Music (Indian Music) Perception Test Battery for Individuals using Hearing Devices

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Abstract

The main objective of the present study was to develop a music perception test battery which can be utilized by those using hearing devices in Indian context. The music perception test battery consists of five tests. They are, pitch discrimination test, pitch ranking test, rhythm discrimination test, melody recognition test and instrument identification test. These tests assess the pitch, rhythm, melody and timber parameters of music perception. The music perception abilities were compared across four groups; normal hearing who were trained in music, normal hearing who were untrained in music, participants who were users of hearing aids and participants who were users of cochlear implants. It was found that individuals with normal hearing who were trained in music performed equally well on all tests of music perception. However, individuals with normal hearing who were not trained in music, scored well on pitch discrimination, rhythm discrimination, and melody recognition tasks. Hence, the music perception test battery developed as a part of this study is a useful test to differentiate the trained and untrained listeners. It was found that the users of cochlear implants performed well on pitch and rhythm discrimination tasks but their performance was reduced on tests related to perception of timber, pitch interval and melody perception. The music perception test battery can be used to assess the efficacy of various hearing devices in processing music.

Key words*: Pitch discrimination & ranking, rhythm, melody, instrument identification.*

Music plays an important role in the everyday life of individuals with normal-hearing as well as those with hearing impairment. For those with hearing impairment, however, the task of listening to music can prove quite challenging and current hearing devices do not often provide much assistance. Historically, hearing devices have been developed with the primary goal of improving speech perception. Because music signals have different acoustic features than speech signals, the speech-centric processing in today's hearing devices may negatively affect music listening (McKinney, 2010).

Acoustically, music and speech are fundamentally similar. Both of them use sound energy, and hence are received and analyzed by the same sense organs. Many of their acoustical features are similar, although used in different ways. Functionally, speech and music are fundamentally different. This is partly because they encode information in a different way (Wolfe, 2002). A full appreciation of music requires the perception of four basic perceptual attributes, i.e., duration, loudness, timber, and pitch as identified by Krumhansl and Iverson, (1992). For those with hearing impairment, the task of listening to music can prove quite challenging and current hearing aids do not often provide much assistance. However, people do not lose their love of music when they lose their hearing, so it is of interest to understand the impact of hearing loss and hearing aid processing on the perception of music (McKinney, 2010).

In recent years, increasing research efforts have been directed towards perception of music through cochlear implant (McDermott, 2004). Users of cochlear implant rank music as the second most important acoustic stimulus in their lives next to understanding speech (Gfeller, Christ, Knutson, Witt, Murray, & Tyler, 2000).

The hearing devices have improved their features to improve the perception of music as well. The test batteries or scales incorporating assessment of some or all the aspects of music perception have been developed to assess music perception in individuals who are users of hearing devices. These parameters include pitch interval, rhythm, timber, melodies and instrument identification. Some of the test batteries are: (1) Seashore Measures of Musical Talent (Seashore, 1919) to assess pitch discrimination, loudness discrimination, rhythm, sense of time, timbre discrimination and tonal memory, (2) Primary Measures of Music Audition or PMMA (Gordon, 1979) to assess tonal and rhythm perception, (3) Montreal Battery for Evaluation of Amusia test or MBEA (Peretz, Champod, & Hyde, 2003). It measures six different aspects of music perception - scale, contour, interval, rhythm, meter, and melody memory. The fourth is Musical Sounds in Cochlear Implant Test (Mu. S. I. C Perception Test) by Fitzgerald (2006). It is a computerized test protocol which consists of six modules and two subjective tests which are as follows; pitch test,

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rhythm test, melody test, distinguish chord test, what instrument test, number of instruments test, emotional response, and dissonance test. (%) Clinical Assessment of Music Perception or CAMP (Nimmons et al., 2008) is a computerized test to measure three different aspects of music perception-pitch direction discrimination, melody identification, and timbre identification. (5) Appreciation of music in cochlear implantees or AMICI (Spitzer, Mancuso & Cheng, 2008) to measure the discrimination of music versus noise, identification of musical instruments, musical styles (closed set) and to recognize individual musical pieces (open set).

In the Indian scenario, tests incorporating assessment tools for the evaluation of speech recognition ability and speech discrimination ability exists, which can be utilized to evaluate the benefit from a hearing device. It is relatively straightforward to measure speech intelligibility through metrics like the word-recognition scores. Listeners are asked to identify spoken words under various conditions and their recognition score is taken as a measure of intelligibility. We have no such straightforward method to measure 'music intelligibility' in general. Instead, we can break music up into its constituent elements (pitch, harmony, rhythm and timbre) and assess the perception of these elements in a focused and independent manner (McKinney, 2010).

