6-2017

Music Perception Performance in Prelingually Deafened Children with Cochlear Implants Pre and Post Structured Music Training Postoperative Habilitation Programs: A Systematic Review

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by

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A capstone research project submitted to the Graduate Faculty in Audiology in partial fulfillment of the requirements for the degree of Doctor of Audiology, The City University of New York

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This manuscript has been read and accepted
for the Graduate Faculty in Audiology
in satisfaction of the dissertation requirement
for the degree of Doctor of Audiology (Au. D.).

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ABSTRACT

MUSIC PERCEPTION PERFORMANCE IN PRELINGUALLY DEAFENED CHILDREN WITH COCHLEAR IMPLANTS PRE AND POST STRUCTURED MUSIC TRAINING POSTOPERATIVE HABILIATION PROGRAMS: A SYSTEMATIC REVIEW

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The goal of this project was to systematically review literature in order to analyze music perception performance in prelingually deafened children with cochlear implants before and after structured music training postoperative habilitation programs. Features of music which were evaluated included pitch, melody, timbre, rhythm, and appraisal. In six studies, these measures of music perception were compared pre and post formal music training; in one study, music perception performance was compared between prelingually deafened cochlear implant users and individuals with normal-hearing sensitivity. Overall, when the music training was sufficiently long, the findings indicated that music training significantly improves pitch perception ability. The duration of musical training is positively correlated with the correct rate of pitch perception. With regards to perception of melody and rhythm, and to music appraisal, the findings were similiar for prelingually deafened children with cochlear implants enrolled in a music group and for children with normal-hearing sensitivity who did not receive music training. Analyses of

timbre perception showed that children with cochlear implants generally made fewer errors with percussive instruments as opposed to nonpercussive instruments. Significant mismatch negativity potentials (MMNs) were found in adolescent users of cochlear implants for deviations in timbre and rhythm, but not for pitch. This pitch discrimination deficit in auditory evoked potentials supports the findings on behavioral measures. Overall, MNN amplitudes are significantly smaller in users of cochlear implants than in individuals with normal-hearing sensitivity, which suggests poor overall music discrimination ability. Even when music training was not directly linked to increased scores on music perception tests of pitch, melody, timbre, rhythm, and/or appraisal, the anecdotal evidence from children, teachers, and parents in all of these studies suggested various other benefits of music training, including increased interest in and enjoyment of music and improved relationships among the children and their parents and teachers.

ACKNOWLEDGMENTS

It is with immense gratitude that I acknowledge the support and help of my capstone advisor and audiology mentor, Dr. Silverman. The completion of this paper would not have been possible without her endless guidance and insight. Her brilliance appears effortless and inspires me to be a better researcher, diagnostician, and audiologist. I consider it an honor to work with her.

To Erik, thank you for filling my life with music and love.

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INTRODUCTION

Although use of cochlear implants has successfully effected marked improvements in users' ability to understand speech and acquire language, such usage is associated with limited success in effecting improvement in users' ability to perceive and enjoy music (Mao et al., 2013). Postlingually deafened individuals already have an internal representation of musical sounds as the representation was acquired from exposure to music during the period of normal-hearing sensitivity in childhood and/or adulthood (Gfeller et al., 2000). Thus, their perception and appreciation of music is usually poor in comparison with their prior experiences when hearing normally (Gfeller et al., 2000). In contrast, prelingually deafened individuals who lack that internal representation, as they did not have normal-hearing sensitivity in childhood, oftentimes learn to appreciate music more easily as they are unaware of an alternate sound representation (Gfeller, 2000). Additionally, music training has been proven to alter sound perception in both individuals with hearing loss and with normal hearing (Besson, Schon, Moreno, Santos, & Magne, 2007). Those with musical training can detect slight change in various aspects of music more accurately and faster than non-musicians (Besson et al., 2007). Consequently, many investigators have researched music perception in users of cochlear implants, particularly in children who are prelingually deafened.

Musical training/therapy programs for children with cochlear implants who are prelingually deafened have gained popularity as a habilitation tool. Whether formally or informally implemented, these programs seek to enhance basic perceptual attributes of music including pitch, melody, timbre, rhythm, and music appraisal. Pitch represents the fundamental frequency, or rather the lowest frequency energy peak in a spectrum (Olsen, Dean, & Leung, 2016). Sound pitch can be represented in music on a wide range scale of low to high. Moreover, the sequencing or patterning of pitches forms the musical correlate of melody (Looi, McDermott, McKay, & Hickson, 2009). Timbre is the attribute of auditory sensation in which a listener can judge that two sounds similarly presented, for instance, in terms of loudness and pitch, are actually different (Looi et al., 2009). The sequencing of durations or temporal patterns form the foundation of rhythm (Looi et al., 2009). Music appraisal represents the perceived enjoyment of the aesthetic of a musical piece (Gfeller et al., 2000). Although each of these characteristics of music are separate entities or attributes of music, the collaboration of them all results in music perception (Looi et al., 2009). Poor music perception and appreciation is typically marked by lack of musical training, specifically those with an already distorted auditory system (Huang et al., 2013). This misrepresentation has the potential to be improved with the implementation of music training among prelingually deafened children using cochlear implants.

The findings on efficacy of music training reveal much greater variability in all dimensions of music perception in users of cochlear implants than in individuals with normal-hearing sensitivity (Stordahl, 2002). Additionally, music appreciation is low in users of cochlear implants as compared with that in listeners with normal-hearing sensitivity (Stordahl, 2002). The results of cochlear-implant research also reveal that performance on rhythm tasks in users of cochlear implants is similar to that in individuals with normal-hearing sensitivity; on the other hand, performance on pitch, melody timbre, and appraisal tasks is poorer in the former than in the latter group (Stordahl, 2002).

One factor underlying poor pitch perception in users of cochlear implants is the inability of implants to stimulate at frequencies associated with the fundamental frequency (50-300 Hz) because of the limitations in the surgical placement of the electrode array (Yucel, Sennaroglu, & Belhin, 2009). Moreover, sound processing in cochlear implants does not retain the fine structure cues associated with good pitch perception and poor neural survival limits the rate discrimination in some users of cochlear implants (Yucel et al., 2009).

Exposure to music during childhood, at a young age, is beneficial, particularly to those with cochlear implants, for a variety of reasons, particularly brain plasticity. For example, evidence from Pantev et al. (1998) shows that cortical representation, as measured by functional magnetic source imaging, is significantly enhanced in young adults who are musicians as compared with those who are non-musicians, as the dipole moment for piano tones compared with that for pure tones was 21-28% greater in the former than in the latter group. Importantly, the strength of cortical activation was increased in the musicians who learned to play a musical instrument before 9 years of age as compared with those who learned to play a musical instrument after 9 years of age. Exposing young children to music, specifically those with hearing loss who have cochlear implants, has the potential to lead to optimal processing of pitch, and several other aspects discussed above of music perception (Yucel et al.).

