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Research Article

The Effect of Input on Music Perception, Appreciation, and Naturalness for Individuals with Cochlear Implants

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Abstract

Purpose

The purpose of this study was to determine if the use of different inputs (sound field versus direct connect) affects the music perception abilities and subjective rating of music quality for individuals with cochlear implants (CI).

Method

The current study evaluated music perception in eight adult CI users. Two subtests of the Appreciation of Music in Cochlear Implantees (AMICI; Spitzer, Mancuso & Cheng, 2008) clinical test of musical perception, identification of musical instruments and identification of musical styles, were assessed for sound field and direct connect input mediums. In addition, participants were asked to rate naturalness and appreciation of the musical styles.

Results

The findings suggested no difference in music perception abilities between direct connect and sound field presentation mediums in CI users for identification of musical instruments and identification of musical styles subtest. However, listeners did rate naturalness and appreciation higher for the direct connect presentation medium than for sound field presentation.

Conclusions

The findings of the current study supported the recommendation to use direct connect input to the CI speech processor as a tool for improving music appreciation and naturalness. However, overall results did not indicate improved performance in a music perception task when using direct connect input to the speech processor.

Introduction

Originally, the goal of cochlear implants (CI) was to provide individuals with assistance with lip reading (Zeng, Popper, & Fay, 2004). With current technology, open-set speech understanding is no longer only sought after but is a realistic expectation for users of Cis (Gfeller et al., 2007). Several studies have shown that although there may be a correlation between music and speech perception, users of CIs continue to have much greater success with speech understanding than music understanding (Gfeller & Lansing, 1991; Gfeller, Woodworth, Robin, Witt, & Knutson, 1997). In fact, it has been reported that approximately 50 percent of individuals with CIs experience a significant decrease in music enjoyment after receiving their CI (Migirov, Kronenberg, & Henkin, 2009) with a percentage of these individuals possibly experiencing an improvement in music enjoyment with practice (Gfeller et al., 2000). This is particularly concerning given that music perception is reported as the second most important sound cochlear implant users experience in their life (Drennan & Rubinstein, 2008).

Music enjoyment and appreciation is an important and sometimes essential part of society. Improved music perception abilities and enjoyment of music could increase an individual's overall quality of life, their satisfaction with the device, and may improve social outcomes (Gfeller et al., 2000). Following implantation, many individuals with CIs aspire to enjoy music as they had prior to implantation (Gfeller & Lansing, 1991).

Although there have been great advancements in processing strategies and electrode design in CIs over the last several years, music perception abilities are still lacking (Gfeller, Jiang, Oleson, Driscolli, & Knutson, 2010). Successful music listening and enjoyment often requires practice and the implementation of listening strategies (e.g., reading lyrics along with the music) for the best outcomes (Gfeller et al. 2009).

Music is a complex signal with a wide frequency spectrum, making it much more difficult to provide CI users the same perception of music through CI processing as individuals with normal hearing (Leal et al., 2003). The structural characteristics of music are variable with several contributing factors (melody, pitch, timbre, and rhythm). Cochlear implants were initially designed to process a speech signal (Gfeller et al., 1997; Leal et al., 2003) and although advancements in CI processing and programming technology have improved speech perception and consequently social outcomes (e.g., increased social activity) for users, music perceptions remains an area of significant difficulty (Gfeller & Lansing, 1991; Gfeller, Woodworth, Robin, Witt, & Knutson, 1997). This discrepancy in improvement suggests that the current processing of a CI is not an ideal means of processing music. For example, it has been shown that users of CIs may experience more difficulty with timbre and pitch perception, than the other elements of music (Limb & Rubinstein, 2012; Gfeller et al., 2007). Current CI technology may not provide listeners with a sufficient representation of timbre and pitch, which are important acoustic cues for music perception (Galvin et al., 2009a; Limb & Rubenstein, 2012). Current CI coding strategies primarily provide information related to the envelope of the signal while (commonly) removing the temporal fine structures of the signal (Zeng et al., 2004). Due to this CI users rely on the envelope of the signal for music perception, as current CI technology primarily only conveys the envelope of the signal to the listener (Zeng et al., 2004).

Given the important role music plays in a person's life and the difficulty users of CIs face in terms of music appreciation, recommendations are commonly made in the clinical setting in effort to improve these challenge areas, such as targeting music during aural (re)habilitation activities or methods for possibly a more immediate impact on music perception through use of direct connect audio input. Specifically, it has been suggested that the use of a direct connect audio input cable may reduce background noise, improved sound quality, and improve lyric identification. Although this is a recommendation provided by manufacturers and possibly many clinicians, and although benefits for use of direct audio input when listening to speech in noise have been found (e.g., Davies et al. 2001) there are no available data regarding benefits of listening to music through direct connect input over standard sound field input.