Early results indicate that if protocols are tuned well, we can measure deficits in the ability to discriminate pitch and timbre in listeners with hearing impairment. Other researchers have proposed similar ideas, such as Russo's (2009) functional hearing test for musicians. Collectively, these protocols could be combined to form a general test for music intelligibility. Such a test would guide the development of signal processing strategies for music processing in hearing devices and allow us to make evidence-based decisions on the correct strategies to pursue.

Hence, there is a need to compile a test battery of music perception, which could be implemented in Indian context and which could efficiently be used during evaluation of a hearing device in an individual who would be interested in listening to music. In addition, results of music perception test battery can be used to improve technology of the hearing device. This would also enable to assess the effectiveness of music training.

In addition to research on individual features of musical signals, a method or protocol to quantitatively evaluate the reception of music information is needed. Thus, the present study aimed at developing a music perception test battery.

The aim of the study is to: (1)To compile music perception test battery in the context of Indian music. (2) To assess the music perception ability of individuals with normal hearing, who are trained in music. (3) To assess the music perception ability of individuals with normal hearing, who are not trained in music. (4) To assess the music perception ability of individuals with hearing impairment who are users of hearing devices i.e., users of hearing aid or cochlear implant. (5) To compare the performance across the groups on various music perception tests.

Method

Participants: Four groups of participants were included in the study; the groups were Group-A, Group-B, Group-C, and Group-D. Ten participants in the age range of 18 to 25 years (mean = 22.00, SD=1.88) were included in each of the Groups A. Group-B also consisted of ten participants in the age range of 18 to 54 years (mean = 28.50, SD= 9.99). In Group-C, 11 participants, who were users of hearing aids, in the age range of 22 to 55 years (mean = 39.22, SD = 12.74) were included. Group-D consisted of five participants who were users of cochlear implants, in the age range of 20 to 61 years (mean = 39.53, SD = 13.58).

Inclusion criteria for participants in Group A and B was hearing within normal limits. Their hearing thresholds in both ears were <15 dB HL at octave intervals between 250 Hz and 8 kHz and speech identification scores were >80%. Participants with normal hearing, who were trained in music, were included in Group A and participants with normal hearing, who did not receive any training in music, were included in Group B. The exclusion criteria were presence of any significant complaint/ history of neurological/psychological deficit.

All the participants were conversant in one of the following languages, i.e.,Hindi/Kannada/English. The participants in Groups C and D had post-lingual acquired bilateral moderate to profound hearing loss with adequate speech and language. The duration of hearing loss was at least one year. All of them had a minimum experience of at least 6 months in hearing device use.

Instruments & test material: A calibrated sound field audiometer was used to administer the music perception test battery. The azimuth of the loudspeaker placement was 0 degree at a distance of one meter from the participant. Two phonemically balanced (PB) word lists (Vandana, 1998) in Kannada were used. Each list consists of 25 words. A questionnaire on music training and experience questionnaire (adapted from Looi, 2008) was used to categorize the participants into trained and untrained groups. Audacity1.3 Beta and Adobe Audition 3 software were used to record the music samples used for the construction of the test. This laptop computer was connected to the auxiliary input of the audiometer for routing the stimuli through the loudspeaker (Martin Audio, C115) of the audiometer.

Procedure

The study was conducted in three stages:

Stage 1- Compilation of the test battery for music perception: A test battery for music perception was developed. This test battery consisted of five parameters. They are (1) Pitch discrimination test (2) Pitch ranking test (3) Rhythm discrimination test (4) Melody recognition test (5) Instrument identification test

Pitch discrimination test: In this sub-test, the task of the participant is to indicate if the pair of musical notes generated from a harmonium is "same" or "different".

Stimuli: A professional harmonium player played four 'sa' notes, each at different pitches on harmonium. Each note was played for duration of three seconds. A WAV file consisting of two practice items + ten test items was created by utilizing the Adobe Audition 3 software. Each practice /test item consisted of pairs of musical notes. The duration of each musical note in the stimuli pair was three seconds, and within each pair, notes were separated by a silence interval of two seconds.

Example of stimuli: A pair of musical notes .i.e., /sa/ note at low pitch and /sa/ note at high pitch. The task is to indicate whether the given stimuli have "same" or "different" notes or pitches.

Instructions for pitch discrimination task: The instructions shall be as follows: You will be hearing to a pair of musical notes. After listening to it, you will have to indicate whether the notes in that pair were same or different. You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every pair of notes. There are 12 pairs of musical notes, the first two are the practice items and the next ten are test items.