Given the increasing popularity of music therapy programs in children with cochlear implants, and their poor performance in music perception, it is important to evaluate the results of these programs to determine whether they have a role in the (re)habilitation of children with cochlear implants. Therefore, the purpose of this systematic review is to examine the efficacy of music therapy on pitch, melody, rhythm, and timbre perception in prelingually deafened children with cochlear implants.

METHODS

In order to search for relevant articles on this specific topic, a comprehensive review of the literature was performed utilizing databases through The CUNY Graduate Center's library. Databases browsed included PubMed, Medline Complete, and Web of Science. The search was limited to peer-reviewed journal articles. Keywords were searched in the article's title, abstract and full text, including "music perception", "pitch", "rhythm", "timbre", "melody", "appraisal" "cochlear implants", "music training", and "music therapy". Articles which were chosen for review evaluated music perception and/or appraisal in prelingually deafened children with cochlear implants. Postlingually deafened children were excluded. All the participants were under the age of 18, with the exception of one child in one article. Most of the articles which were chosen for the systematic review included an analyses of various aspects of music perception pre- and post- music training, except for one which compared music perception performance of prelingually deafened children to that in their peers with normal-hearing sensitivity. Application of this search process led to the browsing of more than 20 articles. Ultimately, 7 articles that contained analyses of various elements of music, such as pitch, rhythm, timbre, melody, and appraisal were selected for this systematic review. The focus here is on cochlear implants and music perception, although findings are presented also on hearing aids and speech perception.

RESULTS

Study Characteristics

The study characteristics are summarized in Table I. Of the 7 studies chosen for this systematic review, the sample sizes of the studies ranged from 14-47 individuals, with a mean of 24.4 individuals and a median of 21 individuals. The age range of the individuals in each study ranged from 1.6 years to 18.8 years at the onset of musical training. All subjects, except for one, were less than 18 years of age. The mean age of all participants for the six of seven studies that presented age was roughly 9.4 years old. In 6 of the 7 studies, the gender of the participants was specified. In those 6 studies, the gender ratio favored males over females. Although the age of identification was unspecified in the 7 studies, all participants with hearing loss were prelingually deafened. The age at implantation ranged from 13 months to 14.6 years. Of the 4 studies that specified cochlear-implant manufacturer, one involved all three manufacturers (Cochlear, Advanced Bionics, and Med-El), one involved only Med-El, and two involved only Cochlear. Of the 5 studies in which type of amplification (unilateral, bilateral or bi-modal implantation or hearing aid) was specified, the implantation type in the experimental group was monaural in 3 of the studies (Yucel et al., 2009, Chen et al., 2010, Kosaner et al., 2012). In one study, 4 participants in the experimental group had unilateral cochlear implants, whereas 2 were bimodally implanted (Innes-Brown et al., 2013). In another study, 9 children in the experimental group had bilateral cochlear implants, whereas 2 were bi-modal (Petersen et al., 2015).

Music Perception and Appraisal Tasks

The music perception and appraisal tasks are summarized in Table II.

Pitch Tasks

Pitch perception was examined in 6 of the 7 studies. The investigators in the Petersen et al. (2015) study evaluated pitch direction based on two or three notes from live demonstrations of various musical instruments.

Four of six of these studies (Abdi et al., 2001, Yucel et al., 2009, Kosaner et al., 2012, Innes-Brown et al., 2013) examined pitch discrimination, or rather whether various tones played were the same or different in pitch. In Abdi et al.'s (2001) study, participants were required to specify the change in frequency of played tone once it was presented differently. A tutor would play the same note two to six times with equal duration and medium tempo. Then, the note would change to a different note and the participant, without looking at the tutor or instrument, was instructed to report when the note that had been playing was different. Additionally, the child was asked to discriminate a wrong note in a familiar sequence in order to further evaluate pitch perception.

The first six levels of the music training program in Yucel et al.'s study (2009) were based on pitch discrimination in which participants were expected to discriminate whether 63 pair of notes were the same or different. At the beginning levels, notes that were chosen were farther away from one another, whereas notes that were more similar to one another were presented in the advanced levels. In the second task, 9 levels were formed by same of different 77 two-note sequences. Again, notes that were chosen in the beginning levels were highly contrasted in pitch, whereas notes that were less contrasting were used in the advanced levels.

Based on The Musical EARS Evaluation form in Kosaner et al.'s study (2012), pitch discrimination was evaluated based on scoring tasks 4, 5, 7, 8, and 9 of the "Recognizing songs, tunes, and timbre" scale. A score of 0 indicated that the child never showed this behavior, a score of 1 revealed that the child sometimes showed this behavior, and a score of 2 meant that the child usually showed this behavior. Tasks included discriminating between two, three, and/or six musical instruments when the same tune was played on each instrument and discriminating between two and/or three different tunes played on the same instrument without lyrics.

Innes-Brown et al. (2013) evaluated pitch via The Intermediate Measures of Music Audiation (IMMA) Tonal Test. Forty items were presented in pairs and the task was to indicate whether the two sequences in the pair were the same—by circling a smiling face—or different—by circling a frowning face.

Chen et al. (2010) measured both pitch direction and discrimination. The task was divided into two parts. The child first was asked whether two notes played on a piano were the same. If the child responded that the two notes were different, then the child also would be asked whether the second note was higher or lower than the first tone. Each part was scored as correct or incorrect.

Melody Tasks

Melody recognition was examined in four of the seven studies, based on singing performance and accuracy of recognition of melodies, songs, and tunes. Abdi et al. (2001) monitored progress of melody development using lessons (short melodies taught from a teaching book). The number of melodies played ‘correctly’ or ‘acceptably’ by the child, as judged by the tutor, indicated overall progress. The melodies were arranged from easy to difficult so the number of melodies played divided by the duration of the music training, or number of sessions, equated the progress rate. Moreover, skill was assessed by the number of mistakes a child made while playing certain familiar melodies that he/she could play best. The number of mistakes made were counted with regard to the length of the piece played.

Stordahl (2002) assessed melody perception through a song recognition subtest of The Iowa Music Perception and Appraisal Battery-Children's Version (IMPAB-C). The participant listened to a well-known song and then was asked to select which song was heard, among a list of distractors or incorrect songs. The song choices included a pictorial representation of each song and the title of the song. Some distractors were similar in rhythm and melody whereas others were dissimilar in these dimensions. Kosaner et al. (2012) assessed melody perception through The Musical EARs Evaluation Form through a "Singing" and Recognizing Tunes (melodies) subscale. The singing subscale scored children on aspects such as "Child imitates some melodic phrases in a song" and "Child sings the words of a song accurately and is fairly tuneful". Petersen et al. (2015) included singing training as part of the music training program. The purpose of the singing training was to establish a sense of basic musical attributes, such as melodic direction. The singing training consisted of exercises involving breath control/belly support and imitation of short phrases with focus on long/short, strong/weak, and open/closed vowel sounds in various vocal registers.

