Music Perception in Individuals with Audio and Audio-visual Impairment

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Abstract

The study was done to analyze the music perception skills of individuals with audio and audio-visual impairment, so as to see how sensory impairments affect the perception of music in isolation and in combination. A test battery was developed which separately assessed different parameters of music such as pitch, rhythm, melody and timbre. Test was done in three groups of subjects: Individuals with normal hearing sensitivity, individuals with sensorineural hearing loss and, individuals with sensorineural hearing loss associated with visual impairment. Results showed that music perception skills in individuals with sensorineural hearing loss were affected. The music perception skills of those with associated visual impairment were superior to those with only hearing loss. This suggests a change in sensory mechanism of hearing (compared to that in individuals with only hearing loss) in individuals with audio visual impairment which is probably due to cortical reorganization.

Key words: *Music perception, rhythm, timbre, sensory hearing loss, visual impairment.*

Music can be defined as sound that is organized according to principles of pitch, rhythm, harmony and timbres that allow us to differentiate between musical sound sources and identify musical instruments, such as violin, piano, and flute (Sessions, 1950). Throughout all genres and historical epochs of musical composition, the organization of sound according to pitch, rhythm, and harmony has provided the acoustic framework by which we perceive and produce music.

Pitch is often described as the perceptual correlate of fundamental frequency, but other dimensions such as timbre and loudness are also known to influence pitch (Donnelly & Limb, 2008). Rhythm in music describes the temporal features of the music that typically occur on the order of seconds (Donnelly & Limb, 2008). It is a set of beats, made up of sounds and silences. These sounds and silences are put together to form patterns of sounds which are repeated to create rhythm. Several studies indicate that rhythm is crucial to the recognition of a familiar song and, at times can be of greater importance than pitch cues alone (Nimmons et al, 2008; Donnelly & Limb, 2008). Kong, Cruz, Jones and Zeng (2004) reported that individuals with normal hearing had difficulty in identifying musical melodies when rhythmic cues were taken off. According to Donnelly and Limb (2008) a musical phrase, or melody, is created when a series of pitches are sequentially and temporally organized into patterns of varying musical contour and interval. The perception of melody requires the fine discrimination of changes in pitch, including both the direction of change (up or down) and the degree of change (interval size). The psycho acoustic property of timbre permits us to differentiate between two musical instruments playing at the same pitch and volume level (Donnelly & Limb, 2008).

To make music, musicians must be able to produce and keep track of subtle changes that occur along numerous dimensions of sound, often unfolding in parallel over time. To understand music, listeners must be able to perceive and make sense of these subtle changes. Processing a highly structured and complex pattern of sensory input as a unified percept of music is probably one of the most elaborate features of the human brain. It extracts the subtle temporal, spectral information from the signal and deliver to the brain, which is the most wonderful and systematic process done by the auditory system.

How this feature of brain and this process of auditory system are affected by sensory losses like hearing and vision, is to be studied, so that it could help in the rehabilitative aspects of such population. Individuals with sensory loss experience music, and indeed the world around them differently than do individuals with typical hearing and vision (Darrow, 2007).

Sensorineural hearing loss affects the auditory skills like localization abilities, frequency selectivity, pitch discrimination skills, intensity resolution, temporal resolution etc. These deficits will grossly affect the perception of complex stimuli such as speech and music.

Individuals with hearing impairment often perceive music differently from typical hearing listeners, as they miss out certain information due to their hearing loss (Darrow, 2007). Perception of timbre was found to be altered in individuals with sensorineural hearing loss than that of normal hearing individuals (Emiroglu & Kollmeier, 2007). They determined the just noticeable differences (JND) of timbre in normal-hearing and hearing-

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impaired subjects and investigated the variance of JND in silence and different background noise conditions and on different sound levels. The results showed that timbre JNDs of subjects with a steep hearing loss are significantly higher than of normal-hearing subjects, both in silence and noise. Perception of sensory dissonance of pairs of pure tones was also found to be impaired in ears with sensorineural hearing impairment (Tufts & Molis, 2006). Pitch discrimination was also found to be affected in individuals with sensorineural hearing impairment (Berstein & Oxenham, 2006). Results showed an increase in the minimum spacing between harmonics required for Fo DLs to transition from large (poor) to small (good) DL for individuals with sensorineural hearing loss compared to normal listeners.

Hearing loss as measured in audiograms is not a good standard for measuring the music perception ability (Chasin, 2003; Darrow, 2007). So as to configure a hearing aid for improved music perception abilities, we should know how an individual with different degrees of hearing loss perceive music differently from that of normal, in spite of configuring based on the audiogram. It is likely that people with mild and moderate hearing losses should be able to hear the difference when a hearing aid is programmed for a music program (Ross, 2009).

