessons with well prepared and practiced material, and it made lessons move forward in timely fashion. As beginner students, it is not surprising that they rated themselves modestly. The parents rating was more aligned with my own observations and ratings.

4c) How does teacher's assessment of children CI users differ to NH children in enjoyment of piano lessons and music learning?

Teacher's rating was similar for both groups with two exceptions on students' progress and ability to learn quickly where major differences are noted. For CI group teacher rated 3.2 (out of 5 Likert scale) for how quickly the student is learning and 4.4 for NH group. Similarly, students' progress in CI group was rated at 1.8 (out of 3 Likert scale) and 2.4 for NH group.

Both groups did their best to achieve all the tasks that were given to them. Weekly practice sheets were used diligently and were checked off and progress was easy to track. The teachers' observations are as follows: the children CI users worked harder at each lesson to decode information given and practice the task at hand. They would read/look at teachers' lips while she would talk and visually observe the gestures. Their eye movements were quick, from teachers' lips to the hands and to piano keys. The lessons of children CI users were slower paced than NH children, and repetitions were more frequent than with NH children group. The children CI user's confidence, eagerness to learn, dedication to master the tasks, and their overall enjoyment while learning to play was equal to NH children group. The children CI users were not shy to ask to repeat if they did not understand the task. They were more animated than NH children group freely using body gestures and expressions to mimic the songs (lamb, bridge, star). The children CI users would rate themselves lower than the teacher possibly due to understanding of their obvious hearing disadvantage. Even the parents would rate their children's progress lower than the teacher which could suggest that maybe the hearing limitations transferred into higher expectations that children seem to happily oblige and not be deterrent at all.

As a teacher with over 25 years of experience it was the most joyful to watch these children's tenacity and determination while learning how to play piano week after week. Their focus on a task, ability to overcome obstacles, and enjoyment in each task was evident in every lesson. The children CI users responded well to teacher's creativity and individualized lessons depending on each child's interest, age group and abilities. The teacher used singing; finger touching while singing the melody,

finger number singing, and singing with lyrics as teaching strategies. The teacher would always break it down to small maintainable and manageable “chunks” and would praise every effort made by children CI users. The teaching strategy was based on auditory- verbal therapy, model that all pediatric cochlear implantees attend after the surgery. Collaboration with parents were of a paramount importance, and this research’s success is due to their diligence in practice of music skills, weekly. The challenges of the implant’s low spectral resolution that would limit a child’s optimal hearing exposure was overcome by staying in the middle and optimal hearing range on a piano. The teacher’s voice is alto, and all children responded well to every sentence communicated. Parents were active observers and would communicate any questions before the lessons therefore our lesson time was fully focused on learning. All five children CI users have completed six songs repertoire, both hands and played with great accuracy and comparable to NH children.

All five children CI users from the experimental group have continued in some form with their music training; one is completing her level 5 RCM program, two are in school bands, one continued with guitar lessons, and one with violin lessons.

Chapter 6

Conclusion

Many studies have addressed that music training has positive impacts on music perception on pediatric cochlear implantees (Hwa, Wen & Ruckenstein, 2021; Nogueira, Nagathil & Martin, 2018; Good, Gordon, Papsin et al., 2017). They conclude that early music exposure and training has greater impact on a child's wellbeing past the music outcomes such as social integration, language shred between peers, collaboration, and motor and developmental skills improvement (Yucel et al., 2009). Also, after evaluating children CI users understanding of music-evoked emotions, Yüksel and collegues (2023) reported that children CI users ranked positive emotions such as happiness, tranquility, love and joy very high, whereas negative emotions such as guilt, fear, anger and anxiety ranked low. Many researchers have used online music training apps and programs that focus on melody recognition and music enjoyment (Calvino et al., 2023; Boyer, Stohl, 2022). Lehmann and colleagues (2021) questioned why some children CI users have better music understanding and pitch perception, and what are the strategies that clinicians can use to improve music perception with children CI users. They also recognize limitations of CI users in music appreciation due to lack of resources available to them. Despite the plethora of literature on music experience with CI users, there is no standard instrument for assessing music after the implantation. Another research highlights the importance of multisensory dimension of music perception by outlining mechanical processes of music sound in the brain; from the middle ear to inner ear where it is converted into a nerve impulse and then send to auditory cortex where the music is processed along with rhythm, memory, creativity, performance, audiation, movement coordination and emotion (Sarma, 2024).

This study examined a set of research questions in aim to find if children CI users would benefit from in person, formal music instruction on a piano using adapted Suzuki method (aural modeling – no notation reading - with visual and tactile cues) after three months of formal piano lessons. The aim

of the study was to see if children CI users' accuracy on music perception would improve with formal piano lessons. The recruited participants were 10 children CI users and 10 NH children, 4-9 years old. They were separated into two groups of experimental – who would receive 12 weeks of piano lessons – and two control groups – who would not. All groups were tested at the same time twice – pre-test (before the lessons occurred) and post-test (after the lessons were completed for the experimental groups). The first test was on melody recognition of eight familiar songs. The second test was Montreal Battery of Evaluation (MBEMA) on melody and rhythm accuracy. Lastly, the third test for this study was assessing children CI users' piano lessons and practice quality, duration, and enjoyment. The results were compared to NH children group.

Both testing and learning environments were chosen to suit optimal setting for the children CI users; the testing room contained no background noise, and the lesson room was isolated from the noisy street.

In this study we report that children CI users' experimental group increased accuracy on all tests except MBEMA rhythm test where a 1% decrease was noted. The piano lessons and adapted formal music training could be correlated factor to these results. As expected, noticed increase in NH children group as is reported. However, NH children group had the advantage over children CI users in better pretest results, but the increase was not as high as children CI users in experimental group. Both groups were diligent in their practices, lessons preparation and overall enthusiasm in learning to play piano. Slight increase in melody recognition through different conditions and decrease in MBEMA rhythm tests is reported in results from children CI users control group. The results from children CI users control group were as hypothesized – lower accuracy than the children CI users' experimental group who received music lessons. We must, however, account for natural maturation and acculturation as contributing factors to these results.

The positive reports of children CI users experimental group indicate that in person, formal

music instructions have had the most positive outcomes.

Limitations

This study has following limitations. First, we recruited only neurotypical cochlear implant participants. We recognize that some cochlear implant children have other challenges such as ADD, ADHD, apraxia, autism etc. It would be beneficial to test neurodivergent children with cochlear implants. Second, we recruited cochlear implant participants with parental background heavily appreciating music culture. These participants were eager to participate as music listening was a part of their daily routine. It would be interesting to pursue a study where participants are not eager about music – for whatever reason. Third, the size of participants is rather limiting. It would be beneficial to see if the same results could be produced with a larger group of participants. Forth, the age group of participants was going in our favour. Most children from age four to nine are obedient, curious, and willing to try new skills. Also, they are willing to please their parents and their teachers and as such, they are easy to teach as their focus on play/games/learning is enormous. Fifth, all the participants' parents in this study have a minimum university degree and strong music understanding and as such have been exposed to arts programs, libraries, galleries and museums. Furthermore, all participants had a piano at home to practice. It would be interesting to see if the same results would be produced if we recruited participants from a different socio-economic status (SES) family with different opportunities and life circumstances. Sixth, the length of the piano lessons was three months and relatively short period in music learning experience. A possibility of a longer study where participants could take lessons for a full school year might show even greater results in music accuracy and reproduction. Seventh, it should be recognized that the primary researcher fulfilled the roles of instructor for both groups, test administrator, data gatherer, and analyst, and the limitations inherent in this dual role should be taken into consideration. Lastly, the pre and posttest familiarity might have led to marginal improvements in all groups. In conclusion, the results of our study

indicate that our methodology was successful and that children with cochlear implants indeed benefited from three months of formal piano lessons. Furthermore, all the children CI users have continued in various levels of music involvement proving that the interest in music learning continued past this study.