Timbre Tasks

Timbre perception was examined in three of the seven of studies. One study (Innes Brown et al., 2013) used an instrument timbre-recognition task, whereas another (Kosaner et al., 2012) used a subscale on an evaluation form. The instrument timbre recognition task measured how well one could recognize twelve different instruments from their sound (Innes Brown et al., 2013. After one five-second segment was played, the child was instructed to circle which instrument was played from a closed set of twelve line drawings of the instruments. Several aspects of sound quality were evaluated using the "Recognizing Timbre subscale" on the

Musical EARS Evaluation Form (Kosaner et al.). Timbre was studied in the Innes-Brown et al. study by ear training.

Rhythm Tasks

Rhythm perception was examined in five of the seven studies. Rhythmic features analyzed including identification of the number of notes played in a series, repeating a simple rhythmical pattern on one tone played by the tutor, and determining whether two, successive rhythmic patterns are the same or different (Abdi et al., 2001). The latter feature also was examined in another study; in that study, the test began with two beats in the beginning levels and then advanced to four beats (Yucel et al., 2009).

The “Responding to Music and Rhythm” subscale of The Musical EARS Evaluation form involved several rhythmic tasks. These tasks included imitating a musical partner by playing a simple rhythm repeatedly using body parts, imitating two simple rhythms played on a percussion instrument, and keeping the basic beat of a tune (Kosaner et al., 2012). The Intermediate Measures of Music Audiation (IMMA) Rhythmic Test assessed rhythm in the study by Innes-Brown et al., 2013. In Petersen et al.’s study (2015), rhythm training sessions established a fundamental sense of meter, period, and subdivision via coordination of foot stomping, clapping, and rapping

Appraisal Tasks

Musical appraisal or preference was examined in 3 of the 7 studies in this systematic review. In one study, an arbitrary score of 1-10 was given by the tutor regarding different aspects of music perception, which was dependent on the tutor’s subjective assessment of the child's progress and enthusiasm (Abdi et al., 2001). After hearing each song, the child was instructed to point to or say the number that reflecting the degree to which he/she liked each song (Abdi et al., 2001). The pictographic scale consisted of cartoon faces with a continuum of positive to negative emotions which correlated with the numbers 1 -5, 1 being a large smile, 3 being a neutral face, and 5 being a large frown. Stordahl (2002) examined music appraisal and preference using a Song Appraisal Test (subtest of IMPAB-C). In that study, both classical and nonclassical styles of music were selected, totaling 45 items. Yucel et al. (2009) looked at the emotional changes evoked by hearing music through a subset of questions in a musical stages profile questionnaire. Example questions regarding music appraisal/preference were as follows: Does your child ever spontaneously ask you to sing or play music? Does your child like to listen to music or your singing when he/she is going to sleep? Does your child ever ask to listen to a particular compact disk or tape? Can your child say when a favorite song is being played? Does music change our child's mood? Does singing have a comforting effect on your child? Does your child react to lively music?

Table I

Study Characteristics.

Author(s)	**Year**	**Sample size**	**Age range**	**Mean age**	**Gender (female;male)**	**Age HL identified**	**Age at implantation**	**Number of years prior to CI[1]**	**Years of CI experience**	**CI manufacturer**	**Monaural vs. binaural vs. bi-modal CI**
Abdi et al.	2001	14 prelingually deafened children who used CI[1]s	2.5-12.5 years		4;10	N/A	2.5-12.5 years		2-20 months	N/A	N/A
		Se-tar group: 4	6.5-12.5 y ears		2; 2	N/A	6.5-12.5 years		8-10 months		
		Orff method group: 10	2.5-8 years		2; 8	N/A	2.5-8 years		2-20 months		
Stordahl	2002	47			22; 25	N/A	N/A	N/A	N/A	N/A	N/A
		CI: 15	CI: 8-14 years	CI: 11.1	CI: 7;8						
		NH[2]: 32	NH: 8-15 years	NH: 11.1	NH: 15;17						
Yucel et al.	2009	18 profoundly hearing impaired children	N/A	N/A	N/A	N/A				N/A	All monaural HiRes stim mode on their right ears
		Experimental group: 9 with CIs					Music group: M(SD), range= 55.2 months(17.6), 39-36	Music group: bilaterally aided with HAs prior M(SD), range= 28.67 months(13.3), 8-49	Music group: 0. Training began from outset		
		Control group: 9 with CIs					Control group: M(SD), range= 49.33 months(20.9), 12-36	Control group: age at HA fitting M(SD), range= 23.11(8.9), 22-96	0		

Chen et al.	2010	27	5-14 years	6.7 years	9;18	Congenital	17-163 months	10-69 months (mean: 29 months)	10-69 months (mean: 29 months)	13 Nucleus24 (Cochlear Americas) 13 Clarion (Advanced Bionics) 1 Med-El	Monaural
Kosaner et al.	2012	25 unilateral CI users	19-91 months		11; 14	N/A	13 to 62 months	N/A	0 to 59 months	Med-EL	Monaural
		Group A: 12 children	Group A: 19-37 months	Group A: 26 months	Group A= 3;9				Group A: M(range)= 2 months (0-6 months)		
		Group B: 7 children	Group B: 34-60 months	Group B: 43 months	Group B= 5;2				Group B: 8(1-15)		
		Group C: 6 children	Group C: 49-91 months	Group C: 72 months	Group C= 3;3				Group C: 35(12-59)		
Innes-Brown et al.	2013	20	9-13 yo			N/A		N/A	N/A	Cochlear Americas	4 unilateral CI, 2 CI and HA together, 5-bilateral HAs
		HI[3]: 11									
		6 with unilateral CI or CI and HA[4] together		CI group: 11.2 years	CI group: 2;4		CI group: 10-16 months				
		5 with bilateral HAs		HA group: 10.4 yrs	HA group: 2;3		HA group: first fitted with HAs from ages 12-18 months				

		NH: 9 (control group)		NH group: 10.3 years	NH group: 5:3						
Petersen et al.	2015	21				N/A					
		Experimental: 11 with CIs	15.6-18.8 years (10/11 < 18 years)	17.0 yo	6;5		Mean (range)= 7.5 years (2.2-14.9 years)	N/A	Mean (range)= 9.5 years (1.8-15.2 years)	Cochlear Americas	9 -bilateral CI, 2 unilateral CI with contralateral HA (bi-modal)
		Control: 10 with NH	15.3-17 years	16.3 years	2;8						

[1] Cochlear implant

[2] Normal hearing

[3] Hearing impaired

[4] Hearing aid

Table II

Music Perception Tasks.