Scoring: For each item, a score of '1' is assigned for every correct response and '0' for every incorrect response. The maximum score for this test will be 10 as the total number of test stimuli in this test are ten.

Pitch ranking test: In this sub-test, the participant will be presented a pair of musical (vocal) notes in differing pitches; the task of the participant is to identify the higher note of each stimuli pair.

Stimuli: Recording of the vowels /a/ was obtained from trained male and female singers using an external microphone connected to the laptop computer. They were asked to sustain phonation of /a/ at a', b', c', d', e', f', g', which represents the notes at half octave interval. They were also asked to sustain phonation of /a/ at quarter octave intervals. The group normalized waveforms were utilized to develop three new WAV files constituting three sub-tests as a part of pitch ranking task, i.e., subtest-A, subtest-B, and subtest-C. Each of these sub-tests consists of eight stimuli pairs (two practice stimuli, one catch trial stimulus, and five test stimuli). Each stimulus pair consists of two notes (/a/ note sung at two pitches; differing in either one, half or quarter octave; sung by the same singer at the designated interval). Subtest-A, consisted of stimuli pairs having a difference of one octave between the two notes in a given pair. Likewise, Subtests-B and C consisted of stimuli pairs with half octave and quarter octave intervals between the two notes in a given stimulus pair respectively.

Instructions for pitch ranking task: You will be hearing to a pair of musical notes. After listening to it you will have to indicate which one of the two in that pair was higher in pitch. You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every task. There will be three sub-tests (A, B and C), each sub-test will consist of two practice items and six test items.

Scoring: In each sub-test, for each item a score of '1' for every correct response and '0' for every incorrect response is allotted. The maximum score for this test will be 15 (i.e.,3 subtests * 5) as it consisted of three sub-tests with five test stimuli each.

Rhythm discrimination test: In this test, the participant will be presented a pair of rhythm excerpts; the task of the participant is to discriminate whether the pair of items is "same" or "different".

Stimuli: A tabla player was asked to play five different rhythm patterns each of which was 15 seconds in duration. All of the waveforms were then group normalized and a WAV file containing 12 stimuli pairs of rhythm excerpts were created utilizing the Adobe Audition 3 software. Out of the 12 stimuli pairs, the initial two stimuli pairs were kept as practice items and the rest were used as test items. The duration of each rhythm excerpt in stimuli pair was 7 seconds. In each pair, the rhythm excerpts were separated by three seconds of silence. Two subsequent stimuli pairs were separated by a gap of approximately five seconds.

Instructions for rhythm discrimination task: You will be hearing to a pair of rhythm excerpts. After listening to it you will have to indicate whether the rhythm excerpts in that pair were "same" or "different". You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every pair of rhythm excerpt. There will be 12 items, with two practice items and ten test items.

Scoring: For each item, a score of '1' is allotted for every correct response and '0' for every incorrect response. The maximum score for this test will be 10 as the total number of test items is 10 in this test.

Melody recognition test: In this sub-test, the participant will be presented the melody played on a Violin at a time, task of the participant is to identify (name or hum) the melody perceived following presentation of each test stimuli.

Stimuli: In order to select five melodies for the test, a list consisting of names of seven well-known melodies was given to 10 individuals with normal hearing and not trained in music. They were asked to rate each of the given melody with respect to their familiarity with the particular melody. A three point rating scale was given, where, 1= common/well-known, 2= heard but not often, 3= unknown. Based upon the familiarity rating, the five melodies were selected. The test comprised of the melodies of Saare jahan se achha, Vande mataram, Ae malik tere bande hum, Raghupati raghav raja ram, and Hum honge kaamyab, A professional violinist was asked to play all of the selected melodies on violin at an appropriate tempo. A new WAV file consisting of two practice stimuli and ten test stimuli was created using the group normalized stimuli. The duration of each stimuli in melody recognition sub-test was15 seconds.

Instructions for melody recognition task: You will be given a list of names of the five melodies. You will be listening to one melody at a time. You will have to either name that melody or hum the melody. You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every item. There will be 12 stimuli, of which two are practice items and ten are test items.

Scoring: For each item, score of '1' is allotted for every correct response and '0' for every incorrect response. The maximum score for this test will be ten, as there are ten test stimuli in this test.

Instrument identification test: In this test, the participant will be presented a musical piece of an instrument/s at a time, the task of the participant is to identify the instrument or instruments, present in a given test stimulus.

Stimuli: This test comprised of two sub-tests.