Recommendations for future research

Piano pedagogy researchers with interest in full inclusion of cochlear implant students could further expand on this study. It would be beneficial to expand the participants number, and the age group. It might be also beneficial to include different teachers and try different teaching methods such as inclusion of electronic apps and other devices as a practice tool. There are opportunities is adding the singing aspect to the study as it was evident that all children CI users loved making sound with their own voices and singing in general. The study can also be longer in length – six plus months. Further studies could possibly focus on specific language demographics; suggestion would be in bilingual or trilingual homes. Also, it would be beneficial to the body of research in CI users and music if infants post implantation would attend some form of music training along with auditory verbal therapy. Early exposure to music while using BA, TA, PA, SA sounds, along with ascending and descending sounds could be a great addition to AVT. Furthermore, due to the difficulties of MBEMA testing, another measuring tool could be used; a simplified, or modified measuring tool is suggested to make children more interested and engaged. Also, an assessment tool incorporating subjective and objective measures of musical evaluation with CI users would be most beneficial to the research evaluations. Lastly, possibilities for piano teachers to affiliate and collaborate with children's hospitals and rehabilitation centers and auditory-verbal therapists could bring out many more possibilities in the field of piano pedagogy.

References

Abdi, S., Khalessi, M. H., Khorsandi, M., & Gholami, B. (2001). Introducing music as a means of habilitation for children with cochlear implants. *International Journal of Pediatric Otorhinolaryngology*, 59(2), 105-113.

Advanced Bionics. (2009). Music perception and enjoyment with the Harmony HiResolution Bionic Ear. Advanced Bionics: Valencia, CA.

Barton, C., & Robbins, A. M. (2015). Jumpstarting auditory learning in children with cochlear implants through music experiences. *Cochlear Implants International*, *16*(sup3), S51–S62.

Bartov, T., & Most, T. (2014). Song recognition by young children with cochlear implants: Comparison between unilateral, bilateral, and bimodal users. *Journal of Speech, Language, and Hearing Research:* JSLHR, 57(5), 1929-1941.

Boyer, J., & Stohl, J. (2022). MELUDIA - Online music training for cochlear implant users. *Cochlear Implants International*, *23*(5), 257–269.

Bruns, L., Mürbe, D., & Hahne, A. (2016). Understanding music with cochlear implants. *Scientific Reports*, *6*(1), 32026–32026.

Caldwell, M., Rankin, S. K., Jiradejvong, P., Carver, C., & Limb, C. J. (2015). Cochlear implant users rely on tempo rather than on pitch information during perception of musical emotion. *Cochlear Implants International*, *16*(sup3), S114–S120.

Calvino, M., Zuazua, A., Sanchez-Cuadrado, I., Gavilán, J., Mancheño, M., Arroyo, H., & Lassaletta, L. (2024). Meludia platform as a tool to evaluate music perception in pediatric and adult cochlear implant users. *European Archives of Oto-Rhino-Laryngology*, *281*(2), 629–638.

Carroll, J. A. (2008). *Enhancing and understanding pitch in cochlear implants*. Available from ProQuest Dissertations & Theses Global.

Chen, M. (2012). *Musical auditory discrimination and perception of mandarin Chinese tones in Taiwanese children with cochlear implants*. Available from ProQuest Dissertations & Theses Global.

Cheng, X., Liu, Y., Shu, Y., Tao, D.-D., Wang, B., Yuan, Y., Galvin, J. J., Fu, Q.-J., & Chen, B. (2018). Music training can improve music and speech perception in pediatric Mandarin-speaking cochlear implant users. *Trends in Hearing*, *22*, 2331216518759214–2331216518759214.

Cheng, L., & Mcgregor, I. (2024). Pedagogical approaches in music and audio education for deaf and hard-of-hearing students. *Organised Sound: An International Journal of Music Technology*, *29*(2), 188–196.

Crew, J. D., Galvin, J. J., & Fu, Q. (2012). Channel interaction limits melodic pitch perception in

simulated cochlear implants. *The Journal of the Acoustical Society of America, 132*(5), EL429-EL435.

Cullington, H. E., & Zeng, F. (2011). Comparison of bimodal and bilateral cochlear implant users on speech recognition with competing talker, music perception, affective prosody discrimination, and talker identification. *Ear and Hearing, 32*(1), 16-30.

Darwin, C. J. (2008). Listening to speech in the presence of other sounds. *Philosophical Transactions of the Royal Society of London, Series B: Biological Sciences*, 363(1493), 1011-1021.

DeLuca, C., & Bolden, B. (2014). Music performance assessment: Exploring three approaches for quality rubric construction. *Music Educators Journal*, 101(1), 70-76.

Deroche, M. L. D., Zion, D. J., Schurman, J. R., & Chatterjee, M. (2012). Sensitivity of school-aged children to pitch-related cues. *The Journal of the Acoustical Society of America,* 131(4), 2938-2947.

Deroche, M. L., Lu, H., Limb, C. J., Lin, Y., & Chatterjee, M. (2014). Deficits in the pitch sensitivity of cochlear-implanted children speaking English or Mandarin. *Frontiers in Neuroscience, 8.*

Dinçer D'Alessandro, H., Nicastri, M., Portanova, G., Giallini, I., Russo, F. Y., Magliulo, G., Greco, A., & Mancini, P. (2024). Low-frequency pitch coding: relationships with speech-in-noise and music perception by pediatric populations with typical hearing and cochlear implants. *European Archives of Oto-Rhino-Laryngology*.

Drennan, W. R., & Rubinstein, J. T. (2008). Music perception in cochlear implant users and its relationship with psychophysical capabilities. *Journal of Rehabilitation Research and Development, 45*(5), 779-89.

Driscoll, V., Gfeller, K., Tan, X., See, R. L., Cheng, H.-Y., & Kanemitsu, M. (2015). Family involvement in music impacts participation of children with cochlear implants in music education and music activities. *Cochlear Implants International*, *16*(3), 137–146.

Driscoll, V. D., Oleson, J., Jiang, D., & Gfeller, K. (2009). Effects of training on recognition of musical instruments presented through cochlear implant simulations. *Journal of the American Academy of Audiology, 20*(1), 71-82.

El Fata, F., James, C. J., Laborde, M., & Fraysse, B. (2009). How much residual hearing is 'useful' for music perception with cochlear implants? *Audiology & Neurotology, 14*, 14-21.

Eskridge, E. N., Galvin, J. J., Aronoff, J. M., Li, T., & Fu, Q.-J. (2012). Speech perception with music maskers by cochlear implant users and normal-hearing listeners. *Journal of Speech, Language, and Hearing Research*, *55*(3), 800–810.

Falcón-González, J. C., Borkoski-Barreiro, S., Limiñana-Cañal, J. M., & Ramos-Macías, A. (2014). Recognition of music and melody in patients with cochlear implants, using a new programming approach for frequency assignment. *Acta Otorrinolaringológica*

Española, 65(5), 289-296.

Firestone, G. M., McGuire, K., Liang, C., Zhang, N., Blankenship, C. M., Xiang, J., & Zhang, F. (2020). A preliminary study of the effects of attentive music listening on cochlear implant users' speech perception, quality of life, and behavioral and objective measures of frequency change detection. *Frontiers in Human Neuroscience*, *14*, 110–110.