It has been suggested by CI manufacturers that the use of direct connect inputs may provide a listener with a 20 to 30 dB improvement in the signal to noise ratio (SNR). FM systems are an example of a system that takes advantage of the direct connect audio input and is currently the only system that is doing so that has been evaluated thus far. Davies et al. (2001) evaluated the benefit of FM systems with direct connect input used in conjunction with cochlear implants in listening environments similar to classroom settings. With the use of an FM system, a mean speech perception score of 70 percent was obtained from all children over the age of 10 years. Without the use of an FM system, speech perception scores showed a decrease of 17 percent at –3 SNR (Davies et al., 2001). These results clearly indicate that individuals using CIs receive a measurable amount of speech perception benefit with the direct connect FM system, when directly compared to speech perception benefit without the direct connect FM system, suggesting the possibility that use of direct audio input may improve music identification and appreciation due to the improved SNR that can be observed with the use of a direct audio input.

In summary, previous studies have illustrated the substantive difficulty individuals with CIS face when listening to music despite advances in technology or experience with their CI (Gfeller et al., 2010; Leal et al., 2003; Limb & Rubenstein, 2012; Migirov et al., 2009). The use of direct connect input has been recommended when listening to music to improve success as opposed to sound field input. However, there is currently no specific data suggesting that direct connect input is superior to sound field input in regards to music appreciation or naturalness in CI users. Therefore, the purpose of this study was to determine if the use of different inputs, sound field versus direct connect, affects the music perception abilities and subjective rating of music quality for individuals with CIs. Specifically, this study aimed to answer three research questions. First, does a relationship exist between music perception abilities and subjective ratings of music quality for individuals with CIs? Second, does input medium, sound field versus direct connect, affect subjective rating of music quality (music appreciation and music naturalness) in individuals with CIs? Third, does input medium, sound field versus direct connect, affect the music perception abilities (style of music and instrument identification) of individuals with CIs? Results from the present study could hold clinical implications for the specific recommendations clinicians provide to persons with Cis when counseling these individuals regarding music perception naturalness and appreciation.

Methods

Participants

The participants of this study included eight (*n*=8) adult listeners, aged 24 to 78 years (*mean*=52.9 years), who used CIs. Descriptive information for participants is shown in Table 1. Each listener had a minimum of three months of listening experience with their CI (*range*=7 to 149 months). The participant's auditory thresholds were screened prior to participation in the study and listeners included in the study exhibited behavioral thresholds of ≤ 45 dB HL at 500 Hz, 1000 Hz, 2000 Hz, 3000 Hz, 4000 Hz, and 6000 Hz. Throughout testing, the listener's used two research MAP's created from their preferred listening setting. The preferred listening setting was the program they entered the testing session with that they typically used. From this preferred listening setting, two research MAP's were created. The first research MAP set the auxiliary mixing ratio to 100% input from the microphone and was used during the sound field test conditions; the second research MAP set the auxiliary mixing ration to 100% input from the auxiliary port and was used during the direct connect test condition. All other user preferences remained unchanged in the research MAP's, but were recorded for inclusion in participant demographics (see Table 2). If listeners received bilateral input in their everyday listening through CI+HA or CI+CI, they participated in the testing using bilateral input for the sound field CI+ contralateral input (CI or HA) condition only. All other conditions were completed with the CI only. For those who were CI+CI, the preferred CI was utilized.

Table 1. Demographic Information

Participant ID #	1	2	3	4	5	6	7	8
Gender	male	female	male	male	male	female	female	female
DOB (years)	76.25	58.75	70.5	78.5	33.58	24.66	26.25	55.08
Duration of Deafness (years)	50	57	12	77	32	23	22	55
Consistency of CI use	everyday	everyday	everyday	everyday	everyday	everyday	everyday	everyday
Ear Implanted (1=left, 2=right, 3=left & right)	2	1	1	2	2	2	3	1
Date of CI surgery	11/10/11	4/10/07	12/11/07	1/24/14	7/13/2007	10/5/00	11/20/31 L 8/21/02 R	10/31/12
Time since CI surgery (months)	12	67	60	13	56	149	129	7
Date of IA	11/22/11	5/1/07	1/10/08	3/2/12	8/14/07	10/20/00	12/7/13 L 10/02 R	12/15/12
HA Model	Phonak Naida X SP	Starkey Destiny	Phonak Naida X SP	Oticon Sumo XP				Starkey
Music Experience	3	0	1	3	5	5	3	2