(a) Single instrument identification sub-test:

Ten instruments were selected. They were sitar, jal tarang, veena, tabla, harmonium, flute, mridangam, dhol, nadaswaram, and violin. For each sub-test, one or two 5 second extracts of ten earlier mentioned instruments or ensembles were either recorded for the purpose or extracted from the commercially available CD albums. This sub-test consisted of two practice and 10 test items. In a single instrument identification sub-test, the duration of each stimulus was approximately five seconds, and the gap between two subsequent stimuli was also five seconds in duration.

Instructions for single instrument identification task: The instructions for administration of this test were as follows: You will be presented with musical sound of ten musical instruments. You will be listening to one musical instrument being played at a time. You will have to identify and name that instrument. You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every item. There will be 12 items, two practice items and ten test items.

Scoring: In this sub-test, for each item, a score of '1' is assigned for every correct identification of the instrument and '0' for every incorrect identification. The maximum score for this sub-test will be 10.

(b) Music ensemble sub-test.

Stimuli: Ten instruments were selected. They were sitar, jal tarang, veena, tabla, harmonium, flute, mridangam, dhol, nadaswaram, and violin. For this sub-test, two 5 second extracts of ten earlier mentioned instruments were either recorded for the purpose or extracted from CD albums commercially available.This sub-test consisted of two practice and 10 test items. In music ensemble sub-test, each stimulus comprised of two pieces of instrumental music grouped together, each musical piece taken from any of the ten above mentioned instruments being played simultaneously. i.e., sitar and veena duet; flute and tabla duet; violin and nadaswaram duet, flute and sitar duet; violin and harmonium duet; flute and dhol duet; mridangam and tabla duet and violin and mridangam duet; harmonium and nadaswaram duet; sitar and flute duet; jaltarang and sitar duet ; and harmonium and sitar duet.

Instructions for music ensemble identification task: You will be presented with 12 instrumental duets (musical ensembles).You will be listening to one musical ensemble consisting of two (duet) instrumental sounds at a time, you will have to identify and name the two musical instruments present in a given duet. You will be given a response sheet, wherein you will have to put a tick mark (√) below the most appropriate response for every item. For example, if you hear a duet of flute and dhol, you have to put a '√' mark for both flute and dhol. There will be 12 items, with two practice items and ten test items.

Scoring: In this sub-test, for each item, a score of '1' is assigned for every correct identification of the instrument and '0' for every incorrect identification. The maximum score for this sub-test will be 10. Total maximum score for instrument identification test will be 20 as this test consists of 10 test stimuli in each sub-test.

Stage 2: Selection of participants under different groups

To ensure normal hearing among participants included in Groups A and B, and to ensure that all the participants who are users of hearing devices in Groups C and D met the criteria for inclusion in the study, the air conduction and bone conduction thresholds of all the participants of Groups A, B, C and D were obtained using a calibrated audiometer. The speech identification scores (SIS) were obtained at 40 dB HL for all the participants in Groups A (unaided), B (unaided), C (aided), and D (aided) by using phonemically balanced word list (Vandana, 1998). For SIS, the stimuli were presented using monitored live voice through the loud speaker of the audiometer.

All the participants were asked to fill-in the given music training and experience questionnaire (adapted from Looi, 2008). The music training and experience questionnaire consisted of six questions. First four questions were intended to seek information regarding areas in which musical training has been taken, i.e., formal training in vocal and / or instrument/instruments. The fifth question probed regarding, the duration of listening to music on everyday basis. The sixth question probed proficiency in five skills related to music using a five point rating scale. A cut-off criterion of 15 out of the maximum score of 25 was kept in order to consider a participant as 'trained' in music. In order to achieve this participant has to score at least three out of five in each of the five questions.

The participants were classified as follows:

Group A- individuals with normal hearing, untrained in music.

Group B- individuals with normal hearing, trained in music.

Group C- individuals with hearing loss, either trained or untrained in music, who were users of hearing aids.

Group D- individuals with hearing loss, either trained or untrained in music, who were users of cochlear implants.

Stage 3: Administration of the test battery:

The participant was seated at the calibrated position in the sound field. The music test battery from the laptop computer was routed via auxiliary input of the audiometer. The sound field speaker was positioned at zero degree azimuth at a distance of one meter in front of the participant. The presentation level of stimuli for all the tests was kept at 40 dB HL. Before administrating the music test battery, a response was given to each of the participant as mentioned in each test.