Fives, H., & DiDonato-Barnes, N. (2013). Classroom test construction: The power of a table of specifications. *Practical Assessment, Research & Evaluation*, 18(3), 7.

Fox, S. E., Levitt, P., & Nelson III, Charles A. (2010). How the timing and quality of early experiences influence the development of brain architecture. *Child Development, 81*(1), 28-40.

Frosolini, A., Franz, L., Badin, G., Mancuso, A., de Filippis, C., & Marioni, G. (2024). Quality of life improvement in cochlear implant outpatients: a non-randomized clinical trial of an auditory music training program. *International Journal of Audiology*, 1–9.

Fu, Q.-J., Galvin, J. J., Wang, X., & Wu, J.-L. (2015). Benefits of music training in Mandarin-speaking pediatric cochlear implant users. *Journal of Speech, Language, and Hearing Research*, *58*(1), 163–169.

Fu, Q.-J., & Galvin, J. J. (2008). Maximizing cochlear implant patients' performance with advanced speech training procedures. *Hearing Research*, *242*(1), 198–208.

Fujita, S., & Ito, J. (1999). Ability of nucleus cochlear implantees to recognize music. *The Annals of Otology, Rhinology & Laryngology, 108*(7), 634-40.

Fuller, C. D., Galvin, J. J., Maat, B., Başkent, D., & Free, R. H. (2018). Comparison of two music training approaches on music and speech perception in cochlear implant users. *Trends in Hearing*, *22*, 2331216518765379–2331216518765379.

Galvin, J. J., Fu, Q., & Shannon, R. V. (2009). Melodic contour identification and music perception by cochlear implant users. *Annals of the New York Academy of Sciences, 1169*(1), 518-533.

Gfeller, K. (2009). Music and cochlear implants: not in perfect harmony. *ASHA Leader, 14*(8), 12-13.

Gfeller, K., Driscoll, V., Kenworthy, M., & Van Voorst, T. (2011). Music therapy for preschool cochlear implant recipients. *Music Therapy Perspectives, 29*(1), 39-49.

Gfeller, K., & Hsiao, F. (2012). Music perception of cochlear implant recipients with implications for music instruction: A review of the literature. *Update - Applications of Research in Music Education, 30*(2), 5-10.

Gfeller, K., Jiang, D., Oleson, J. J., Driscoll, V., & Knutson, J. F. (2010). Temporal stability of music perception and appraisal scores of adult cochlear implant recipients. *Journal of the American Academy of Audiology, 21*(1), 28-34.

Gfeller, K., Jiang, D., Oleson, J. J., Driscoll, V., Olszewski, C., Knutson, J. F., . . . Gantz, B.

(2012). The effects of musical and linguistic components in recognition of real-world musical excerpts by cochlear implant recipients and normal-hearing adults. *Journal of Music Therapy, 49*(1), 68-101.

Gfeller, K., Witt, S., Adamek, M., Mehr, M., Rogers, J., Stordahl, J., & Ringgenberg, S. (2002). Effects of training on timbre recognition and appraisal by postlingually deafened cochlear implant recipients. *Journal of the American Academy of Audiology, 13*(3), 132-145.

Gfeller, K. (2000). Accommodating children who use cochlear implants in music therapy or educational settings. *Music Therapy Perspectives, 18*(2), 130.

Gfeller, K., Christ, A., Knutson, J. F., Witt, S., & et al. (2000). Musical backgrounds, listening habits, and aesthetic enjoyment of adult cochlear implant recipients. *Journal of the American Academy of Audiology, 11*(7), 406.

Gfeller, K., Olszewski, C., Turner, C., Gantz, B., & Oleson, J. (2006). Music perception with cochlear implants and residual hearing. *Audiology & Neurotology, 11*, 5.

Gfeller, K., Woodworth, G., Robin, D. A., Witt, S., & Knutson, J. F. (1997). Perception of rhythmic and sequential pitch patterns by normally hearing adults and adult cochlear implant users. *Ear and Hearing, 18*(3), 260.

Good, A., Gordon, K. A., Papsin, B. C., Nespoli, G., Hopyan, T., Peretz, I., & Russo, F. A. (2017). Benefits of music training for perception of emotional speech prosody in deaf children with cochlear implants. *Ear and Hearing*, *38*(4), 455–464.

Hamer, M. (2005). Music for those who have never heard it. *New Scientist, 188*, 32.

Hidalgo, C., Falk, S., & Schön, D. (2017). Speak on time! Effects of a musical rhythmic training on children with hearing loss. *Hearing Research*, *351*, 11–18.

Hidalgo, C., Pesnot-Lerousseau, J., Marquis, P., Roman, S., & Schön, D. (2019). Rhythmic training improves temporal anticipation and adaptation abilities in children with hearing loss during verbal interaction. *Journal of Speech, Language, and Hearing Research*, *62*(9), 3234–3247.

Hopyan, T., Gordon, K. A., & Papsin, B. C. (2011). Identifying emotions in music through electrical hearing in deaf children using cochlear implants. *Cochlear Implants International, 12*(1), 21-26.

Hopyan, T., Peretz, I., Chan, L. P., Papsin, B. C., & Gordon, K. A. (2012). Children using cochlear implants capitalize on acoustical hearing for music perception. *Frontiers in Psychology, 3*, 425.

Houston, D. M., Beer, J., Bergeson, T. R., Chin, S. B., Pisoni, D. B., & Miyamoto, R. T. (2012). The ear is connected to the brain: Some new directions in the study of children with cochlear implants at Indiana university. *Journal of the American Academy of Audiology, 23*(6), 446-63.

Hsiao, F. (2008). Mandarin melody recognition by pediatric cochlear implant recipients. *Journal of Music Therapy, 45*(4), 390-404.

Hwa, T. P., Wen, C. Z., & Ruckenstein, M. J. (2021). Assessment of music experience after cochlear implantation: A review of current tools and their utilization. *World Journal of Otorhinolaryngology-Head and Neck Surgery*, *7*(2), 116–125.

Isaiah, A., Vongpaisal, T., King, A. J., & Hartley, D. E. H. (2014). Multisensory training improves auditory spatial processing following bilateral cochlear implantation. *The Journal of Neuroscience*, *34*(33), 11119–11130.

Jentschke, S., & Koelsch, S. (2009). Musical training modulates the development of syntax processing in children. *NeuroImage (Orlando, Fla.)*, *47*(2), 735–744.

Jiam, N. T., Deroche, M. L., Jiradejvong, P., & Limb, C. J. (2019). A randomized controlled crossover study of the impact of online music training on pitch and timbre perception in cochlear implant users. *Journal of the Association for Research in Otolaryngology*, *20*(3), 247–262.

Jiam, N. T. & Limb, C., 2020. Music perception and training for pediatric cochlear implant users. *Expert Review of Medical Devices, 17*(11), pp.1193-1206.

Jung, K. H., Won, J. H., Drennan, W. R., Jameyson, E., Miyasaki, G., Norton, S. J., & Rubinstein, J. T. (2012). Psychoacoustic performance and music and speech perception in prelingually deafened children with cochlear implants. *Audiology & Neurotology, 17*(3), 189-97.

Kasturi, K. S. (2006). *Signal processing strategies for better melody recognition and improved speech understanding in noise for cochlear implants*. Available from ProQuest Dissertations & Theses Global.

Koelsch, S., Wittfoth, M., Wolf, A., Müller, J., & Hahne, A. (2004). Music perception in cochlear implant users: An event-related potential study. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology, 115*(4), 966-972.

Koroleva, I., Ogorodnikova, J., & Ross, J. (August 12, 2009). Development of the music perception habits with cochlear-implanted patients. *International Journal of Psychophysiology*, *69*(3), 304–305.