Individuals with visual impairment are commonly thought to have special musical abilities that in some way compensate for their poor vision or lack of sight. For those who are born blind or with very little useful vision (perhaps just being able to perceive light) or who lose their sight early (say up to the age of three or four), the development of musical abilities is often substantially different from normal (Ockelford et al, 2006). Different studies prove the superiority of individuals with visual impairment for the perception of music (Matawa, 2009). These studies show us the evidence of plasticity happening in the brain, to compensate for a sensory loss. If it is associated with a hearing impairment whether the music perception skills are altered than those without a hearing impairment, is to be studied. We need to know whether the plasticity happening in the brain compensate to a certain extent, the auditory perception deficits caused by a sensory hearing loss, thus helps us to rearrange our treatment plans for those individuals with hearing impairment who have an associated visual impairment.

The purpose of present study was to investigate whether individuals with hearing impairment and those with visual impairment associated with the hearing loss, process music as same as those without such sensory losses. For individuals with hearing loss, how much of the musical complexities can be missed out? We know that individuals who have hearing loss often perceive music differently from typical hearing listeners, yet they do have similar musical aptitude, preferences and performance abilities (Darrow, 2007). Can such individuals, even with missing musical information, decode the music in ways similar to hearing individuals?? If different, how is it different? For individuals who have hearing loss along with vision loss, how do they perceive music? Do they perceive music just like individuals with hearing loss alone or with typical vision and hearing or different from all these??. The present study aimed to answer these questions.

Method

Subjects: 61 ears of individuals within the age range of 18 to 55 years who are not trained in music were divided in to 3 groups. Group I includes 15 ears with hearing sensitivity within normal limits, where the air conduction and bone conduction thresholds were $\leq$ 15dB. Group II includes 30 ears with flat sensorineural hearing loss were divided into mild, moderate and moderately severe hearing loss with 10 ears in each group. Group III includes 11 ears with sensorineural hearing loss of those individuals with visual impairment were divided into moderate hearing loss and moderately severe hearing loss with 6 and 5 ears respectively.

The procedure included two phases,

Phase I – Development of test battery for the assessment of music perception skills.

Phase II – Administering the test battery and obtaining the music perception skills in individuals with normal hearing, individuals with hearing impairment and individuals with hearing impairment associated with visual impairment for the four different parameters of music – pitch, rhythm, melody and timbre.

Phase I: A test battery for evaluating the music perception skills was developed based on existing music perception test batteries like Clinical Assessment of Music Perception developed by Nimmons et al. (2008) & Primary Measures of Music Audiation developed by Gordon (1986) (as cited in Gfeller & Lansing, 1991) and from studies reporting test for assessing music perception skills (Leal et al, 2003; Kong et al, 2004; McDermott, 2004; Drennan & Rubinstein, 2008). Suggestions were also taken from experts in the field of music production and speech & hearing. The test included four subtests.

Pitch discrimination: A musically pleasing complex tone played through violin by an expert violinist, with duration of 2550 ms, having spectral peak at 526Hz (C5) was recorded. Four more tones were created from this, whose pitches differed by 1, 2, 3, 4 and 5 semitone tones from the first tone, i.e. the spectral peak were at 526 Hz, 548 Hz, 573 Hz, 622 Hz, 644 Hz & 697 Hz for the five created tones.

Pairs were created with the tones, such that the difference in pitch between the tones in a pair was kept 1, 2, 3, 4 and 5 semitones, which served as five different conditions with difficulty increasing from 5 through 4, 3, 2 to 1. Catch trial pairs were created with both the tones having the same pitch/spectral peak. Total 7 pairs were made. An interval of 1 second was maintained between the two musical samples of each pair.

Rhythm discrimination: Four rhythm patterns from 'Aadi Thala'; of duration 4000 ms played by an expert through mridanga was recorded. The recorded patterns include 4 beats, 3 beats, 5 beats, 7 beats. Pairs were made combining these four rhythm patterns. Catch trial pairs were also created with both of them in the same rhythmic pattern. An interval of 1 second was maintained between the two musical samples of each pair.

Melody discrimination*:* Different melodic patterns were recorded through violin by an expert violinist, with duration of 5000 ms each. Songs from three different categories of Carnatic music were recorded (Folk song, light music, classical music). Two different songs from each category were recorded. Pairs were created combining these. Catch trial were also created with both the songs in a pair in same melody. An interval of 1.5 seconds was maintained between the two melodies of each pair.