Table 1. Mean and Standard deviation (SD) values of speech Identification scores for four groups of participants

Speech identification Score (Maximum score=25)	Group-A (N= 10) (Trained)		Group-B (N= 10) (Untrained)		Group-C (N=11) (Hearing aid users)		Group-D (N= 5) (CI users)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
	25.00	0.00	24.40	1.07	16.73	3.90	14.00	5.47

Table 2. Mean, standard deviation (SD) and 95th percentile of group A (N=10) on different tests of music perception test battery

Test		Maximum score	Mean	SD	95th percentile
1.	Pitch discrimination test	10	9.90	0.31	10
2A.	Pitch ranking (sub-test A)	5	5.00	0.00	5
2B.	Pitch ranking (sub-test B)	5	4.90	0.31	5
2C.	Pitch ranking (sub-test C)	5	4.50	0.52	5
3.	Rhythm discrimination test	10	9.50	0.70	10
4.	Melody recognition test	10	10.00	0.00	10
5A.	Instrument identification test (single instrument identification sub-test)	10	9.30	0.82	10
5B.	Instrument identification test (music ensemble identification sub-test)	10	8.50	1.17	10

The overall duration for administration of music perception test battery was 25 minutes. Each of the above tests was administered on all the participants. A response sheet was developed which was used by the participants to write down their responses when the music perception test battery was administered? Scoring was done separately for each sub-test and then summed. The maximum score was 65.

Results and Discussion

Speech identification performance: The mean and SD values obtained on open set speech identification test administered in audio mode (maximum score =25) for Groups A, B, C, and D are depicted in Table 1.

Results obtained from speech identification scores revealed that Groups A and B performed similarly on speech identification test. Scores obtained by the participants of Groups C and D were reduced, which could be attributed to presence of hearing impairment in these participants.

Performance of the Participants in Group-A on Music Perception Tests: The mean, standard deviation (SD) and 95th Percentile values of the performance on all the tests of music perception test battery were obtained for Group-A, Group B, Group C & Group D is given in Table 2, 3, 4 and 5 respectively.

Comparison between the groups based upon music training and experience scores: As can be seen In Table 6, mean and SD values for each of the groups on music training and experience are calculated. Results obtained from MANOVA showed that there was a statistically significant difference between groups, with $F(2, 28) = 84.990$, $p = 0.000$. Results obtained from Duncan's Post-Hoc analysis suggested that there was a significance difference between Groups A and B, Groups A and C but there was no significant difference between Groups B and C with respect to performance on music training and experience scores.

Similarly, performance of Group-D was compared with that of Groups A, B and C by administering Mann-Whitney U test. There was a significant difference between Groups A and D with, $/Z/ = 3.147$, $p = 0.002$. There was no significant difference between Groups B and D (users of cochlear implants) with, $/Z/ = 1.750$, $p = 0.001$. There was no significant difference between Groups C and D with, $/Z/ = 1.185$, $p = 0.236$. These differences in music training and experience scores between the groups can be attributed to effect of training in music.

It was found that even individuals with normal hearing with good speech identification scores though, who are not trained in music found difficulty in perception of pitch interval (quarter octave) which demands training related expertise to perceive the quarter octave interval change in pitch. In addition, timber perception also requires prior knowledge in music or training.

Table 3. Mean, standard deviation (SD) and 95th percentile values of group-B (N=10) on different tests of Music Perception Test Battery

	Test	Maximum score	Mean	SD	95th percentile
1.	Pitch discrimination test	10	9.70	0.67	10
2A.	Pitch ranking (sub-test A)	5	3.60	0.96	5
2B.	Pitch ranking (sub-test B)	5	3.50	1.26	5
2C.	Pitch ranking (sub-test C)	5	3.00	0.94	4
3.	Rhythm discrimination test	10	8.90	0.99	10
4.	Melody recognition test	10	9.90	0.31	10
5A.	Instrument identification test (single instrument identification sub-test)	10	7.16	1.52	9
5B.	Instrument identification test (music ensemble identification sub-test)	10	4.60	2.27	9

Table 4. Mean, standard deviation (SD) and 95th percentile of group-C (N=11) on Different Tests of Music Perception Test Battery

	Test	Maximum score	Mean	SD	95th percentile
1.	Pitch discrimination	10	9.36	0.92	10
2A.	Pitch ranking (sub-test A)	5	3.36	0.67	5
2B.	Pitch ranking (sub-test B)	5	2.36	1.74	5
2C.	Pitch ranking (sub-test C)	5	1.64	1.02	4
3.	Rhythm discrimination test	10	8.64	0.92	10
4.	Melody recognition test	10	7.45	3.41	10
5A.	Instrument identification test (single instrument identification sub-test)	10	6.09	2.25	10
5B.	Instrument identification test (music ensemble identification sub-test)	10	3.73	1.73	6

Comparison of pitch discrimination test results between the groups: As can be seen in Table 7, the mean scores and SD values for each of the groups are given. The results obtained from MANOVA and Mann-Whitney U test showed no significant difference between the groups on pitch discrimination task. There was no effect of hearing impairment or hearing devices on the performance. This could be due to wider differences between stimuli pairs being used for this task, making the task easy. These findings are consistent with the results obtained by Leal et al. (2003) who reported that cochlear implant listeners obtained better results on pitch discrimination task.