Kosaner, J., Kilinc, A., & Deniz, M. (2012). Developing a music programme for preschool children with cochlear implants. *Cochlear Implants International, 13*(4), 237-247.

Kraus, N., & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature Reviews: Neuroscience, 11*(8), 599-605.

Lehmann, A., Limb, C. J., & Marozeau, J. (2021). Editorial: Music and cochlear implants: Recent developments and continued challenges. *Frontiers in Neuroscience*, *15*, 736772–736772.

Laneau, J., Wouters, J., & Moonen, M. (2006). Improved music perception with explicit pitch coding in cochlear implants. *Audiology & Neurotology, 11*(1), 38-52.

Levitin, D. (2024). How and why? What does it mean to be musical? In R.F (Ed). Music and Mind (ed. 2024, pp 20-32). Penguin Random House Canada.

Lo, C. Y., Looi, V., Thompson, W. F., & McMahon, C. M. (2020). Music training for children with sensorineural hearing loss improves speech-in-noise perception. *Journal of Speech, Language, and Hearing Research*, *63*(6), 1990–2015.

Looi, V., & She, J. (2010). Music perception of cochlear implant users: A questionnaire, and its implications for a music training program. *International Journal of Audiology*, *49*(2), 116–128.

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.

Lu, T., Huang, J., & Zeng, F. (2014). Accurate guitar tuning by cochlear implant musicians: e92454. *PLoS One, 9*(3), n/a.

Marsella, P., Scorpecci, A., Vecchiato, G., Maglione, A. G., Colosimo, A., & Babiloni, F. (2014). Neuroelectrical imaging investigation of cortical activity during listening to music in prelingually deaf children with cochlear implants. *International Journal of Pediatric Otorhinolaryngology, 78*(5), 737-743.

Mitani, C., Nakata, T., Trehub, S. E., Kanda, Y., Kumagami, H., Takasaki, K., . . . Takahashi, H. (2007). Music recognition, music listening, and word recognition by deaf children with cochlear implants. *Ear and Hearing, 28*(2 Suppl), 29S-33S.

Mortensen, M. V., Hansen, M., Vuust, P., & Petersen, B. (2012). Singing in the key of life: A study on effects of musical ear training after cochlear implantation. *Psychomusicology, 22*(2), 134-151.

Nakata, T., Trehub, S. E., & Kanda, Y. (2012). Effect of cochlear implants on children's perception and production of speech prosody. *The Journal of the Acoustical Society of America, 131*(2), 1307-1314.

Nakata, T., Trehub, S. E., Mitani, C., Kanda, Y., Shibasaki, A., & Schellenberg, E. G. (2005). Music recognition by Japanese children with cochlear implants. *Journal of Physiological Anthropology and Applied Human Science, 24*(1), 29-32.

Nogueira, W., Nagathil, A., & Martin, R. (2019). Making music more accessible for cochlear implant listeners: recent developments. In *IEEE signal processing magazine*, *36*(1), 115–127.

Ogorodnikova, J., Koroleva, I., & Ross, J. (2008). Development of music perception by patients with cochlear impants. *International Journal of Pychophysiology, 69*(3), 304-305.

Olszewski, C., Gfeller, K., Froman, R., Stordahl, J., & Tomblin, B. (2005). Familiar melody recognition by children and adults using cochlear implants and normal hearing

children. *Cochlear Implants International, 6*(3), 123-140.

Omran, S., Lai, W., & Dillier, N. (2010). Pitch ranking, melody contour and instrument recognition tests using two semitone frequency maps for nucleus cochlear implants. *EURASIP Journal of Audio, Speech, and Music Processing, 2010.*

Patel, A. (2024). How and why? Musicality, evolution, and animal responses to music. In R.F (Ed). Music and Mind (ed. 2024, pp 3-19). Penguin Random House Canada.

Patel, A. (2014). Can nonlinguistic musical training change the way the brain processes speech? The expanded OPERA hypothesis. *Hearing Research, 308*, 98-108.

Petersen, B., Mortensen, M. V., Gjedde, A., & Vuust, P. (2009). Reestablishing speech understanding through musical ear training after cochlear implantation. *Annals of the New York Academy of Sciences, 1169*(1), 437-440.

Pressnitzer, D., Bestel, J., & Fraysse, B. (2005). Music to electric ears: Pitch and timbre perception by cochlear implant patients. *Annals of the New York Academy of Sciences, 1060*, 343-345.

Prevoteau, C., Chen, S. Y., & Lalwani, A. K. (2018). Music enjoyment with cochlear implantation. *Auris, Nasus, Larynx*, *45*(5), 895–902.

Rauschecker, J. P., & Shannon, R. V. (2002). Sending sound to the brain. *Science (Washington), 295*(5557), 1025-1029.

Reifinger, J. L. (2018). Music education to train hearing abilities in children with cochlear implants. *Music Educators Journal*, *105*(2), 57–63.

Roy, A. T., Scattergood-Keepper, L., Carver, C., Jiradejvong, P., Butler, C., & Limb, C. J. (2014). Evaluation of a test battery to assess perception of music in children with cochlear implants. *Archives of Otolaryngology - Head & Neck Surgery, 140*(6), 540.

Saindon, M. R. (2013). Music processing in deaf adults with cochlear implants. *Available from Linguistics and Language Behavior Abstracts (LLBA)*. (201407305).

Sandmann, P., Kegel, A., Eichele, T., Dillier, N., Lai, W., Bendixen, A., . . . Meyer, M. (2010). Neurophysiological evidence of impaired musical sound perception in cochlear-implant users. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology, 121*(12), 2070-2082.

Schraer-Joiner, L., & Prause-Weber, M. (2009). Strategies for working with children with cochlear implants. *Music Educators Journal, 96*(1), 48-55.

See, R. L., Driscoll, V. D., Gfeller, K., Kliethermes, S., & Oleson, J. (2013). Speech intonation and melodic contour recognition in children with cochlear implants and with normal hearing. *Otology & Neurotology: Official Publication of the American Otological Society, American Neurotology Society [and] European Academy of Otology and Neurotology, 34*(3), 490-498.

Spahr, A. J., Litvak, L. M., Dorman, M. F., Bohanan, A. R., & Mishra, L. N. (2008). Simulating the effects of spread of electric excitation on musical tuning and melody identification with a cochlear implant. *Journal of Speech, Language, and Hearing Research, 51*(6), 1599-1606.

Spitzer, J. B., Mancuso, D., & Cheng, M. (2008). Development of a clinical test of musical perception: Appreciation of music in cochlear implantees (AMICI). *Journal of the American Academy of Audiology, 19*(1), 56-81.

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.

Stordahl, J. (2002). Song recognition and appraisal: A comparison of children who use cochlear implants and normally hearing children. *Journal of Music Therapy, 39*(1), 2-19.

Surma, J. (2024). Music therapy in the treatment of people with hearing deficits: A review of selected strategies. *Musicology Today (Warsaw)*, *21*(1), 77–83.

Thompson, W. F., Schellenberg, E. G., & Husain, G. (2004). Decoding speech prosody: Do music lessons help? *Emotion (Washington, D.C.)*, *4*(1), 46–64.

Tobey, E. A., & Devous, M. D. (2007). Neuroimaging and cochlear implants. *ASHA Leader, 12*(12), 6-9.

Torppa, R., Faulkner, A., Laasonen, M., Lipsanen, J., & Sammler, D. (2020). Links of prosodic stress perception and musical activities to language skills of children with cochlear implants and normal hearing. *Ear and Hearing*, *41*(2), 395–410.