Timbre identification*:* Melodic sequences of 12 seconds duration were recorded from 6 different instruments played by experts. The instruments played were flute and harmonium (wind instruments), violin and veena (string instruments) & mridanga and table (percussion instruments). Two different melodies were recorded from each instrument. Total 12 musical samples were recorded and arranged in random order.

The developed test battery was evaluated by 3 experts in the field of speech and hearing & 3 experts in carnatic instruments and appropriate modifications were made based on the suggestions.

Phase II

Subject selection criteria: Subjects with speech recognition thresholds in good agreement with pure tone average and tympanogram revealing normal middle ear functioning were selected for the study.

Procedure

The music test stimuli developed were presented at 40dB SL from a computer through the head phones of the audiometer.Music perception skills were e valuated for the four different parameters.

Practice sessions were given for the subjects in each parameter to get acquainted with the procedure.

Table 1. Subtests of the test battery

Test	Stimulus	Subject task
Pitch discrimi nation	Pairs of musical notes were presented.	Subject had to indicate whether the notes in that pair are same or different.
Melody discrimi nation	Pairs of melodies were presented.	Subject had to indicate whether both the musical pieces in the pair has the same melody or different.
Rhythm discrimi nation	Pairs of rhythm excerpts were presented.	Subject had to indicate whether the items in the pair are same or different.
Timbre identific ation	Melodies played by 6 different instruments were presented.	Subject had to identify the instrument, which is playing the melody from the closed set.

Scoring sheets were used to score the responses. A score of 1 was given for each correct response and 0 for incorrect response. In case of pitch subtest, responses were seen separately for the 5 different difficulty conditions, in terms of the pitch difference between the tones in a pair. For rhythm, melody and timbre subtests, the total scores were seen.

Results

The present study utilized stimuli based on discrete musical elements such as pitch, rhythm, melody and timbre. The performance in all the four subtests for pitch, rhythm, melody and timbre were compared between the three groups:

Group I: Individuals with normal hearing sensitivity and vision

Group II: Individuals with hearing impairment with normal vision (Mild hearing loss, moderate hearing loss & moderately severe hearing loss).

Group III: Individuals with hearing impairment with visual impairment (Moderate hearing loss with visual impairment & moderately severe hearing loss with visual impairment).

Kruskal-Wallis test was administered using (SPSS 16.0) statistical package, to compare the rhythm, melody and timbre performance between the six groups.

Table 2 shows a significant difference between the performances of all the six groups for all the three subtests – rhythm, melody and timbre.

Table 2. Comparison between the six groups for the performance in rhythm, melody and timbre subtests

	Rhythm	Melody	Timbre
'p' for the six groups	0.000*	0.000*	0.000*

* 0.05 level of significance.

Mann-Whitney test was administered further using (SPSS 16.0) statistical package to (1) Compare the perception of rhythm across different groups (2) Compare the perception of melody across different groups (3) Compare the perception of timbre across different groups.

Test for equality of proportion was administered to (1) Compare the perception of pitch across different groups (2) Compare the performance of each group across different difficulty levels (difference of semitones in a pair) (3) Comparison was also done within the groups across different parameters from the mean scores for the three subtests (rhythm, melody & timbre).

Rhythm: Almost all the groups performed similarly (no significant difference) except that of those with moderately severe hearing loss, where they performed significantly poorer than any other groups. Also moderate hearing loss and moderately severe hearing loss with visual impairment performed significantly inferiorly to normal.

Table 3. Mean and standard deviation for the scores of rhythm subtest for all the groups

Group	Rhythm	
	Mean	SD
Normal	10.00	0.000
MHL	10.00	0.000
MdHL	9.80	0.422
MSHL	8.00	0.943
MdHL with VI	10.00	0.000
MSHL with VI	9.80	0.447
Total	9.62	0.840

Melody: Results of Mann-Whitney test showed that, individuals with moderate hearing loss with visual impairment performed similarly (no significant difference) like normal, while all the other groups performed significantly poorer than normal. Individuals with moderately severe hearing loss had the least scores in the melody subtest, which was significantly poorer than individuals with moderately severe hearing loss with visual impairment. Also scores of individuals with moderate hearing loss differed significantly from those of individuals with moderate hearing loss associated with visual impairment.

Timbre: Mann-Whitney test showed that individuals with mild hearing loss and those with moderate hearing loss associated with visual impairment performed similarly (no significant difference) like

Table 4. Mean and standard deviation for the scores of melody subtest for all the six groups

Group	Melody	
	Mean	SD
Normal	9.00	0.000
MHL	8.40	0.516
MdHL	8.00	0.816
MSHL	5.40	1.174
MdHL with VI	8.83	0.408
MSHL with VI	8.00	1.000
Total	8.05	1.407

individuals with normal hearing. Timbre perception of individuals with moderate hearing loss varied significantly from that of moderate hearing loss with visual impairment. Likewise that of moderately severe hearing loss was also significantly different from moderately severe hearing loss with visual impairment.