Author(s)	**Year**	**Pitch task (discrimination: same/diff vs. direction: up/down)**	**Melody recognition task**	**Timbre task**	**Rhythm task**	**Appraisal/preference task**
Abdi et al.	2001	-Same/different -Discrimination of a wrong note in a familiar melody	-Number of melodies played correctly by child -Number of mistakes made playing certain familiar melodies	N/A	-Telling the number of notes played in the row -Repeating a rhythmic pattern on one tone played by the tutor -Telling if the two successive rhythmic patterns are different	Score of 1-10 given by tutor dependent on tutors assessment of child's progress and enthusiasm
Stordahl	2002	N/A	Song Recognition Test (subtest of IMPAB-C[1])	N/A	N/A	Song Appraisal Test (subtest of IMPAB-C)
Yucel et al.	2009	Same/different	The musical stages profile (Melody and dynamic changes Questions 5-14)	N/A	Same/different	The musical stages profile (emotional aspects Questions 20-26)
Chen et al.	2010	Same/different. If 2 notes different, pitch direction (up/down)	N/A	N/A	N/A	N/A
Kosaner et al.	2012	"Recognizing songs, tunes, and timbre" subscale -questions 4 5 7 8 9	"Singing" subscale "Recognizing songs, tunes (melodies)" subscale	"Recognizing timbre" subscale	"Responding to music and rhythm" subscale	N/A
Innes-Brown et al.	2013	IMMA[2] Tonal Test: same/diff	N/A	Instrument timbre-recognition task	IMMA rhythmic test	N/A
Petersen et al.	2015	Pitch direction (up/down) of two notes or three notes	-Singing training	Timbre ear training	Establish fundamental sense of meter, period, and subdivision via coordination of foot stomping, clapping, and "rapping"	N/A

[1] The Iowa Music Perception and Appraisal Battery—Children's Version
[2] The Intermediate Measures of Music Audiation

Music Training Characteristics

The characteristics of music training are summarized in Table III. In one of the seven studies (Stordahl, 2002), music perception was not compared pre- and post music training but instead, the music perception outcomes of children with cochlear implants were compared with those of children with normal-hearing sensitivity. Stordahl did not employ music therapy or training. In the other six studies, music training was administered and music perception was evaluated pre- and post training.

Group music training sessions were administered in 4 of the 6 studies involving music training; individual music training was administered in 1 of these 6 studies, and combined individual/group music training was administered in another 1 of these 6 studies. A habilitation program was implemented through structured music school/club classes in 4 of the 6 studies that included music training (Abdi et al., 2001, Chen et al., 2010, Innes-Brown et al., 2013, Petersen et al., 2015). In the Yucel et al. (2009) study, music training program was implemented via individual sessions through a family-centered home habilitation program. In the Kosaner et al. (2012) study, music training was implemented through a family centered habilitation program utilizing a combination approach whereby group session activities were repeated within individual sessions. Parents also were asked to repeat the activities gone over in group sessions at home and were encouraged to participate in both sessions.

The stimulus presentation of the music training varied for each of the six studies that incorporated music training programs. In 2 of the 6 studies, music training involved a live stimulus (Abdi et al., 2001, Chen et al., 2010). Abdi et al. (2001) used two different methods of training based on the child’s age: the Orff method and the Se-tar method. The former method is a standard method for teaching music to young children, which was developed by Carl Orff, a prominent German composer (Abdi et al., 2001). This method of teaching contains an element of play in music lessons, engaging the children's' minds and bodies while encouraging them to learn naturally at their own level of understanding and comfort (Abdi et al., 2001). The latter method used in Abdi et al.'s (2001) music training is targeted towards children older than 8 years of age. These older children are taught Se-Tar, which consists of plucking three strings on easy to play string instruments as compared with other stringed instruments (Abdi et al., 2001). Chen at al. (2010) conducted music training using a live YAMAHA Shizyoka tuned piano in an acoustically shielded room.

In another 2 of the 6 studies, music training involved recorded music rather than live music. In one of these studies, music training involved recordings from a YAMAHA electronic keyboard (Yucel et al., 2009), whereas in the other study, music training involved recorded CDs played from a laptop computer (Innes-Brown et al., 2013).

Petersen et al. (2012) gave live music-making sessions as well as recorded options through computer-based exercises for the music therapy. Kosaner et al. (2012) also gave both live and recorded options for music therapy through basic instruments such as guitar, violin, keyboard, xylophone, cymbals, triangles, hand drum, recorder, cabadas, chimes, metalophone, woodball, stirring drum, finger bells, jingle drums, wrist bells, maracas, and woodblocks.

The duration of the music training programs ranged from 2 weeks up to 2 years among the 6 music training studies. The frequency of music training sessions during these time periods was daily for 2 studies (Yucel et al., 2009, Petersen et al., 2015) and weekly for 3 studies (Abdi et al., 2001, Kosaner et al., 2012, Innes-Brown, 2013). In Abdi et al.'s study (2001), 3 children were trained once a week using the Se-Tar method for 12 months, whereas 1 child was trained once a week using the Se-Tar method for 14 months. Ten children were trained weekly using the

Orff method for 3-8 months (Abdi et al., 2001). Two children were trained for 3 months, 4 children were trained for 4 months, 1 child was trained for 6 months, and 3 children were trained for 8 months (Abdi et al., 2001). Of the 2 children trained for 3 months, 1 child attended 5 sessions in this time frame whereas the other attended 6 sessions during that time frame. The 4 children who were trained for 4 months attended 10-12 sessions during that time frame. The child who attended music training for 6 months attended 10 sessions during that time frame. The children who attended music training for 8 months attended 30 sessions during that time frame.

In another study (Yucel et al., 2009), the children were trained for a duration of two years, ten minutes daily. The mean values for musical training hours spent by each child from the music training group were obtained from parental diaries that noted the amount of musical training monthly and after two years. In Chen et al.'s (2010) study, children were trained from 2-35 months, with the mean music training duration being 13.2 months. The frequency of the music training sessions was unspecified (Chen et al., 2010). Kosaner et al. (2012) administered musical training over 3-18 months; groups A and B incurred 18 months of music training whereas group C incurred 3 months of training. Groups A and B's music training program consisted of 1 weekly group session with parents, which lasted 45 min, and one individual session, which lasted 20-30 min. Group C's music training program included one weekly group session and one individual session, with parents occasionally present. Innes-Brown et al.'s (2013) music training program was carried out for one school year and sessions were weekly for 45 minutes (Innes-Brown et al., 2013) The music training duration for Petersen et al. (2015)'s study was only 2 weeks long and it totaled 20 hours.