Comparison of pitch ranking test results between the groups: As shown in Table 8, summarizes the mean scores and SD values for each of the groups on the three sub-tests of the pitch ranking test.

Results of pitch ranking test revealed that the performance of individuals with normal hearing (trained in music) was significantly better than individuals with normal hearing (untrained in music), hearing aid users and cochlear implant users. This can be attributed to effect of training. Sucher and McDermott (2007) reported that prior musical experience was found to be associated with

Table 5. Mean, standard deviation (SD) and 95th percentile values calculated for group-D (N=5) on different tests of music perception test battery

	Test	Maximum score	Mean	SD	95th percentile
1.	Pitch discrimination	10	9.40	0.89	10
2A.	Pitch ranking (sub-test A)	5	1.80	0.83	3
2B.	Pitch ranking (sub-test B)	5	2.00	1.58	4
2C.	Pitch ranking (sub-test C)	5	1.80	1.48	4
3.	Rhythm discrimination test	10	9.00	1.00	10
4.	Melody recognition test	10	4.40	3.05	9
5A.	Instrument identification test (single instrument identification sub-test)	10	4.00	1.87	6
5B.	Instrument identification test (music ensemble identification sub-test)	10	1.60	1.51	3

Table 6. Mean and SD Values in four groups of participants for music training and experience scores

Participants	Groups	N	Mean	SD
Individuals with normal hearing	A (Trained)	10	18.10	0.99
	B (Untrained)	10	7.00	1.94
Individuals with hearing impairment	C (Hearing aid users)	11	6.55	3.17
	D (CI users)	05	5.40	0.89

Table 7. Mean Scores and standard deviation (SD) Values for groups A, B and C for pitch discrimination test

Participants	Groups	N	Mean (Max score = 10)	SD
Individuals with normal hearing	A (Trained)	10	9.90	0.31
	B(Untrained)	10	9.70	0.67
Individuals with hearing impairment	C (Hearing aid users)	11	9.36	0.92
	D (CI users)	5	9.40	0.89

Table 8. Mean and SD Values found for groups A, B, C and D for the three Sub-tests of Pitch ranking test

Participants	Groups	N	Sub-test A (max score= 5)		Sub-test B (max score= 5)		Sub-test C (max score= 5)	
			Mean	SD	Mean	SD	Mean	SD
Individuals with normal hearing	A (Trained)	10	5.00	0.00	4.90	0.31	4.50	0.52
	B (Untrained)	10	3.60	0.96	3.50	1.26	3.00	0.94
Individuals with hearing impairment	C (Hearing aid users)	11	3.36	0.67	2.36	1.74	1.64	1.02
	D (CI users)	5	1.80	0.83	2.00	1.58	1.80	1.48

higher scores on pitch-ranking test for the individuals with normal hearing.

The performance of hearing aid users was similar to that of Group B (individuals with normal hearing, untrained in music) on sub-test A and B. However their performance was significantly lesser than that Group B for sub- test C. Performance of cochlear implant users were equivalently reduced for all the three sub-tests. Pijl & Schwarz (1995) reported that encoding strategies that are highly successful in restoring speech understanding do not necessarily provide information regarding melodic pitch interval size. Hence, pitch interval information does not appear to be available to cochlear implant recipients when they were listening to acoustical stimuli via their speech processors. It was found that performance of cochlear implant users was similar to that of hearing aid users for sub-test-B and C and it was different for sub-test-A. However, Looi, McDermott, McKay, and Hickson, (2004) and Looi (2008) reported that hearing aid users were found to obtain higher scores than users of cochlear implant. They also reported that cochlear implant recipients' performance on quarter octave pitch test was at chance level, with no significant difference between scores for the half and one octave interval. The differences in the findings of present study could be due to music experience, as more than 50% of the participants in that study were trained in music.

Comparison of performance on rhythm discrimination test between the groups: As can be seen in Table 9, depicts the mean scores and SD values on the rhythm discrimination test for each of the groups.