Table 2. CI Map Settings

Participant ID #		1	2	3	4	5	6	7	8
CI Device Man.		Cochlear Am.	Adv. Bionics	Adv. Bionics	Adv. Bionics	Cochlear Am.	Adv. Bionics	Med-El	Adv. Bionics
Internal Device		Freedom	HR90K	HR90K	HR90K	Freedom	CI/HiFocus	C40+	HR90K
External Device		CP 810	Harmony	Harmony	Harmony	CP 810	Harmony	Opus 2	Harmony
Current Coding Strategy		ACE/ACE (RE)	HiRes-P w/ Fidelity 120	HiRes-P w/ Fidelity 120	HiRes-P w/ Fidelity 120	ACE/ACE (RE)	SAS	FSP	HiRes-P
Everyday Input		CI + HA	CI + HA	CI + HA	CI + HA	CI only	CI only	CI + CI	CI + HA
Everyday Map Settings	Prog 1	9, 2:1 access.	8, 50/50 mic/ aux	12, 50/50 mic/aux	1, aux only	20, 2:1 access.	1, 50/50 mic/ aux	R-10, L-13 1=mic only	1, 50/50 mic/ aux
	Prog 2	9, 2:1 access.	9, 50/50 mic/ aux	11, 50/50 mic/aux	1, aux only	20, 2:1 access.	2, 50/50 mic/ aux	R-10, L-13 1=mic only	2, 50/50 mic/ aux
	Prog 3	9, 2:1 access.	10, 50/50 mic/aux	10, 50/50 mic/aux	1, aux only	20, 2:1 access.	3, 50/50 mic/ aux	R-10, L-13 1=mic only	3, 50/50 mic/ aux

Procedures

For the study, music perception, naturalness, and appreciation were measured for adult CI users using two input mediums (direct connect input and sound field input). The testing was administered in a sound-treated room which had noise levels in accordance with American National Standards Institute S3.1-1999. The listener was seated in the sound treated room facing the speaker at 0° azimuth at a distance of 3 feet (Spitzer et al., 2008). For sound field test conditions, the stimuli were played using a CD player connected to an Interacoustic AC 40 clinical audiometer at a presentation level of 60 dB HL. For the direct-connect input condition, the participant's CI was directly connected to the sound source (CD player) via a personal audio cable connected to the accessory port on the participant to the level that they judged to be their most comfortable listening level and most comparable in volume to the sound when played via the sound field speakers.

For both sound field and direct connect input mediums, music perception was measured using the identification of musical instruments and identification of musical styles subtests from the Appreciation of Music in Cochlear Implantees (AMICI; Spitzer, Mancuso, & Cheng, 2008). The list presented to each participant was randomly selected. Both subtests (identification of musical instruments and identification of musical styles) were counterbalanced across listeners and condition (direct connect input and sound field input) to control for learning effects (e.g., The order of conditions for participant 2 was the reverse order than was presented to participant 1). Scoring of each of the AMICI subtests was based on the percent correct of correctly identified musical instruments and musical styles within each subtest. Percent correct was used to represent results, as this is an approach that clinical audiologists would be familiar with and is consistent with previous publications using the AMICI (e.g., Wright & Uchanski, 2012). In addition to the identification tasks, participants were asked to rate their appreciation of each musical style on a 7-point Likert scale (7 points=strongly pleasant and 1 point= strongly unpleasant) following presentation of each item on the identification of musical styles subtest. The participant also rated naturalness on a 7-point Likert scale (7 points= strongly natural and 1 point= strongly unnatural) following the presentation of each item on the identification of musical styles subtest.

The listener completed the direct connect input condition using the CI only device arrangement. The listener completed the sound field condition for both CI only and CI+ HA or CI+CI if they were bimodal or bilateral user. Each listener completed four measures of music perception (instrument identification, musical style identification, music naturalness, and appreciation) in two or three listening conditions (direct connect monaural, sound field input monaural, and sound field input binaural) throughout the study, for a total of 12 test conditions for bimodal and bilateral CI users and eight test conditions for monaural CI users.

Data Analysis

For each of the AMICI test measures (identification of musical styles and identification of musical instruments) in each condition (sound field and direct connect), percent correct was calculated for each listener. Mean percent correct was calculated across listeners for each test and each listening condition. In addition, mean ratings of naturalness and appreciation were calculated across listeners and for each listener for each subjective scale (appreciation and naturalness) and each listening condition. Results for both individual and mean data were initially visually analyzed for patterns and outliers and a repeated measures ANOVA was completed to test the statistical significance for the main effects of connection (monaural direct connect, monaural sound field) and measure (AMICI subtest: identification of musical styles and identification of musical instruments, appreciation, naturalness) and the corresponding interactions. A second repeated measures ANOVA was completed to test the statistical significance for the main effects of connection (monaural direct connect, monaural sound field) measure (percent correct musical style, appreciation, naturalness), musical style (country, Latin, rock & roll, classical jazz) and the corresponding interactions. The third level of analysis included a repeated measures ANOVA for performance across instrument identification to test the statistical significance for the main effects of connection (monaural direct connect, monaural sound field), instrument (female, male, guitar, drum, flute, piano, saxophone, trumpet, tuba, string) and the corresponding interactions. Statistical significance was evaluated at an alpha error level of .06. A pair-wise post-hoc analysis was conducted on any effects reaching statistical significance.

Results

Individual results for the musical style identification and instrument identification test measures in each presentation medium and mode are shown in Table 3. Overall, the participants performed better on the instrument identification subtest than the musical style identification subtest. Listeners 3 and 6 performed highest on the musical style subtest when compared to the other participants. According to demographic information, both listeners were long-term CI

Table 3. Individual Performance in Percent Correct Across Musical Style Identification and Instrument Identification Subtests.