Statistical Analyses

The statistical analyses employed in the studies are presented in Table IV. Statistical analysis of the music training data was performed in five of the six studies (Stordahl, 2002, Yucel et al., 2009, Chen et al., 2010, Kosaner et al., 2012, Innes-Brown et al., 2013, Petersen et al., 2015). In one of these five studies (Stordahl), music perception pre and post music training was not compared, but rather the outcomes of users of cochlear implants were compared with the performance of children with normal-hearing sensitivity on a 2-sample parametric *t*-test. Yucel et al. employed statistical analysis using the non-parametric Mann-Whitney *U*-Test. In the Chen et al. study, pitch perception performance was organized into six groups based on correct rate for statistical analysis. The groups were classified as overall, prime degree, ascending interval, ascending interval larger than perfect-fourth degree, descending interval, and descending interval larger than perfect-fourth degree. Analysis of variance (ANOVA) was employed to evaluate pitch perception in terms of pitch-interval size.

In the Kosaner et al study, the statistical findings clearly confirmed an increase in mean total score on the Evaluation Form for all three groups over time, reflecting improved performance on musical activities. For groups A and B, the results were evaluated using one-way repeated measures ANOVAs, with time as a factor and the Total score as the dependent variable. For each ANOVA, Mauchly's test of sphericity was applied. If sphericity could not be assumed, the Greenhouse-Geisser correction was used. The results revealed a significant improvement for Groups A and B over time ($p < 0.001$). Additionally, paired-sample *t*-tests were performed to examine the increase in mean total score for each group between each test interval; a significant improvement between test intervals 1 and 2 was found for group C ($p = 0.027$). The results of statistical analyses also showed increases in score between test intervals. Every child improved on all measures to some extent as evidenced by inspection of the minimum individual scores before and after music training.

One-way ANOVAs were also conducted by Innes-Brown et al. (2013) on the scores from the rhythmic, tonal and timbre tests. This analysis was used to test for statistically significant difference between groups on each task. Another statistical analysis technique that was used, rather than the traditional repeated-measures ANOVA, was a linear mixed model (LMM) for repeated measures (Innes-Brown et al.) with time as the repeated-measure factor.

Lastly, Petersen et al. (2015) performed two-tailed, one-sample *t*-tests on each of the deviant difference waves in order to test for significant MMN amplitudes. Mixed-effects ANOVA also was used to analyze the behavioral data from the musical multi-feature discrimination test. The between-subjects factor was group (normal-hearing sensitivity and the within-subjects factor was time (times 1 and 2). Post hoc tests (Bonferroni correction) also were performed using Bonferroni-corrected t-tests (Petersen et al.).

Music Perception and Appraisal Performance

Pitch Performance

Pitch performance was statistically analyzed in five of the seven studies (Yucel et al., 2009, Chen et al., 2010, Kosaner et al., 2012, Innes-Brown et al., 2013, Petersen et al., 2015). In the Yucel et al. study, the music group demonstrated the capability to determine pitch differences, of both one- and two-note sequences. The children showed significant progress of this task after 24 months of training (Yucel et al.). Chen et al. obtained the correlation between pitch perception and period of musical training; the duration of musical training positively correlated with the correct rate of overall perception (r^2= .389, p = .045) and ascending pitch-interval perception (r^2= .402, p = .038) for all children combined. Kosaner et al. analyzed pitch performance based on the mean values of the "Recognizing songs, tunes, and timbre" subscale at test interval 1 versus 7 for Groups A and B and test interval 1 versus 2 for group C. For group A, the mean value was 0% before music training in test interval 1 versus 50% after music training in test interval 7. Group B showed an improvement in mean value from ~5% in test interval 1 to ~74% in test interval 7. Group C showed progress in mean value from 45% in test interval to 95% at test interval 2 post music training.

Innes-Brown et al. (2013) analyzed pitch performance based on IMMA scores of the Tonal task, which were converted to percentile ranks using published norms. Between-group differences were assessed in session 1. The group with cochlear implants obtained a lower mean percentile rank than the group with normal-hearing sensitivity; this finding indicates that children using cochlear implants have more difficulty in differentiating between pitch patterns than those with normal-hearing sensitivity. In sessions 2-4, between-session differences for pitch assessed and the results showed that percentile rank scores for both groups, cochlear implant users and normal hearing children, improved with time.

Lastly, Petersen et al. (2015) analyzed pitch performance by comparing MMN amplitudes in users of cochlear implants and in the listeners with normal-hearing sensitivity. For the users of cochlear implants, the musical multi-feature paradigm elicited significant MMNs for deviants GuiD3, SaxD4, IntD5, and RhyD6 at both time sessions. For the two pitch deviants, the users of cochlear implants exhibited a significant MMN only for Pitch1D1 and at time 1. In contrast, significant MMNs were present for the listeners with normal-hearing sensitivity for all 6 deviants at both times of testing, except for the time 1 IntD5. The group with cochlear implants did not exhibit significant MMN responses to changes in pitch of two or four semitones; only one of the two pitch deviants elicited an MMN. A significant interaction between group and time was found (p = .014). This was shown by a significantly larger overall MMN negativity in the group with normal-hearing sensitivity at time 2 as compared with that for the group with cochlear implants (p = 0.002; mean amplitude was .94 mV for the normal group versus .47 mV for the implant group). Post-hoc testing revealed no significant difference in MMN amplitude between the groups at time 1. Thus, the group with cochlear implants produced pitch discrimination scores that were significantly lower than those produced by the group with normal-hearing sensitivity. This pitch discrimination deficit was supported by the findings on behavioral measures. For instance, users of cochlear implants achieved mean behavioral score that was 19.72% points lower than that in listeners with normal-hearing sensitivity, , as shown by the results of a mixed-effects analysis of the behavioral musical multi feature discrimination test.

Melody Performance

Melody performance was statistically analyzed in 3 of the 7 studies (Stordahl, 2002, Yucel et al., 2009; Kosaner et al., 2012). Users of cochlear implants performed significantly poorer in the Song Recognition Test (subtest of IMPAB-C) than the group with normal-hearing sensitivity (p < .0001). The means and standard deviations for the groups in the Stordahl study are provided in Table IV. Yucel et al. (2009) statistically evaluated melody performance using the non-parametric Mann-Whitney U-test based on the musical stages profile, specifically melody and dynamic changes on Questions 5-14. The median scores for the music and control groups at the end of music training at 24 months can be seen in Table IV. Table IV also notes when differences between the experimental and control groups were significant (p < .05). Kosaner et al. (2012) reported the mean scores for the "Singing" subscale before and after music training. The mean score for group A improved from ~14% at interval 1 pre- music training to 56% at test interval 7 post music training. The mean score for group B improved from ~19% at test interval 1 to ~75% at test interval 7. For group C, the mean score improved from 42% at test interval 1 to 76% after music therapy at test interval 2. The results of one-way repeated measures ANOVAs on the singing scores revealed significant improvement over time for groups A and B ($p < .001$). The results of a dependent t-test showed significant gain between sessions 1 and 2 for group C ($p < .05$).