Findings obtained for rhythm discrimination test revealed no significant differences between groups. This finding is in consonance with that reported by Geiserrab, Ziegler, Lutz, and Martin (2009). They reported that non-musicians are as proficient as musicians when it comes to rhythm perception, suggesting that correct rhythm perception is crucial not only for musicians but for every individual.

Gfeller and Lansing (1991) have reported that adult cochlear implant users's percent correct performance on rhythm sub-test was 88%. Other studies also report that people with hearing impairment, including both cochlear implant and hearing aid users, perceive musical rhythm approximately as well as those with normal hearing (Darrow, 1979; 1984).

Similar findings have been reported by Cooper, Tobey, and Loizou (2003) wherein cochlear implant recipient's and normal hearing listeners scores were higher on rhythm sub-test than pitch based tests. Looi (2008) also reported in their study that the average scores of cochlear implant users was 93% correct and hearing aid user's average score was 94% correct, suggesting no significant difference between the two groups.

The findings of the present study are consistent with the literature indicating that participants with hearing impairments can generally discriminate rhythms as well as those with normal hearing (Gfeller & Lansing, 1991). The perception of rhythm requires the perception of the time-varying envelope fluctuations that occur in the frequency range of approximately 0.2 Hz to 20 Hz (McDermott, 2004). These low rates provide amplitude envelope information, which for music, corresponds to the gross rhythm and tempo of the stimuli.

Comparison of melody recognition test results between the groups: In Table 10, the mean scores and SD values for each of the groups are calculated.

It has been observed that among individuals with normal hearing there was no significant difference between those trained in music and untrained in music based on melody perception test. In addition, it was found that the performance of normal hearing groups was significantly different from that of hearing aid users and cochlear implant users.

Table 9. Mean and SD values found for Groups A, B, C and D for rhythm discrimination test

Participants	Groups	N	Mean (Maximum score= 10)	SD
Individuals with normal hearing	A (Trained)	10	9.50	.70
	B(Untrained)	10	8.90	.99
Individuals with hearing impairment	C (Hearing aid users)	11	8.64	.92
	D (CI users)	5	9.00	1.00

Table 10. Mean and SD for each group are shown for melody recognition test

Participants	Groups	N	Mean (Maximum score= 10)	SD
Individuals with normal hearing	A (Trained)	10	10	0.00
	B(Untrained)	10	9.90	0.31
Individuals with hearing impairment	C (Hearing aid users)	11	7.45	3.41
	D (CI users)	5	4.40	3.05

Table 11. Mean and SD found for groups A, B, C and D for Instrument identification test

Participants	Groups	N	Single instrument identification sub-test (Maximum score = 10)		Music ensemble identification sub-test (Maximum score = 10)	
			Mean	SD	Mean	SD
Individuals with normal hearing	A (Trained)	10	9.30	.823	8.50	1.179
	B (Untrained)	10	7.10	1.524	4.60	2.271
Individuals with hearing impairment	C (Hearing aid users)	11	6.09	2.256	3.73	1.737
	D (CI users)	5	4.00	1.871	1.60	1.517

Gefeller, Woodworth, Robin, Witt, and Knutson, (2002) found that normal-hearing adults were significantly more accurate than cochlear implant recipients for familiar melody recognition task. Findings of the studies conducted by Looi et al. (2004) revealed that cochlear implant listeners scored lower than those with normal hearing.

Similar findings have been reported by Gfeller, Olszewski, Rychener, Sena, Knutson, Witt and Macpherson (2005). They found that cochlear implant users were not nearly as good as normal hearing listeners at identifying real-world melodies. Nimmons et al. (2007) reported a mean score of 23% correct for eight cochlear implant listeners.

In the present study, based on mean scores, the hearing aid users performed better than the cochlear implant users, but the difference was not statistically significant. However, Looi, McDermott, McKay, & Hickson (2008) reported that there was a significant difference between the mean percentage score of (52%) of cochlear implantees and the hearing aid users (91%). These differences could be attributed to factors such as familiarity and enjoyment of music.

Comparison of instrument identification test results between the groups:The Table 11 reveals the mean scores and SD values for each of the groups on single instrument identification and music ensemble identification tests.

Results obtained from the group comparison on single instrument identification test reveals that the performance of individuals with normal hearing trained in music was better than that of individuals with normal hearing (without training in music), hearing aid users and CI users. The better performance of individual with normal hearing (trained in music) on single instrument could be attributed to the effect of training in music. Kraus, Skoe, Clark, and Ashley (2009) in a study had reported that musically trained individuals are found to have enhanced sub-cortical representations of pitch, timbre, and timing. Rentz (1992) had also reported that musicians indicated focus on three or more instrumental families simultaneously more than did non-musicians.