Participant ID #			1	2	3	4	5	6	7	8
MS	Monaural	SF	42.000	58.000	82.000	50.000	58.000	76.000	48.000	52.000
		DC	66.000	60.000	60.000	46.000	58.000	86.000	38.000	56.000
	Binaural	SF	58.000	66.000	58.000	56.000			52.000	54.000
IID	Monaural	SF	61.700	68.333	78.333	63.333	66.667	76.667	55.000	40.000
		DC	70.000	61.667	78.333	55.000	70.000	73.333	51.667	61.667
	Binaural	SF	75.000	76.786	76.667	70.000			56.667	36.667

users. At the time of data collection, Listener 3 had been implanted for 60 months, which was the fourth longest duration of all the participants and Listener 6 had been implanted for 148 months, which was the longest duration of all the participants. Comparison of monaural and binaural input modes for instrument identification in the sound field indicated that seven out of eight participants performed better in the binaural condition, the other participant performed comparable across modes. Comparison of monaural and binaural input modes for musical style identification indicated large variability in performance across listeners. However, there was less variability in performance across listeners for sound field binaural input than sound field monaural input.

Separate repeated measures ANOVAs were used to evaluate the statistical significance for the main effects of measure (percent correct musical style, percent correct instrument identification, naturalness, appreciation), connection (monaural direct connect, monaural sound field) and the corresponding interactions for monaural listeners and for binaural listeners. For monaural listeners, sphericity was not met for measure so the analysis was conducted using a Greenhouse-Geisser adjustment. For binaural listeners, sphericity was met for connection so no correction was applied. The Greenhouse-Geisser correction was used for all other factors. For both monaural and binaural listeners, there were no significant main effects of interactions at an alpha level of .05.

Table 4. Individual Data in Percent Correct for Performance on the Musical Style Identification Measure for Each Musical Style Presented.

Participant ID #			1	2	3	4	5	6	7	8
Monaural	SF	Classical	50.0	60.0	100.0	80.0	60.0	80.0	40.0	90.0
		Latin	40.0	20.0	60.0	40.0	30.0	80.0	30.0	40.0
		Rock & Roll	0.0	50.0	80.0	20.0	70.0	80.0	40.0	40.0
		Country	100.0	100.0	100.0	50.0	70.0	70.0	80.0	40.0
		Jazz	20.0	60.0	70.0	60.0	60.0	70.0	50.0	50.0
	DC	Classical	70.0	30.0	80.0	60.0	70.0	90.0	40.0	60.0
		Latin	30.0	30.0	70.0	30.0	60.0	100.0	20.0	60.0
		Rock & Roll	90.0	80.0	20.0	30.0	70.0	90.0	40.0	40.0
		Country	100.0	100.0	60.0	70.0	50.0	80.0	60.0	70.0
		Jazz	40.0	60.0	70.0	40.0	40.0	70.0	30.0	50.0
Binaural	SF	Classical	80.0	70.0	90.0	70.0			40.0	80.0
		Latin	50.0	20.0	50.0	30.0			40.0	70.0
		Rock & Roll	20.0	70.0	30.0	40.0			60.0	40.0
		Country	100.0	90.0	60.0	80.0			50.0	50.0
		Jazz	40.0	80.0	60.0	60.0			70.0	30.0

Table 5. Individual data in percent correct for performance on the instrument identification measure for each musical instrument presented

Participant ID #			1	2	3	4	5	6	7	8
Monaural	SF	Female	83.3	33.3	66.7	33.3	50	83.3	0	50
		Male	83.3	16.7	33.3	83.3	66.7	83.3	66.7	50
		Guitar	16.7	66.7	33.3	16.7	100	83.3	66.7	33.3
		Drum	100	83.3	100	83.3	83.3	100	83.3	50
		Flute	0	50	100	5.	83.3	50	66.7	16.7
		Piano	100	83.3	100	66.7	83.3	66.7	66.7	50
		Saxophone	33.3	100	100	16.7	16.7	66.7	33.3	33.3
		Trumpet	100	83.3	66.7	83.3	0	66.7	83.3	50
		Tuba	100	83.3	100	100	100	83.3	50	33.3
		String	0	83.3	83.3	100	83.3	83.3	33.3	223.3
	DC	Female	66.7	50	83.3	33.3	50	83.3	66.7	83.3
		Male	100	16.7	66.7	50	100	100	66.7	83.3
		Guitar	16.7	33.3	16.7	0	100	83.3	66.7	33.3
		Drum	83.3	100	83.3	100	83.3	100	83.3	33.3
		Flute	83.3	50	83.3	33.3	83.3	50	33.3	66.7
		Piano	100	66.7	100	83.3	100	66.7	50	66.7
		Saxophone	33.3	66.7	83.3	50	33.3	50	33.3	66.7
		Trumpet	83.3	66.7	66.7	66.7	0	33.3	83.3	50
		Tuba	100	100	100	83.3	100	83.3	0	50
		String	33.3	66.7	100	50	50	83.3	83.3	83.3
Binaural	SF	Female	100	33.3	33.3	33.3				50
		Male	83.3	33.3	50	66.7				50
		Guitar	16.7	100	66.7	16.7				16.7
		Drum	83.3	100	83.3	100				83.3
		Flute	33.3	100	83.3	66.7				16.7
		Piano	100	100	100	83.3				66.7
		Saxophone	83.3	66.7	100	66.7				16.7
		Trumpet	100	50	66.7	83.3				33.3
		Tuba	100	83.3	100	100				33.3
		String	50	100	83.3	83.3				0