Timbre Performance

Three of the seven studies statistically analyzed timbre performance (Kosaner et al., 2012, Innes-Brown et al., 2013, Petersen et al., 2015). Kosaner et al. reported that the mean percentage on the “Recognizing songs, tunes, and timbre” subscale at test interval 1 before music training versus test interval 7 after music training improved from 0% to 50% for group A and from ~5% to ~74% for group B. The mean percentage for group C improved from 45% at interval 1 to 95% at interval 2 post training.

Innes-Brown et al. (2013) converted the raw timbre scores from the IMMA to percentile ranks. Although all of the children in session 1, the mean scores were lower for the children with cochlear implants as compared with the mean scores for the other two groups (children with hearing aids and the children with normal-hearing sensitivity). Although significant differences were not obtained, a trend towards a statistically significant difference among groups was observed [$F(2,14) = 3.4$, $p = .06$, $h^2 = .33$]. Post hoc tests revealed significantly lower scores for users of cochlear implants than normal hearing children ($p = .02$). In sessions 2-4, the mean scores for the children with cochlear implants and for the children with normal-hearing sensitivity improved with time but such improvement was seen for the group with hearing aids. Statistically significant changes in scores with time, assessed using a linear mixed model for repeated measures, revealed a significant group effect in the timbre task was found as mean scores for the group with cochlear implants were significantly lower than those for the group with normal-hearing sensitivity [$F(2, 13.4) = 13.3$, $p = .001$]. Petersen et al., who examined MMN responses, found robust responses for deviations in timbre for the cochlear implant group.

Rhythm Performance

Of the 5 studies that evaluated rhythm performance, 4 employed statistical analysis of the results (Yucel et al., 2009, Kosaner et al., 2012, Innes-Brown et al., 2013, Petersen et al., 2015). Yucel et al. employed the non-parametric Mann-Whitney U-test to analyze the results of the musical stages profile (rhythmical changes Questions 15a-19). At 12 months, no significant differences in median scores were obtained between the music training and control groups ($p > .05$). At 24 months, significant differences in median scores were obtained between groups on the questions 15a, 15b, 16, 17, 19 (all at $p < .05$) and 18 ($p < .01$). Yucel et al. concluded that the music therapy group had better perception of rhythmic changes than the control group. Nonetheless, the groups performed similarly on the ability to follow a change in beat, based on the results on question 19. The authors contended that the ability to follow a change in beat requires modifying motor skills due to fine auditory attention.

Kosaner et al. (2012) analyzed rhythmic perception by evaluating the mean percentage values of the “Responding to music and rhythm” subscale, pre- and post- music training, from test interval 1 (pre training) to interval 7 (post training) in groups A and B and from interval 1 to interval 2 post training) in group C. In group A, the mean rhythmic perception improved from 14% at interval 1 to 68% at interval 7; in group B, the mean rhythmic perception improved from 30% at interval 1 to 94% at interval 7. In group C, the mean score improved from 52% at interval 1 to 95% at interval 2.

Innes-Brown (2013) conducted one-way ANOVAs on the rhythm scores of the groups. No significant differences on mean rhythmic score were obtained between the group with cochlear implants and the group with normal-hearing sensitivity. In order to test for statistically significant changes in scores with time, a linear mixed model (LMM) for repeated measures was used. The results revealed a significant decline in mean percentile rank over time, particularly for the group with cochlear implants as the LMM revealed a significant effect of session for the rhythmic test [$F(3, 14.4) = 12.4$, $p < .001$].

Petersen et al. (2015) observed robust MMN responses for deviations in rhythm. They concluded that users of cochlear implants are able to produce significant MMN responses to a change in rhythm as fast as 60 ms. Furthermore, The mean rhythm discrimination score of the group with cochlear implants did not differ significantly from that in the control group with normal-hearing sensitivity.

Music Appraisal Performance

Two of the seven studies statistically analyzed music appraisal performance (Stordahl, 2002; Yucel et al., 2009). Stordahl's measure of music appraisal was the Song Appraisal Test, a subtest of IMPAB-C. For the group with cochlear implants, mean total score, standard deviation, and range was 126.3, 29.3, and 66-185, respectively. For the subset of classical items, the mean score for the implant group was 40.4 with a standard deviation of 18.7 and range of 17-72. For the subset of nonclassical items, the mean was 82.9 with a standard deviation of 20.3, and range of 49-13. For the group with normal-hearing sensitivity, the mean total score was 112.6 with a standard deviation of 20.8, and the range was 74-151. For the subset of classical items, the mean, standard deviation, and range was 43.3, 14.7, and 19-73, respectively. For the subset of nonclassical items, the mean, standard deviation, and range was 69.2, 20.9, and 40-125, respectively. No significant difference in mean total score was seen between groups, although the mean difference approached significance ($p < 0.0.7$). For the subset of nonclassical items, the group with cochlear implants rated the items as significantly less likeable than the group with normal-hearing sensitivity ($p < .05$).

Yucel et al. (2009) examined the emotional aspects by evaluating the responses to the musical stages profile questions 20-26. Based on the responses to these questions, the emotional changes experienced through music differed significantly between the groups ($p < 0.05$).

Table III

Music Training Characteristics and Statistical Analyses.