Torppa, R., Faulkner, A., Huotilainen, M., Järvikivi, J., Lipsanen, J., Laasonen, M., & Vainio, M. (2014). The perception of prosody and associated auditory cues in early-implanted children: The role of auditory working memory and musical activities. *International Journal of Audiology*, *53*(3), 182–191.

Torppa, R., Huotilainen, M., Leminen, M., Lipsanen, J., & Tervaniemi, M. (2014). Interplay between singing and cortical processing of music: a longitudinal study in children with cochlear implants. *Frontiers in Psychology*, *5*, 1389–1389.

Torppa, R., Salo, E., Makkonen, T., Loimo, H., Pykäläinen, J., Lipsanen, J., Faulkner, A., & Huotilainen, M. (2012). Cortical processing of musical sounds in children with cochlear implants. *Clinical Neurophysiology*, *123*(10), 1966–1979.

Trehub, S. E., Mitani, C., Kanda, Y., & Nakata, T. (2006). Pitch and timing in the songs of deaf children with cochlear implants. *Music Perception, 24*(2), 147-154.

Trehub, S. E., Schellenberg, E. G., & Vongpaisal, T. (2009). Identification of TV tunes by children with cochlear implants. *Music Perception, 27*(1), 17-24.

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.

van Besouw, Rachel M, Grasmeder, M. L., Hamilton, M. E., & Baumann, S. E. (2011). Music activities and responses of young cochlear implant recipients. *International Journal of Audiology, 50*(5), 340-348.

Veekmans, K., Ressel, L., Mueller, J., Vischer, M., & Brockmeier, S. J. (2009). Comparison of music perception in bilateral and unilateral cochlear implant users and normal-hearing subjects. *Audiology & Neurotology, 14*(5), 315-26.

Volkova, A., Trehub, S. E., Schellenberg, E. G., Papsin, B. C., & Gordon, K. A. (2014). Children's identification of familiar songs from pitch and timing cues. *Frontiers in Psychology, 5*, 863.

Vongpaisal, T. (2004). Recognition of popular songs by children and adolescents with cochlear implants Available from ProQuest Dissertations & Theses Global.

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), 1091-103.

Vongpaisal, T., Trehub, S. E., Schellenberg, E. G. & Papsin, B. (2004). Music recognition by children with cochlear implants. *International Congress Series,* 1273, 193-196.

Wright, R., & Uchanski, R. M. (2012). Music perception and appraisal: Cochlear implant users and simulated cochlear implant listening. *Journal of the American Academy of Audiology,23*(5), 350-65; quiz 379.

Yennari, M. (2010). Beginnings of song in young deaf children using cochlear implants: the song they move, the song they feel, the song they share. *Music Education Research*, *12*(3), 281–297.

Yitao, M., & Li, X. (2013). Music and cochlear implants. *Journal of Otology (Beijing)*, *8*(1), 32–38.

Yucel, E., Sennaroglu, G., & Belgin, E. (2009). The family oriented musical training for children with cochlear implants: Speech and musical perception results of two year follow-up. *International Journal of Pediatric Otorhinolaryngology, 73*(7), 1043-1052.

Yüksel, M., Sarlik, E., & Çiprut, A. (2023). Emotions and psychological mechanisms of listening to music in cochlear implant recipients. *Ear and Hearing*, *44*(6), 1451–1463.

Zhang, F., Benson, C., & Cahn, S. J. (2013). Cortical encoding of timbre changes in cochlear implant users. *Journal of the American Academy of Audiology, 24*(1), 46-58.

Zhou, N. (2010). *Lexical tone development, music perception and speech perception in noise with cochlear implants: The effects of spectral resolution and spectral mismatch.* Available from ProQuest Dissertations & Theses Global.

APPENDIX A: Pamphlet On Cochlear Implants - For Piano Teachers

Pamphlet On Cochlear Implants - For Piano Teachers

Cochlear Implants

(Information from the Canadian Academy of Audiology)

What is a cochlear implant?

A cochlear implant is an electronic device that is designed to provide hearing to those with profound deafness. Part of the device is surgically implanted into the inner ear and part is worn externally. As a prosthetic device, the cochlear implant stimulates the auditory or hearing nerve directly, bypassing the damaged part of the inner ear or cochlea. Many viable nerve fibers remain in the auditory nerve even in cases of profound deafness, and the cochlear implant can restore activity to this nerve and the hearing pathway.

Many individuals who have lost their hearing after acquiring speech and language (post-lingual deafness) are capable of excellent speech understanding with their implant. When children who are deaf are provided with cochlear implants, they can perceive speech and environmental sounds previously unavailable to them. As they learn to attach meaning to the sounds they are hearing, they build the foundations for spoken language.
How does a cochlear implant work?

The implant has two components, an externally worn microphone and processor and the internal electrode array. The microphone picks up sounds near the ear level and sends it to the speech processor. The speech processor takes the acoustic signal and codes it for speech electrically.

The signal is sent to the transmitter worn on the head where it is then sent through the skin to the implanted device. Under the skin, the receiver decodes the signal and sends it to the electrode array. The electrode array distributes the signal and stimulates the nerve endings in the cochlea, producing nerve impulses. The impulses are sent to the brain where they are interpreted as sound.

Who is a candidate for a cochlear implant?

Cochlear implants are available to children and adults in Canada who meet the following criteria:

Children

- Age 0-18 years
- Severe-to-Profound sensorineural hearing loss bilaterally
- Receive little or no benefit from appropriate hearing aids.
- No medical contraindications.
- An educational placement where the development of listening and speaking skills is emphasized.
- Family support that includes the commitment to the rehabilitative process

What is the process of getting a cochlear implant?

Before receiving a cochlear implant, an extensive evaluation is performed that includes a hearing aid evaluation, an audiological evaluation, an ontological evaluation, CT scan, a speech-language evaluation, and possibly a psychological evaluation. These tests are performed to ensure that candidacy requirements have been met and that certain benefits may be provided by the implant. Counselling will also be provided by the cochlear implant team regarding the benefits and risks of cochlear implantation.
This will include the medical and surgical risks, the possible benefits to be expected, and the follow-up necessary to ensure an appropriate fitting of the speech processor and rehabilitation.

When does surgery take place?

Once patients have completed the necessary testing to determine candidacy, surgery can be scheduled. Surgery is performed under general anaesthesia, and typically takes two to three hours to complete. The electrode array is fed into the cochlea, and the receiver is placed behind the ear. Most hospitals require a one-to-two-day hospital stay before going home.

What happens after surgery?

Four to six weeks following surgery the speech processor will be programmed. Threshold and comfort levels are obtained for each electrode on the internal array, which creates a "map" that is stored on a computer chip inside your processor. This process is usually done in two to three hours.

During the first three months of wearing the device, some fine-tuning needs to take place. Numerous "mapping" sessions may need to be performed to obtain the best possible sound for each patient. Typically, once a stable map is established, the map is checked, and speech perception testing is performed every six months following activation.

Why is rehabilitation important?

Rehabilitation following cochlear implantation offers a structured approach by which patients learn to identify and associate meaning to the new sounds they are hearing. For children, rehabilitation is vital to develop an understanding of what is being heard through a cochlear implant. Therapy allows children to take the restored level of sensitive hearing and learn to understand spoken language and produce intelligible speech. Unlike adults who have lost their hearing after the development of speech and language, deaf children have no auditory memories to draw upon to understand spoken communication. Rehabilitation is a lifelong process that takes the child through language acquisition learning to attach meaning first to syllables, then to words, phrases, and sentences and ultimately to conversation. For adults, rehabilitation can provide the structure necessary to fine-tune their listening skills. Some adults feel that they are receiving enough stimulation in their everyday life that therapy is not needed.