Table 5. Mean and standard deviation of the scores of timbre subtest for all the six groups

Group	Timbre	
	Mean	SD
Normal	11.40	1.142
MHL	10.30	1.703
MdHL	7.50	1.958
MSHL	6.80	1.814
MdHL with VI	10.33	1.366
MSHL with VI	9.80	0.837
Total	9.59	2.319

Pitch: The pitch subtest included pairs where the tones differed in 1-5 semitones. The pairs in which the tones differed by 5 semitones was the easiest in all groups and those differed in 1 semitone being the toughest. The difficulty level decreased as the difference in semitones increased between the tones in a pair. The different conditions tested were,
Condition 1 - (1 semitone difference within the pair)
Condition 2 - (2 semitones difference within the pair)
Condition 3 - (3 semitones difference within the pair)
Condition 4 - (4 semitones difference within the pair)
Condition 5 - (5 semitones difference within the pair)

Test for equality of proportion was done to (1) Compare the perception of pitch across different groups (2) Compare the performance of each group across different difficulty levels (difference of semitones in a pair)

Comparison across condition within different groups: Test of equality of proportion was performed in order to find the differences, if any, in the pitch scores across different condition within each group. In the normal group, the mild hearing loss group and the moderate hearing loss with visual impairment group, subjects performed equally for all the 5 conditions. In the moderate hearing loss group, the performance for condition 1 was significantly better than any other conditions. Performance for condition 2 was significantly different from all other conditions except condition 3. Condition 3, 4 & 5 yielded equal performance in the moderate hearing loss group. Performance for moderately severe hearing loss group for condition 1&2 and 4&5 were not significantly different, while for all the other condition there showed a significant difference between them. In the moderately severe hearing loss with visual impairment group the performance for condition 1 was significantly better than all other conditions. While the rest of the conditions showed no significant difference in performance between them.

Comparison across groups for the same condition

For condition 1: Normal, mild hearing loss and moderate hearing loss with visual impairment performed almost equally. While the rest of the groups performed inferiorly to that of normal. Moderate hearing loss performed inferiorly to the mild hearing loss group but equally to the moderately severe hearing loss group and moderately severe hearing loss with visual impairment. The performance of moderately severe hearing loss was the worst of all and it was equal to that of moderately severe hearing loss with visual impairment group. The performance of moderate hearing loss with visual impairment differed significantly form that of moderately severe hearing loss with visual impairment.

For condition 2: Normal, mild hearing loss, moderate hearing loss with visual impairment and moderately severe hearing loss with visual impairment performed almost equally. While the rest of the groups performed inferiorly to that of normal. Moderate hearing loss performed inferiorly to the mild hearing loss group but equally to the moderately severe hearing loss group and moderately severe hearing loss with visual impairment. The performance of moderately severe hearing loss was the worst of all and it was equal to that of moderately severe hearing loss with visual impairment group. Both moderate hearing loss with visual impairment and moderately severe hearing loss with visual impairment performed equally.

For condition 3: The performance of moderate hearing loss with visual impairment and moderately severe hearing loss with visual impairment performed inferiorly to that of normal, while all other groups performed equally to that of normal. There was no significant difference between the performances of other groups for condition 3.

For condition 4 & 5: All the groups scored the maximum performance.

Discussion

The performance for the subtests in the test battery by individuals in different groups can be concluded as, rhythm subtest got the maximum scores in all the groups than timbre and melody. It can be because that temporal resolution is less affected by sensory hearing loss as far as the stimulus is audible (Fitzgibbons & Wightman, 1982; Tyler et al, 1982; Glassberg, Moore & Bacon, 1987; Nelson & Thomas, 1997). It is found that individuals with sensory hearing loss depend more on temporal information and less on spectral information than normally hearing individuals (Moore, 1998), which means that they have better temporal resolution than any other process.

Timbre subtest yielded the least scores in all the groups. One of the reasons can be that of the musical experience of the subject. The subjects taken for the study were non trained listeners, the lack of exposure and training can add up to the reduction of scores in timbre perception. Individuals with sensory hearing losses generally do not show an interest to listen to music as their hearing loss affects the perception of music. Another factor is that the cognitive abilities of the subject. Subjects were given practice session for all the six instruments before the testing. Subject's ability to pick up the difference between the qualities of sound can also play a role in the reduction of scores. None of the groups scored 100% in timbre subtest.