Author(s)	**Year**	**Music training sessions (group vs. individual)**	**Stimulus presentation of music training**	**Music training duration**	**Frequency of music training**	**Statistical analysis**
Abdi et al.	2001	Group	Live	Se-tar method: 12-14 months	Weekly	N/A
				Orff method: 3-8 months	Weekly	N/A
Stordahl	2002	N/A - No music training.	N/A - No music training.	N/A - No music training.	N/A - No music training.	Compared CI[1] users with children with NH[2] children 2-sample t-test
Yucel et al.	2009	Individual - family-centered habilitation program done at home	Recorded	2 years - 10 minute sessions	Daily	Mann-Whitney U-test
Chen et al.	2010	Group	Live	2-36 months; mean: 13.2 months	N/A	Analysis of variance (ANOVA)
Kosaner et al.	2012	Combination: Family center habilitation program in group session	Combination: live and recorded			1 way repeated measures ANOVAs

		activities repeated in individual sessions at home				Paired-sample T-tests
				Group A 18 months 1 group session (45 minutes) and one individual session (20-30 minutes) with parents	Weekly	
				Group B: 18 months 1 group session (45 minutes) and one individual session (20-30 minutes) with parents	Weekly	
				Group C 3 months 1 group and 1 individual session (with parents occasionally)	Weekly	
Innes-Brown et al.	2013	Group	Recorded	1 school year; 45 minutes per session	Weekly	Between group differences: One-way ANOVAs Between session differences: Linear mixed model (LMM) for repeated measures
Petersen et al.	2015	Group	Combination: live music-making sessions and computer-based listening exercises	2 weeks - 20 hours total	Daily	Two-tailed one-sample t-tests Post hoc tests Behavioral tests-mixed-effects ANOVA

[1] Cochlear implant

[2] Normal hearing

Table IV

Music Perception and Appraisal Performance – Results.

Author(s)	**Year**	**Pitch performance**	**Significance**	**Melody performance**	**Significance**	**Timbre performance**	**Significance**	**Rhythm performance**	**Significance**	**Music appraisal performance**
Abdi et al.	2001	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Stordahl	2002	N/A	N/A	CI[1]: M(SD) =8.3(3.9)	Significantly[2] poorer performance in the group with CI than in group with NH[3]	N/A	N/A	N/A	N/A	Mean(SD), range Entire test (all items): -CI children: 126.31(29.29), 66-185 Classical (all items): -CI children: 40.36(18.67), 17-72 Nonclassical (all items): -CI children: 82.85(20.34), 49-134
				NH: M(SD) =24.9(2.4)						Entire test (all items): NH children: 112.56(20.81), 74-151 Classical (all items): NH children:

										43.34(14.66), 19-73 Nonclassical (all items): NH children: 69.22(20.88), 40-125
Yucel et al.	2009	Levels 1-6: one note sequences Levels 7-11: two note sequences	Significant familiarity in both levels of pitch discrimination	The musical stages profile (melody and dynamic changes Questions 5-14)	-24 months: Music Group: Median Question 5: 5.00 6: 5.00[4] 7: 5.00[4] 8: 4.00[2] 9: 4.00[2] 10: 3.00[2] 11: 4.00[5] 12: 5.00[2] 13: 3.00 14: 3.00[4]	N/A	N/A	The musical stages profile (rhythmical changes Questions 15a-19)	-24 months Music Group: Median Question 15a: 5.00[4] 15b: 5.00[4] 16: 5.00[4] 17: 5.00[4] 18: 4.00[5] 19: 3.00[4]	The musical stages profile (emotional aspects Questions 20-26)
Chen et al.	2010	Correlation between pitch perception and duration of musical training	Correct rate of overall perception (r^2= 0.389[3] Ascending pitch interval (r^2= 0.4023[4]	N/A	2	N/A	N/A	N/A	N/A	N/A
Kosaner et al.	2012	Mean values (%) of "Recognizing songs, tunes, and timbre" subscale at test interval 1 vs. 7 (Group A and B), 1 vs. 2 (Group C) (see Figure 2)		Mean values (%) of "Singing" subscale at test interval 1 vs. 7 (Group A and B), 1 vs. 2 (Group C) (Figure 1)		Mean values (%) of "Recognizing songs, tunes, and timbre" subscale at test interval 1 vs. 7 (Group A and B), 1 vs. 2 (Group C) (Figure 2)		Mean values [%] of "Respond to music and rhythm" subscale at test interval 1 vs. 7 (Group A and B), 1 vs. 2 (Group C) (Figure 3)		N/A

			Test interval 1 (pre): 0% mean values vs. test interval 7 (post): 50%		Test interval 1 (pre): 14% mean values versus test interval 7 (post): 56%		Test interval 1 (pre): 0% mean values versus test interval 7 (post): 50%		Test interval 1 (pre): 14% mean values versus. test interval 7 (post): 68%	
			Test interval 1 (pre): 5% mean values versus Test interval 7 (post): 74%		Test interval 1 (pre): 19% mean values versus test interval 7 (post): 75%		Test interval 1 (pre): 5% mean values versus test interval 7 (post): 74%		Test interval 1 (pre): 30% mean values versus test interval 7 (post): 94%	
			Test interval 1 (pre): 45% mean values versus test interval 2 (post): 95%		Test interval 1 (pre): 42% mean values versus test interval 2 (post): 76%		Test interval 1 (pre): 45% mean values versus test interval 2 (post): 95%		Test interval 1 (pre): 52% mean values versus test interval 2 (post): 95%	
Innes-Brown et al.	2013	IMMA[6] Tonal Task	Trend toward difference between groups, *p* = .07, h^2 = .30 and post hoc tests indicated that CI scores were significantly lower than NH scores[3] Significant group effect[5] Post hoc tests- CI group had significantly worse scores than the NH group[3]	N/A		IMMA tonal task	Trend towards differences between groups, *p* = .06, h^2= .33 and post hoc tests showed that CI users had significantly lower scores than NH children[4] Significant group effect[5] scores in the CI group significantly lower than in the NH group	IMMA Rhythm Task	No statistically significant differences between groups on Rhythmic test LMM indicated a significant effect of Sessions for the rhythmic test[4]	N/A

Petersen et al.	2015	MMN[7] amplitudes Behavioral musical multi feature discrimination test	No consistent MMNs in CI users for pitch deviants Poor hit rates for behavioral pitch discrimination	N/A	N/A	Ear training	Robust MMN responses for deviations in timbre	Rhythm training	Robust MMN responses for deviations in rhythm	N/A

[1] Group with cochlear implants

[2] $p < .001$

[3] Group with normal-hearing sensitivity

[4] $p < .05$

[5] $p < .01$

[6] The Iowa Music Perception and Appraisal Battery—Children’s Version

[7] The Intermediate Measures of Music Audiation

DISCUSSION

Music training programs are gaining popularity in cochlear implant postoperative habilitation programs in various settings. Due to poor music perception in children who are prelingually deafened and promising research regarding the improvement of music perception through structured therapy, the value of such programs are being recognized. The purpose of this systematic review was to evaluate the efficacy of music training on music perception in prelingually deafened children with cochlear implants. Based on the findings of this systematic review, one can conclude that in prelingually deafened children with cochlear implants, early music training improves several aspects of music perception, including pitch, melody, rhythm, and timbre. A summary of the major findings in each investigation evaluated in this systematic review follows, along with the limitations of each.