APPENDIX B: Study Description

Study Description

To whom it may concern,

We are currently seeking children to participate in our research project on the ability of children with cochlear implants to recognize simple tunes played on the piano and reproduce them on the piano as well as their normal hearing peers. As such, we are looking for a group of children with cochlear implants and a normal hearing group of children for comparison purposes.

Your child will participate in a weekly 30-minute piano lesson week for a total of 3 months. The piano lessons will take place in the Piano Pedagogy Research Laboratory at the University of Ottawa, located at 50 University Private, in a private music school in the Ottawa area or in a private studio. The same tests taken before beginning piano lessons will be taken after the end of the lesson period in addition to piano performance assessment that will be taken after the lesson period.

In order to participate your child must:

- Be between 4 and 9 years of age.
- Use French and/or English at school or in your home.
- Have no overall development problems, language development disorders, learning disorders, or cognitive, neurologic or attention disorders.
- Have no experience with piano, i.e., he or she must never have taken piano lessons.

The hearing-impaired participants must have a hearing loss in both ears and wear hearing aids/cochlear implants in both ears. They must have been using them for a minimum of two years before their participation in this research project.

If by any chance you happen to know children who qualify and who might want to participate, please don't hesitate to invite them for us.

Children younger than 4 and over 10 years of age are not candidates for participation in this research project. Children who do not speak either French and/or English or who have a hearing loss in only one ear will not be able to participate. Children will be selected according to principle of first come first served.

To schedule an appointment or get more information concerning this research project, you can simply reply to this email, call **Sandra Marković.**

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Sandra Marković MA candidate **University of Ottawa**	**Gilles Comeau, Ph.D.** Professor **University of Ottawa**

APPENDIX C: Parental Consent Form

Parental Consent Form

Title of the research project: Piano Performance, and Identification of Melodic Contour and Pitch of Prelingually Deaf Children with Cochlear Implants After Three Months of Formal Music Instruction

Invitation to participate: Your child is invited to participate in a research project directed by Professor Gilles Comeau (613) 562-5800, ext. 2704). This form explains the purpose of the research and describes the advantages your child and you could experience during their participation as well as any potential risks. A laboratory assistant will be available to discuss this research with you and answer any questions you may have.

The goal of this research

Many studies have shown that children with cochlear implants are capable of perceiving music, however there is little evidence to suggest that they are capable of producing music. We are interested in the effectiveness of piano lessons for children with and without hearing loss. More specifically, the goal of this study is to compare the ability of children with bilateral cochlear implants to recognize melodies and to reproduce them on the piano to their normal hearing counterparts. Furthermore, we will be assessing children's' abilities to sing, perceive melodic contours and pitch after formal piano training.

Why do this research?

At one point, not too long ago, it was thought that children with cochlear implants who were deaf from birth or lost their hearing at an early age were unable to perceive music. Later it was assumed they could recognize music but not enjoy it as much as their peers. Today we are further investigating abilities of children with cochlear implants to enjoying and play music.

> "All Canadians, including deaf Canadians and Canadians with disabilities, have the right to fully participate in society, and the arts are an integral part of societal experiences and citizenship."
>
> -Canada Council for the Arts

Where will this research be done?

The piano lessons will take place in the Piano Pedagogy Research Laboratory at the University of Ottawa, located at 50 University Private, in a private music school in the Ottawa area or in a private studio. Each participant will attend a weekly 30-minute lesson for a total of 3 months.

How many people will participate in this study?

We are looking for 20 Francophone or Anglophone children between the ages of 4 and 9. Two groups of children will participate: 10 children with hearing loss due to neural damage who have been bilaterally implanted and 10 children without hearing loss that will be paired for analysis based on age and sex.

Who is allowed to participate in this study?

All the participants must speak French and/or English at school or at home and the parents of the participating children must specify that their child does not have a learning disability, developmental disorder, language-development disorder, neurologic disorder or attention disorder. The participants must be beginners in piano and have never taken piano lessons.

The participants with hearing loss must: 1) have hearing loss in both ears, 2) have worn implants for at least two years before their participation in this research project, and 3) have been followed by an audiologist or speech pathologist for a minimum of 2 years.

Hearing participants will need to have a hearing range of ≤15 dB HL at 250, 500, 1000, 2000, 4000 et 8000 Hz.

What does it involve?

1) Personal Data Form:

This form contains information regarding ethology of deafness, longitude of cochlear implant use, as well as personal contact information.

2) Piano lessons

The piano lessons will be offered on an individual basis. Each child will be assigned to a piano teacher and will receive all his or her lessons from that teacher. Children must have access to an acoustic piano or an electronic keyboard so they can practice between lessons. There will be no charge for the lessons for the duration of the study.

Equipment:

Pianos are located at the university's Piano Pedagogy Research Laboratory or in a private music school or studio.

How will my child's name and results stay confidential?

An identification number will be assigned to each participant on the forms collected. All information will be kept in a locked file in the office of the head researcher. None of your personal information such as your name or your child's name will be published or mentioned. None of the information we use will be associated with your child's medical file. All information will stay confidential and your child's name will not show on any document used for the research.

What are the risks?

There are no risks to your child's health or self-esteem associated with his or her participation in this project.

Storage of data

The results will be kept in a locked folder or in a computer protected with a password for 5 years after the publication of the study. This information will be kept in the office of the principal researcher. All data will be destroyed after 5 years.

Advantages

Your child will have free piano lessons for 6 months. When the study is complete, you will receive a summary of the results from the test group. You do not have to pay for anything while participating.

Participating voluntarily

Your child's participation is fully voluntary. You can at any time cancel your appointment without any consequences. We will respect your choice if you or your child refuses to participate even though your consent had already been given.

Declaration

Signing this form tells us that you and your child understand the information we have provided about this research project.

Conflicts of interest

There are no conflicts of interest between the principal researcher and the assistants. This research project is not financed by any outside organization.

PARENTAL CONSENT

Please read the instructions carefully and check the boxes below to show that you have understood. If you have any questions regarding this project, please talk to a team member. You can contact Sandra Marković (principal researcher), University of Ottawa, or Dr. Gilles Comeau (613)-562-5800, ext. 2704.

Confidentiality:

- I understand that all information will be kept confidential.
- I understand that the information and data collected will be kept confidential.
- I understand that neither my name nor my children's nor any other information will be included in the publication of this research.
- My information will be kept always locked up.
- I understand that the results of this study might be published but that my child's name will not be included.

Dropping out of the study:

- I understand that my child can choose not to participate to this study and that I will not be affected by this.
- I understand that my child can drop out of this study at any moment by telling a member of the research team that we are no longer interested.
  I understand that my services will not be altered if I decide not to participate.
- The nature of the test and the way it will be carried out has been explained to me. I have received a copy of the consent form and have had the chance to read and ask questions, which were answered. I agree to participate.

Child's name: _____

Age of the child: _____

Name of parent (guardian): _____

Parent signature: _____ Date: _____

The research project as well as the terms and conditions of participation have been described to the participant. A member of the research group has answered any questions that have been asked and has explained that participation is completely voluntary. The team will respect the agreement made in this consent form.

Name of the researcher (or representative): Signature of the researcher (or representative):

_____

Date:_____

APPENDIX D: Audio Recording Consent Form

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Laboratoire de recherche en Pédagogie du piano

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Audio Recording Consent Form

PARTICIPANTS CONSENT FORM – AUDIO RECORDING

I, _____, hereby confirm that I have been a participant in the research project "Piano Performance, Identification of Melodic Contour and Pitch of Prelingually Deaf Children with Cochlear Implants after Three Months of Formal Music Instruction", conducted by Sandra Marković from the Piano Pedagogy Research Lab at the School of Music of the University of Ottawa. For this reason, I allow researchers and students conductng this research to audio record my child _____piano performance during the testing session. I understand that these audio files will be used for educational purposes only and that no name or personal information will be used.