Individual results for presentation medium and presentation mode for each musical style presented for the musical styles identification test measure are shown in Table 4. Results showed that three out of eight listeners and three out of six listeners performed highest for country and classical musical styles during the monaural and binaural sound field conditions, respectively. In addition, five out of eight participants performed highest for the country musical style in the monaural direct connect condition. Five out of eight listeners and four out of eight listeners performed poorest for the Latin musical styles during the monaural sound field condition and monaural direct connect condition, respectively. Performance was variable for the binaural sound field condition.

A repeated measures ANOVA was used to evaluate the connection (monaural direct connect, monaural sound field), musical style (country, Latin, rock and roll, classical, jazz) and the corresponding interactions for monaural listeners. Sphericity was met for the interaction between connection and musical style so no correction was applied. The Greenhouse-Geisser adjustment was applied for all other factors. There was a significant interaction between measure and musical style, $F(2.208, 15.458) = 4.180$, $p = .032$, $\eta 2 = 0.374$. Due to the significant interaction between measure and musical style, these factors were evaluated in separate repeated measures ANOVA. For the connection and musical style performance analysis, the main effect of musical style, $F(4, 28) = 4.836$, $p = .004$, $\eta 2 = 0.409$) was significant. Results from post-hoc analysis showed that performance for country music ($M = .663$, $SD = .1995$) was significantly greater than

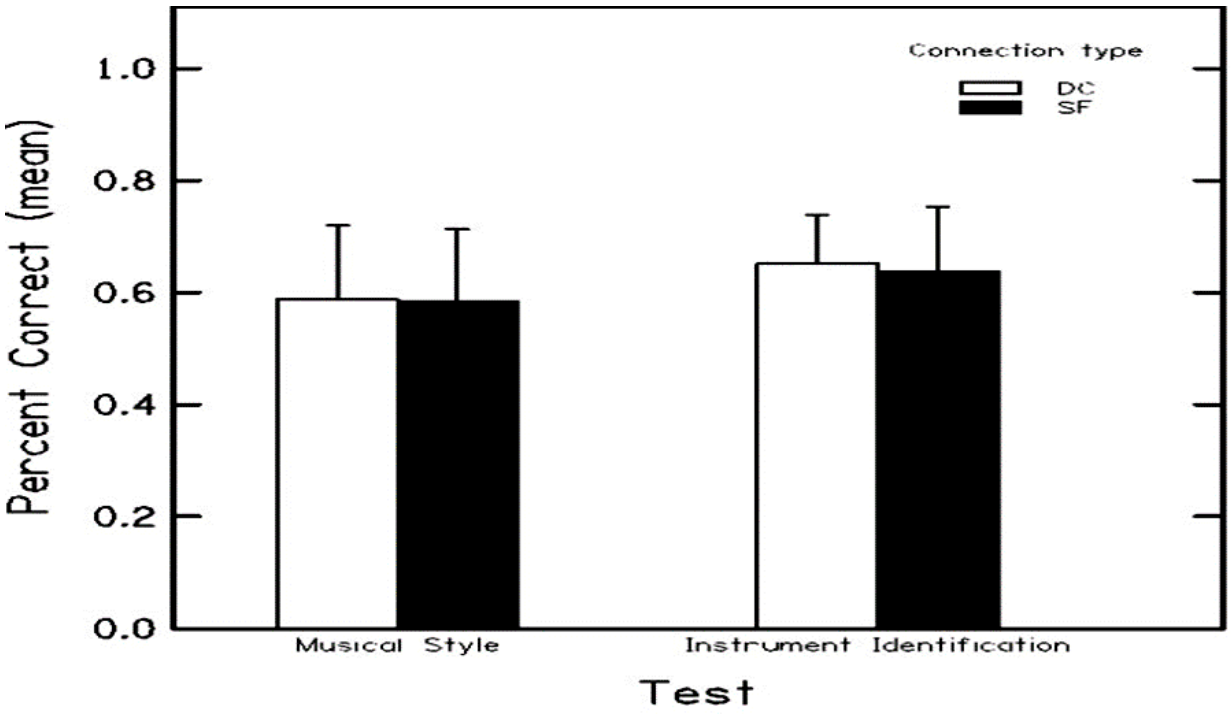

Figure 4. Mean performance across listeners in percent correct plotted as a function of objective test measure, musical style identification and instrument identification. The parameter is presentation medium. Error bars indicate +/- 1 standard deviation across listeners.