The mechanism of enhanced pitch perception effected by music training is not fully understood, but one hypothesis is the concept of auditory plasticity of the brain (Chen et al. 2010). According to Chen et al., the alteration of the disorganized tonotopic central auditory pathway potentially plays a large role. The restoration of afferent input through cochlear implantation may help reduce additional deterioration in the nervous system. This phenomenon, in addition to changes in neurotransmission, may help reverse the disorganized tonotopic central auditory system (Guiraud et al., 2007), leading to better development of frequency tuning in the auditory cortices. Guiraud et al.'s theory helps to explain why music training led to better pitch perception in the prelingually deafened children with cochlear implants in the Chen et al. study. A limitation of the Chen et al. study is the fact that testing intervals may have been too small to allow generalization of the results to the real-world setting. Moreover, loudness needs to be monitored with a more precise matching utilizing computerized tones, rather than a piano (Chen et al.). The use of computerized tones rather than a live piano helps to differentiate between tone discrimination and loudness discrimination (Chen et al.).

In the Yucel et al. (2009) study, music training led to progress in discriminating pitch differences and melody appraisal. After 24 months of training, the families of the music training group found the experience to be enjoyable, indicating that outcome of music training was enjoyable as well as effective in improving music perception. According to the results obtained from musical stages questionnaire, the beneficial effects of the music training program were significant and seen for all aspects of musical development by the end of the second year.

Kosaner et al. (2012) found that a music program, in their case Musical EARS, leads to positive outcomes in music perception despite limited abilities of users of cochlear implants because of technical limitations of cochlear implants. Although the results showed significant improvements in music perception, future research is needed to exclude extraneous factors as confounding factors. For instance, in order to increase the objectivity of the findings and prevent a possible bias, independent observers rather than the teachers should be scoring the test. Also, maturity may have played a factor in the improvement seen in at least some of the children. Ceiling effects were seen in group C after just 3 months of training, which indicates that this program is more appropriate for younger than older children, which is why the final published version has 2 age ranges (2-4, 4-6 years). All in all, children acquired the "Recognizing songs, tunes, and timbre" skills father than "Singing" skills and they acquired the "Responding to music and rhythm" subscale skills faster than those of other subscales. The former finding was expected as auditory skills precede spoken language skills. The latter finding probably results from the fact that cochlear implants perform relatively well at transmitting basic rhythmic patterns (McDermottt, 2004). Kosaner et al's findings support Chen et al's finding that the length of musical training, not length of listening experience with an implant, and higher music perception scores are strongly correlated. That is, children with long listening experience, or rather, long length of cochlear implant use, only develop strong music perception skills if specifically trained. Nonetheless, the effects of late implantation in music perception cannot be evaluated as all participants in this study were implanted before 5 years of age.

In the Innes-Brown et al. (2013) study, children with cochlear implants who participated in a structured “Music Club” using showed trends with time between sessions towards lower scores than children with normal-hearing sensitivity on the tonal, but not on the rythmic tests. On the timbre tests, no significant improvement was seen across sessions. The findings of the Innes-Brown study highlights the benefits from participation in the Music Club, beyond improvement in tonal, rhythmic, and timbre perception, such as increased engagement and interest in music.

Although Abdi et al’s (2001) did not intend to train children to become musicians, but intended only to enhance their contact with music, two participants voluntarily became musicians. The psychological effects of learning a new task is valuable in itself (Abdi et al.). Abdi et al.’s study was limited to the extent that no statistical analyses were performed. Conclusions were drawn based on rather subjective observations.

The findings Petersen et al. (2015) suggest that adolescent users of cochlear implants have the ability to discriminate music to some extent, as shown by their significant MMN responses to changes in timbre, rhythm, and intensity. But comparison of the implant and control groups revealed significantly poorer discrimination abilities in the implant group than the control group, as indicated by the significantly weaker brain responses and poorer behavioral performance in the implant group than in the control group. Some limitations of the Petersen et al, study include brevity of the program, possible interpolated channels due to position of the electrodes, artifact, and degraded signal-to-noise ratio during recordings because testing was done in the field as opposed to a shielded setting in a laboratory.

In contrast with the stated purpose of the other studies, the purpose of the Stordahl (2002) study was to compare music perception in users of cochlear implants users with that in children with normal-hearing sensitivity, rather than to examine the effect of music training music perception. The users of cochlear implants not only performed significantly less accurately than the reference group on the song recognition task, they also demonstrated greater dislike of the music on the song appraisal test than did the children with normal-hearing sensitivity. But much greater inter-subject variability in appraisal was seen in the implant group than in the control group. Future studies are needed to explore the reasons this variability in music appraisal in users of cochlear implants. Limitations of this study include short duration and frequency of the testing battery. An interesting finding despite the difference in outcomes between the groups was the fact that the self-reported informal musical involvement and listening habits were very similar for the two groups.

CONCLUSION

Children who are prelingually deafened experience significant auditory difficulties compared to their normal hearing peers, even when implanted at an ideal age and enrolled in an aural habilitation program. Although, with appropriate management and habilitation, they have the capability to understand and express speech, they still struggle with music perception. Various elements of music, such as pitch, melody, timbre, rhythm, and appraisal, have shown to be enhanced in prelingually deafened children with cochlear implants who undergo music training programs.

The purpose of this systematic review was to analyze these elements before and after music training programs. Overall, children perform better in all of these aspects of music perception when given appropriate music training. For instance, the ability to discriminate pitch was improved with music training in prelingually deafened children with cochlear implants in the Chen et al. (2010) study. This shows the importance of the inclusion of structured music training as early as possible in childhood for children who are prelingually deafened. Thus, music training should be included in cochlear implant rehabilitation programs. Incorporating parental involvement not only may help build better relationships, but also furnishes opportunity for both children and adults to participate in something rewarding and beneficial. Teachers, clinicians, and parent should be encouraged to participate in the music training to enhance quality of life. Based on the great compliance and enthusiasm of participants, such music perception training programs could be easily implemented (Petersen et al., 2015). Further research is needed in order to compare the outcomes in prelingually deafened children to post lingually deafened children with cochlear implants. According to Gfeller, Driscoll, Smith, and Scheperle (2012), prelingually deafened users of cochlear implants are generally more satisfied with music than postlingually deafened users because they have no comparisons with previous music listening experience. Future studies should also assess the abilities of children with cochlear implants and contralateral hearing aids to see if their abilities are superior compared to those of children who are solely implanted (Yucel et al., 2009).

Gfeller et al. (2007) concluded that residual acoustic hearing that exists postoperatively, typically in the low frequencies, improves music perception as does the combination of both a hearing aid and cochlear implant, rather than hearing electrically with cochlear implant(s) alone. Nonetheless, incorporating a structured postoperative music training habilitation program for prelingually deafened children with cochlear implants has been proven to be beneficial and should be implemented more often and early on in life.

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