I allow the University of Ottawa to use the audio files on this day in the laboratory of Audiology by signing this paper.

Participant's signature: _____ Date: _____

Researcher's signature: _____ Date: _____

APPENDIX E: Personal Data Form

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Laboratoire de recherche en Pédagogie du piano

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Personal Data Form

Child's Name						
Child's Age						
Gender		M / F				
Address						
Telephone 1						
Telephone 2						
Email address						
		Parents				
Mother's name						
Highest level of education obtained						
Father's name						
Highest level of education obtained						
		Bottom section to be filled out for Cochlear Implant group only				
Age at implant activation		Right ear				Left Ear
Hearing age		Right ear				Left Ear
Etiology of deafness						
Brand of CI						
Program for music?		Y / N				
Hearing Threshold						
Audiologist contact information						
Any language development disorders?		Y / N	Any audition disorders?	Y / N	Any general development disorders?	Y / N

APPENDIX F: List of Familiar Children's Songs

List of Familiar Children's Songs

	Degree of Familiarity		
	Very	Some	None
1. Twinkle Twinkle/ABC Song/Baa Baa Black Sheep	1	2	3
2. Wheels On the Bus	1	2	3
3. Mary Had a Little Lamb	1	2	3
4. London Bridge / Head and Shoulders	1	2	3
5. Old MacDonald Had a Farm	1	2	3
6. Happy Birthday	1	2	3
7. If You're Happy and You Know It	1	2	3
8. Itsy Bitsy Spider	1	2	3

APPENDIX G: Lesson Plan - Table of Specifications

Lesson Plan - Table of Specifications

Weighting of class time. Used to identify the learning outcomes in order to establish the assessment outcomes.

Learning Objectives	**Time Allotment**	**Percentage of lesson time**
Repertoire • Pitch Accuracy • Rhythm accuracy • Finger number accuracy • Dynamics • Articulation • Singing of repertoire pieces	20 min	33.3%
Games • Melodic Contour exercise for CI users	5 min	16.6%
Games • Pitch discrimination exercise for CI users	5 min	16.6%
TOTAL	**30 min**	**100%**

APPENDIX H: Weekly Teacher's Report

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Laboratoire de recherche en Pédagogie du piano

Weekly Teacher's Report

Teacher's name/ Nom du/de la professeur(e): _____
Child's name* / Nom de l'enfant*: _____
Date: _____

FORM FOR **TEACHERS** / FORMULAIRE POUR **PROFESSEURS**

Please circle the appropriate number on a scale of 1-5 (1 "not true at all" and 5 being "very true": SVP encercler la réponse appropriée sur une échelle de 1 à 5 (1 "complètement faux" et 5 étant "complètement vrai":

The lesson this week went well / La leçon cette semaine a bien été:

1 2 3 4 5

My student seemed excited to come/be at the lesson today /
Mon étudiant(e) semblait avoir hâte de venir/d'être à la leçon aujourd'hui :

1 2 3 4 5

I believe my student practiced well this week according to his accomplishments at the lesson /
Je crois bien que mon étudiant(e) a bien pratiqué cette semaine d'après la performance observée au cours :

1 2 3 4 5

In general, this student seems to like learning piano /
En général, mon étudiant(e) semble aimer apprendre à jouer du piano:

1 2 3 4 5

In general, this student seems to learn quickly /
En général, mon étudiant(e) semble apprendre rapidement:

1 2 3 4 5

Please circle the appropriate answer: / SVP encercler la réponse appropriée:
The rate of progress of my student seems to be / Le progrès de mon étudiant(e) semble être:
Slower than most students / Plus lent que la moyenne
Average / La moyenne
Faster than most students / Plus rapide que la moyenne

APPENDIX I: Weekly Parent's Report

Weekly Parent's Report

Teacher's name/Nom du/de la professeur(e): _____
Child's name*/Nom de l'enfant*: _____
Date: _____

FORM FOR **PARENTS** / FORMULAIRE POUR **PARENTS**

Please circle the appropriate number on a scale of 1-5 (1 "not true at all") and 5 being "very true":
SVP encercler la réponse appropriée sur une échelle de 1 à 5 (1 "complètement faux") et 5 étant "complètement vrai":
Practices this week went well/Les pratiques cette semaine ont bien été:

1 2 3 4 5

My child seemed excited to come to the lesson today/
Mon enfant semblait avoir hâte de venir à la leçon aujourd'hui:

1 2 3 4 5

At practice time, my child sat the piano willingly/
Au moment de la pratique, mon enfant s'est assis au piano sans résistance apparente:

1 2 3 4 5

This week my child went and sat at the piano outside of practice time, on his or her own /
Cette semaine mon enfant s'est assis(e) au piano par lui/elle-même à un moment autre que celui de sa pratique régulière:
1 2 3 4 5

Please answer accordingly/SVP répondre à la question en fonction du contexte:

- At present, what is the quality of your child's piano practices/Au moment présent, quelle est la qualité des pratiques de piano de votre enfant:
    A) Of poor quality/De mauvaise qualité
    B) Of medium quality/De qualité moyenne
    C) Of good quality/De bonne qualité

D) Of Excellent quality/D’éxcellent qualité

APPENDIX J: Weekly Practice Chart

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Laboratoire de recherche en Pédagogie du piano

Weekly Practice Chart

Teacher's name / Nom du/de la professeur(e): _____

Student's name / Nom de l'étudiant(e): _____

Date: _____

Weekly Practice Chart / Feuille de pratique hebdomadaire

Assignments / Devoirs	**/ Mon. / Lun.**	**/ Tues. / Mar.**	**/ Wed. / Mer.**	**/Thurs./ Jeu.**	**/ Fri. / Ven.**	**/ Sat. / Sam.**	**/ Sun. /. Dim. /.**
Repertoire (Practicing time 20 mins/day)							
Length of practice session (Length in minutes)							
Singing Exercise for CI users							
Listening to the CD (Length in minutes)							
Repertoire Listening (15 mins/day)							
Melodic Contour (5 mins/day)							
Pitch Discrimination (5 mins/day)							
Student: How would you rate the quality your practice today ☺ 😐 ☹							
Parent: How would you rate the quality the practice of your child today ☺ 😐 ☹							

APPENDIX K: Exiting – Thank You Email

Exiting – Thank You Email

Dear _____(participant's name),

Thank you for coming today and thank you for playing for me the pieces you were practicing. You did a wonderful job and I enjoyed listening to your music. Thank you for participating in this study and for practicing all these months. I hope you enjoyed your time, as I know your teacher _____(teacher's name) did as well. I hope you continue learning piano and I hope this experience was pleasant and enjoyable.

Best regards,
Sandra Marković

(To the parent)

Dear _____(parent's name),

Thank you for your time and your dedication to practice. I hope you enjoyed your time and I hope this was as great of experience for the whole family as it was for us teaching you piano and seeing your musical growth. Please, know, that your participation means a great deal to us and that you have contributed to science and research. We are very grateful for you allowing us this opportunity with your involvement.

If you wish to know the results of the study, I will be more than happy to share them with you upon data collection and analysis.