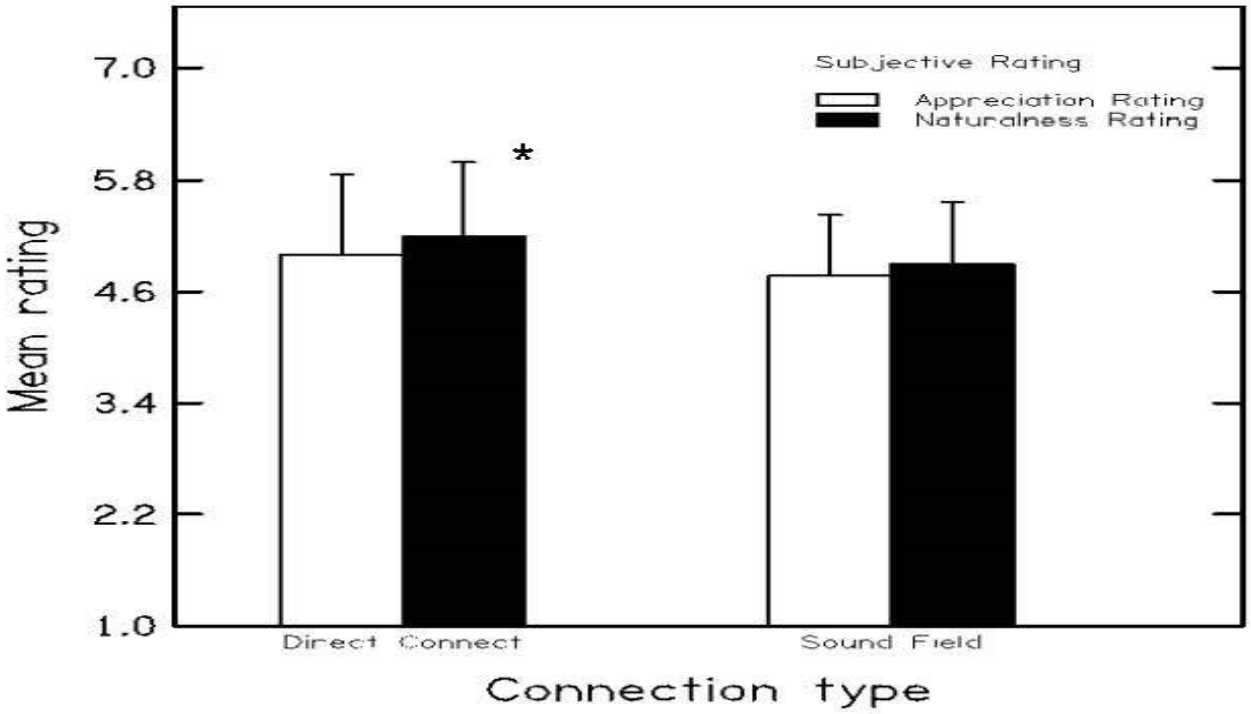

Figure 5. Mean rating across listeners plotted as a function of presentation medium. The parameter is subjective rating. Error bars indicate +/- 1 standard deviation across listeners (*=statistically significant).

performance for Latin music (*M*=.461, *SD*= .2284) and jazz music (*M*=.525, *SD*=. 1537). Performance for classical music (*M*=.750, *SD*=.2033) was significantly greater than Latin music (*M*=.461, *SD*=.2284), rock and roll music (*M*=.525, *SD*=. 0279), and jazz music (*M*=.525, *SD*=.1537).

Individual results for presentation medium and presentation mode for each instrument presented during the instrument identification test measure are shown in Table 5. Results showed that seven out of eight listeners performed highest for the drums, piano and tuba. Results also showed that five out of eight listeners for the monaural sound field condition, three out of six for the binaural sound field condition, and three out of eight for the monaural direct connect condition performed poorest on the guitar presentation. Mean performance across listeners in percent correct plotted as a function of test measure is plotted in Figure 4.

The finding of most importance suggested that when comparing the use of direct connect and sound field presentation mediums there was no difference in the CI users' music perception abilities for both identification of the style of music and instrument identification. Mean appreciation and naturalness rating across listeners plotted as a function of presentation medium is plotted in Figure 5. The results were represented with the presence of error bars, these represent +/- one standard deviation. Results from the ANOVA were presented earlier in the results section. It is possible that the finding of no difference between direct connect and sound field presentation mediums my be due to the small sample size in the study.The results were suggestive of listeners rating both appreciation and naturalness higher for the direct connect presentation medium when compared to the sound field presentation medium. For the direct connect presentation medium, listeners rated naturalness slightly higher than appreciation. The repeated measures ANOVA for performance across musical styles for naturalness the assumption of sphericity was violated, so this analysis was conducted using a Greenhouse-Geisser adjustment. The results from this ANOVA demonstrated a significant main effect of connection, $F(1,7) = 6.459$, $p = .039$, $\eta 2 = .480$. Results from post-hoc analysis showed that performance with the direct connect connection (*M*=5.189, *SD*=1.0811) was significantly greater than for sound field connection (*M*=4.897, *SD*=.9571). The assumption of sphericity was not met for any factor with the ANOVA for performance across musical style for appreciation, so the analysis was completed using a Greenhouse-Geisser adjustment. There were no significant main effects or interactions at an alpha level of .05. There was no difference observed between appreciation and naturalness ratings for the sound field presentation medium.