Fitz, Burk, and McKinney (2009) reported that people with hearing loss are able to discriminate musical instrument timbres, though somewhat less effectively than people with normal hearing. Looi, McDermott, McKay, & Hickson (2008) reported that the least performance by cochlear implant user the degree of discreteness of electrode stimulation sites, and thus the spectral selectivity is not nearly as precise as it is for individuals with normal hearing.

In the present study, it was found that the performance of cochlear implant users was least precise among all the groups. Studies on assessment of timber perception in cochlear implant users have also found similar findings. Gfeller, Witt, Woodworth, Mehr, and Knutson (2002) reported a mean performance of 47 % correct. McDermott (2004) reported that cochlear implant users scored a mean score of 44% correct and Nimmons et al. (2008) had also found similar results, reporting the mean timbre recognition 49% correct scored by cochlear implant users.

All of these studies suggest that the performance of cochlear implant users was below chance level on single instrument identification test it was observed that in the present study there was no significant differences between the performance of hearing aid users and individuals with normal hearing (untrained in music) on single instrument identification test. Although there was a difference in scores obtained for users of hearing aids group and cochlear implant users group, these differences between these two groups was not statistically significant on single instrument identification test, whereas, these difference are statistically significant on music ensemble identification test. The additional instruments present in the music ensemble identification sub-test, added to the complexity of the sound, which seemed to negatively affect the perception of the stimuli in individuals with hearing impairment, irrespective of the type of device being used (Looi et al. 2008).

Reliability Check of Music Perception Test Battery: In order to assess the reliability of tests of music perception, performance of two randomly selected participants from each of the four groups was re-assessed using music perception test battery. Table 4.13 summarizes the raw scores obtained in first trial and second trial, performed with in 10 to 15 days of first trial.

Since, two participants from each of the four groups were selected for reliability check no statistical analysis was done. Visual inspection of scores obtained on Trial 1 and Trial 2 revealed that there was no much variation in the scores in all the groups on all music perception tests.

In the present study, it was found that individuals with normal hearing who were trained in music performed equivalently well on all tests of music perception. However, individuals with normal hearing who were not trained in music, scored well on pitch discrimination, rhythm discrimination, and melody recognition task. They reported difficulty in ranking quarter octave pitch interval and identification of music ensembles. The study also revealed that users of hearing aids did not found any difficulty performing pitch discrimination and rhythm discrimination task. Similar to untrained individuals with normal hearing, they also found pitch ranking, instrument identification test difficult. However, unlike untrained individuals with normal hearing their performance was reduced on melody recognition tasks.

It was found that performance of users of cochlear implants performed well on pitch and rhythm discrimination task but their performance was reduced on tests related perception to perception of timber, pitch interval and melody perception. Looi et al. (2004) investigated the pitch discrimination and melody recognition abilities of cochlear implant (CI) users. Their results indicated that cochlear implant participants scored significantly lower than those with normal hearing on all tests (p<0.001). Galvin, Fu and Oba (2009) reported that the reduced performance on pitch ranking test and timber identification test could be due to inability to access fundamental frequency variation cues and timber cues.

Consistent with previous research, this study too found that the CI users found it difficult to perform on tests involving pitch, instrument identification, or melody perception than those involving just rhythm perception (Dorman, Basham, McCandless, G., & Dove et al., 1991; Fujita & Ito, 1999; Gfeller & Lansing, 1991, 1992; Gfeller et al, 1997, 1998, 2002; Leal et al., 2003; McDermott, 2004; Schulz & Kerber, 1994).

Conclusions

The results obtained from the group comparison on instrument identification test reveals that the performance of individuals with normal hearing (trained in music) was better than that of individuals with normal hearing (without training in music), hearing aid users and cochlear implant users. The better performance of individual with normal hearing (trained in music) on single instrument could be attributed to effect of training in music. Hence the music perception test battery developed as a part of this study is a useful test to differentiate the trained and untrained listeners.

Implications of the Study

The music perception test battery can be used to assess the efficacy of various hearing devices in processing music. In addition, this battery can be used during pre-operative and post-operative comparison of music listening abilities in individuals who are users of cochlear implant. During ear (music) training programs, progress could be monitored and the efficacy of the program can be assessed. Development of new processing strategies/technology in hearing devices could be facilitated by the use of music perception test battery.

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