Thank you for all your time.
Sincerely,

APPENDIX L: MCI Data Collection

MCI Data Collection

Melodic Contour Identification (MCI) test (pre-test and post-test) data collection sheet

Participant:_____ NH CI (circle one)

	Contour	correct	incorrect
Trial 1	1		
	2		
	3		
	4		
	5		
Trial 2	1		
	2		
	3		
	4		
	5		
	total		

APPENDIX M: Data Collection Chart—Weekly Practicing Charts

Data Collection Chart—Weekly Practicing Charts

	Practice Data								Parent Evaluation					Teacher Evaluation					
	# of days of practice	Avg duration of practice	# of times duration	Avg listening task duration	Avg MCI Task duration	Avg 'Pitch' task duration	Student rating (1-3)	Parent rating (1-3)	Went well? (1-3)	Excited? (1-3)	Willing? (1-3)	On their own? (1-3)	Quality? (1-3)	Went well? (1-3)	Excited? (1-3)	Practice Well? (1-3)	Likes learning? (1-3)	Learns quickly? (1-3)	Progress (1-3)
week 1																			
week 2																			
week 3																			
week 4																			
week 5																			
week 6																			
week 7																			
week 8																			
week 9																			
week 10																			
week 11																			
week 12																			
week 13																			
week 14																			
week 15																			
week 16																			
week 17																			
week 18																			
week 19																			
week 20																			
week 21																			
week 22																			
week 23																			
week 24																			
TOTAL																			
number of weeks																			
AVG																			

Minor Assent Form (Experimental Group)

Title of the research project:

Piano Performance, Identification of Melodic Contour and Pitch, and Familiar Song Recognition of Prelingually Deaf Children with Cochlear Implants after Three Months of Formal Music Instruction.

Investigator: Sandra Marković
Address: School of Music
50 University Private
Telephone: (613) 562-5800, ext. 2704

The investigator will read the text below the child prior to the assessment session. This procedure will be attended by the parent / guardian of the child, who will sign as a witness.

Thank you for helping me today; I would like to invite you to be part of a research study. Research is a way to test new ideas to see if we can do things better.

In our study we want to understand the difference piano training makes between deaf children who have cochlear implants, children who have hearing aids, and children with normal hearing. We think there may be difference between children with Children CI users and hearing aids that get music training and those who do not. We would like to see if children who receive piano training can better recognize songs and different instruments and learn how to play piano.

We will do two little tests today:
First, I will ask if you recognize a favorite song that will be played on my computer. You can point to the name or a picture of the song.
Second, you will hear twenty samples of two short songs (at the time) where I would like you to tell me if the music is the same of different.

After you finish here, I will see you again every week for three months because I will be teaching you piano! I'm going to teach you five songs, and at the end of three months, we

are going to record you playing the songs that you learned.

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Are there bad things that can happen from this study?

We do not think that anything bad would happen if you decide to join this study.

Is this private?

We will keep your information private whether you decide to join this study or not.

Can I say no?

You can choose to be a part of this study or not. You can also decide to stop being in this study at any time once you start. Talk to your parents if you want to stop being in the study, and they will tell the researchers. No one will be mad at you if you choose not to take part in this study.

What if I have questions?

Please ask us and we will do anything we can to answer your questions.

I understand that even if the child is too young to understand the importance of this study, he / she will not be forced to complete the activities. The child has the right to decide whether he / she will not participate in this study. If he / she agrees to participate in this study, they can change their mind and withdraw at any time. We will stop the assessment if the child's behaviour demonstrates a refusal to participate. I obtained the consent of the child for this assessment in reciting the text above.

Researcher Name (print)
Researcher Signature
Date
Child's Name (print)

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Laboratoire de recherche en Pédagogie du piano

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Participant **Name:** _____ **Date:** _____

Conditions		**Songs**	
Original	A	Old MacDonald	1
Accompaniment	B	Happy Birthday	2
Voice	C	Wheels on the Bus	3
Flute	D	London Bridge	4
Octave higher Flute	E	Twinkle, Twinkle	5
		If You're Happy…	6
		Mary Had a Little Lamb	7
		Itsy Bitsie Spider	8

Trial	Condition	Song	C or I	Answer if I
1	E	2	C	
2	A	6		
3	C	2		
4	A	4		
5	B	7		
6	E	1		
7	E	7		
8	D	5		
9	A	1		
10	D	7		
11	D	6		
12	C	1		
13	B	8		
14	A	7		
15	C	5		
16	D	2		
17	D	3		
18	D	4		
19	E	5		
20	B	6		

Trial	Condition	Song	C or I	Answer if I
21	B	2		
22	A	8		
23	C	6		
24	B	4		
25	B	1		
26	B	5		
27	C	7		
28	A	3		
29	A	2		
30	E	8		
31	E	4		
32	D	8		
33	C	8		
34	A	5		
35	D	1		
36	B	3		
37	E	7		
38	E	6		
39	C	4		
40	C	3		

Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Laboratoire de recherche en Pédagogie du piano

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Identification form

Montreal Battery of Evaluation of Amusia

-Children version -

DATE OF EVALUATION: ____ / ____ / ____

FIRST NAME: _____

LAST NAME: _____

DATE OF BIRTH: _____

SCHOOL YEAR: _____

NATIVE LANGUAGE: _____

HANDEDNESS: RIGHT: ☐ LEFT: ☐

HAD MUSICAL LESSONS OUTSIDE THE REGULAR CURRICULUM?

NO ☐ YES ☐

IF YES, FOR HOW MANY YEARS: _____

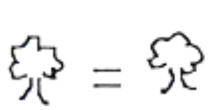
Université d'Ottawa | University of Ottawa

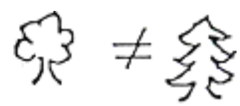
School of Music, Faculty of Arts, University of Ottawa

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Laboratoire de recherche en Pédagogie du piano

Melody test





	Same	Different
Example 1:	__________	_____x_____
Example 2:	_____x_____	__________

– –

		Same	**Different**
1-	(scale)	__________	_____x_____
2-		_____x_____	__________
3-	(contour)	__________	_____x_____
4-	(interval)	__________	_____x_____
5-	(contour)	__________	_____x_____
6-		_____x_____	__________
7-	(contour)	__________	_____x_____

8- _____x_____ _____

9- _____x_____ _____

10- _____x_____ _____

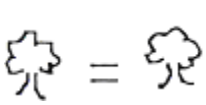
		Same	**Different**
11-	(interval)	_____	_____x_____
12-		_____x_____	_____
13-	(scale)	_____	_____x_____
14-		_____x_____	_____
15-	(scale)	_____	_____x_____
16-		_____x_____	_____
17-	(contour)	_____	_____x_____
18-		_____x_____	_____
19-		_____x_____	_____
20-	(interval)	_____	_____x_____

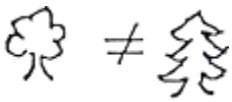
Université d'Ottawa | University of Ottawa

School of Music, Faculty of Arts, University of Ottawa

Research Project – Piano performance, identification of melodic contour and pitch, and familiar song recognition of prelingually deaf children with cochlear implants after three months of formal music instruction.

Rhythm test





	Same	Different
Example 1:	_____	____x____
Example 2:	___x_____	_____

_ _

	Same	**Different**
1-	_____	____x____
2-	____x____	_____
3-	____x____	_____
4-	_____	____x____
5-	_____	____x____
6-	____x____	_____

7- _____ ____x____

8- _____ ____x____

9- ____x____ _____

10- _____ ____x____

	Same	**Different**
11-	____x____	_____
12-	_____	____x____
13-	____x____	_____
14-	____x____	_____
15-	_____	____x____
16-	____x____	_____
17-	____x____	_____
18-	_____	____x____
19-	____x____	_____
20-	_____	____x____