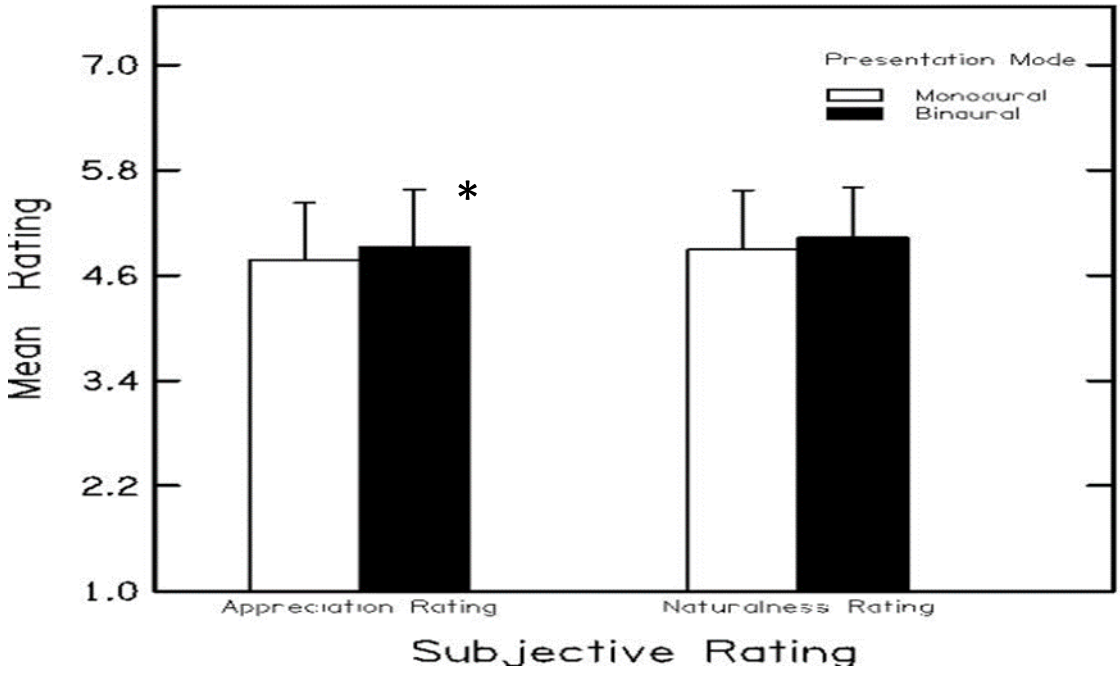

Figure 6. Mean rating across listeners plotted as a function of subjective measures. The parameter is presentation mode. Error bars indicate +/- 1 standard deviation across listeners (*= statistical significant).

Lastly, mean appreciation and naturalness rating across listeners plotted as a function of subjective test measures are plotted in Figure 6. As in figure 5, the results were represented with the presence of error bars, these represent +/- one standard deviation, statistically significant difference is indicated by an asterisk (*). The results were suggestive of listeners rating appreciation and naturalness as being slightly higher for the binaural presentation mode when compared to the monaural presentation mode. This comparison pertains to the sound field medium only as the direct connect presentation medium was not administered for the binaural presentation mode.

Summary and Discussion

Music enjoyment is a type of listening most individuals with cochlear implants (CI) aspire to improve after implantation (Gfeller & Lansing, 1991). For many, music enjoyment contributes to social, emotional and cultural aspects of everyday life (Gfeller et al., 2000). As such, it is important to identify effective ways to improve music perception for users of CIs.

The results from the current study suggested that the listeners performed better on the instrument identification measure than the musical style identification measure. This finding is consistent with results of Gfeller et al. (2009), suggesting that music therapy should begin with simple tasks such as listening to solo instruments or a small number of instruments, and then progressing to more difficult tasks such as listening to music with multiple instruments and different musical styles. Further, the results showed that, overall, listeners performed better for the drums, piano and tuba and poorest for the guitar. Drums are classified as a percussive instrument and piano is classified as a percussive string instrument (Strong & Plitnik,1992). The drums are rhythmic in nature, perceived as having low pitch (Forsyth, 1982), and tend to have prominent temporal envelope and rhythmic cues (Drennan & Rubinstein, 2008). As discussed previously, CI users rely on the envelope of the signal for music perception, as current CI technology primarily conveys the envelope of acoustic signals. The piano is a string instrument from which sound is generated from vibration of a fixed string. In Gfeller et al. (2002), CI users demonstrated the highest performance for the piano on a musical identification test. In addition, Gfeller et al. (1998) found that on a tumbrel recognition test CI participants were able to most accurately recognize the piano. The tuba produces predominately low-frequency signals like the drums, which may aid in identification (Forsyth, 1982). The guitar is classified as a string instrument and currently there is no literature to explain why the CI users performed more poorly for the guitar on the instrument identification task than other string instruments. One possible contributing factor is the harmonic structure of a guitar cord. When a guitar is strummed it creates a complex tone with harmonic structure, much like many other instruments. It may be possible that a guitar cord creates a complex tone but with less harmonic structure than other instruments.

The results also suggested that the participants performed highest for the country musical style and poorest for the Latin musical style. According to Gfeller et al. (2005) CI users most accurately identify country music than other musical genres. This may be due to the repetitive and characteristic rhythm, and vocal quality of most country songs (Gfeller et al., 2005). Country music also is very prevalent in the Midwest and may even be considered the most common genre of music in the Midwest. It is possible that CI users perform better on musical identification tasks in which recognizable solo instruments and lyrics are included. In contrast, poor performance demonstrated for the Latin musical style may be attributed to less familiarity with the musical style and lyrics. Monaural CI listeners ranked appreciation and naturalness significantly higher than their performance (in percent correct) in the identification of musical styles task, where jazz music and rock and roll music were perceived with greater naturalness and appreciation than was evident in performance. This finding indicated that perceptually CI users may be over estimating how well they are performing.

A second finding was that the results showed a positive relationship between music appreciation and performance for the binaural mode and sound field medium, whereas there was no relationship observed for the monaural mode and both the sound field and direct connect mediums. Performance across music styles for binaural listeners was significantly greater for appreciation than percent correct performance and naturalness. This suggested that the listeners found the music to be more pleasant while listening binaurally in the sound field than monaurally in both the sound field and direct connect mediums. Additionally, the results suggested a negative relationship between naturalness rating and performance when listening monaurally through the direct connect medium, but a positive relationship between naturalness rating and performance when listening binaurally through the sound field medium. The implication is that in the direct connect medium the listeners perceived the music as natural regardless of their ability to identify the style of the musical piece. Furthermore, a positive relationship existed between performance and music naturalness when listening binaurally in the sound field.

Finally, the results from the current study suggested that when comparing the use of direct connect and sound field presentation mediums there was no difference in the CI users music perception abilities for either identification of musical style or instrument identification. In addition, there was no significant effect of connection for percent correct, appreciation or naturalness which indicated that using direct connect input did not improve the performance of the CI users. This lack of a difference between input may reflect a true lack of difference in performance on the AMICI between direct connect and sound field input, or it may be due to a lack of statistical power from the small sample size. The performance on the AMICI, although providing information on performance tasks, may not address an aspect of appreciation or naturalness that represents music enjoyment. Further, it is possible that because the subjective measurements were based on personal judgement they may have been affected by music preference or individual attitude whereas the perceptual measures were based on a performance score.

The results from the current study bring into question the suggestion that the use of direct connect input will improve music listening and more specifically, music perception for CI users. This result is important as it may impact the specific recommendations clinicians provide to people with CIs during counseling about music perception, and expectations for different inputs for music listening. Despite no improvement in performance through the use of direct connect, listeners did rate naturalness and appreciation higher for the direct connect presentation medium when compared to the sound field presentation medium. More specifically, performance for naturalness for monaural listeners was significantly greater with direct connect input than with sound field input. This finding is in agreement with manufacturer recommendations that music listening may be more enjoyable with the use of direct connect input than with sound field input (Advanced Bionics, 2011; Cochlear Americas, 2009; Med -El, 2010). In addition, Davies et al. (2001) found that using FM systems with direct connect input produced a mean speech perception score of 70 percent with children over the age of 10 years. Without the use of an FM system, speech perception scores decreased 17% at -3 SNR. These findings supported the use of FM systems with direct connect to benefit speech perception in children. The implication is that musical stimuli were more enjoyable and sounded more natural to the participants with the use of the direct connect input because of the association with increased speech perception abilities and possibly lyric identification. A final observation is that during data collection it was noted that participants assigning highest appreciation and naturalness ratings demonstrated extremely positive personalities during data collection. Future studies may investigate the relationship between participant attitude and appreciation and naturalness ratings.

The use of direct connect input while listening to music could provide listeners who have CIs with improved naturalness and appreciation for music. As mentioned previously, music listening and enjoyment are difficult for listeners with CIs, which argues for recommending direct connect audio input as a tool for improving music appreciation and naturalness. However, this recommendation cannot be made solely for the purpose of improving music perception ability. Providing listeners with CIs a means to better enjoy and appreciate music may contribute to their ability to enjoy music, increase satisfaction with the device and improve quality of life through music appreciation and enjoyment.

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