In the timbre subtest the maximum confusions were for tabla and mridanga. Another common mistake happened was between harmonium and violin. Harmonium-veena confusion was also present.

In melody subtest only individuals with normal hearing scored 100%. Melody perception was severely impaired in individuals with moderately severe hearing loss (60%). The sensory changes happening in the cochlea as a result of cochlear hearing loss affects the person's skills to correctly track the pitch changes taking place in the signal (Moore & Peters, 1992; Arehart, 1994; Moore, 1998). These findings are been supported by the result of the present study.

In melody subtest the maximum confusion was with light music. Light music was confused with classical music. Also the two different melodies from light music were also found to be difficult to discriminate. The reason may be because that for light music and classical music, the temporal characteristic was almost same. They had almost the similar tempo and rhythm. Thus the rhythmic or temporal cues would be minimal for the discrimination of these two. As the folk song has a faster rhythm and tempo than light music and classical music, there would be more temporal cues and thus the errors were less. As it said that individuals with sensory hearing loss rely more on temporal information than spectral information (Moore, 1998), this difficulty in discriminating light music and classical music can be attributed to the reduced temporal cues. This is been also supported by Kong et al (2004) and Nimmons et al (2008), where they found deteriorated scores in melody identification when the rhythm cues were taken out.

Pitch subtest revealed impaired pitch perception in individuals with cochlear hearing loss. It supports the findings of several studies (Hoekstra & Ritsma, 1977; Rosen, 1987; Moore & Glassberg, 1988; Moore & Peters, 1992; Arehart, 1994) were they found impaired perception of pitch in ears with cochlear hearing loss. Only individuals with normal hearing, mild hearing loss & moderate hearing loss associated with visual impairment were able to make out the difference of 1 semitone between the pitches of two musical samples. Individuals with moderate and moderately severe hearing loss failed to discriminate the difference of 1 semitone. Individuals with moderately severe hearing loss had also problem in discriminating 2 semitones while 50% of ears with moderate hearing loss could make out the difference of 2 semitones. All the groups could easily make out 4 semitone differences. The performance of normal hearing individuals in the pitch subtest is consistent with the findings of Drennan and Rubinstein (2008) where they found that ears with normal hearing could discriminate the difference in pitch of 1 semitone.

The performance of each group for the different subtests is discussed below, mild hearing loss. From the results of the study it is seen that individuals with mild hearing loss are performing almost equal to normal in rhythm, pitch and timbre subtests. The results on pitch subtest do not go with the findings from the study by Halliday and Bishop (2005) where they found elevated frequency DLF for individuals with mild to moderate hearing loss.

While for melody subtest showed a slight deterioration in the performance of individuals with mild hearing loss, which is consistent with the findings of Halliday and Bishop (2005).

Moderate hearing loss: For subjects with moderate hearing loss all the four subtests reduced inferior performance from that of normal. They had difficulty in discriminating two musical samples which differ in 1 semitone and 2 semitones. None of the subjects with moderate hearing loss could discriminate 1 semitone difference, while half of the subject could discriminate 2 semitones difference. This correlates with the study by Halliday and Bishop (2005) where they found elevated frequency DLF for individuals with mild to moderate hearing loss. It suggests the sensory changes happening in the cochlea of an individual with moderate hearing loss affect the music perception skills of the individual.

Moderately severe hearing loss: The scores of individuals with moderately severe hearing loss had the least performance for all the subtests. They showed difficulty in discriminating musical samples which differ in 3 semitones. All of the subjects with moderately severe hearing loss could discriminate 4 semitones difference. Melody subtest especially yielded very poor scores in these individuals with moderately severe hearing loss, suggesting very poor music perception skills. The widening of auditory filters and reduced frequency selectivity seen in these ears as a result of moderately severe sensory hearing loss (Carney & Nelson, 1983; Festen & Plomp, 1983; Nelson, 1991; Moore, 1998) may contribute to these poor scores obtained in the pitch and melody subtests. They also scored poor scores in rhythm subtest, where it suggests deterioration in the temporal processing in these ears.

Moderate hearing loss associated with visual impairment: Individuals with moderate hearing loss associated with visual impairment performed equally to normal for all the four subtests. They performed superior to those with moderate hearing loss with normal vision in all the subtests, which shows superiority in music perception skills for those with visual impairment. This is consistent with the findings of Matawa (2009), where they reported enhanced auditory and musical skills for those who have associated visual impairment. It can be because of the plasticity changes happening in the cortex due to early visual impairment, which to an extent compensate for the sensory disturbances due to cochlear hearing loss.

Moderately severe hearing loss associated with visual impairment: These individuals performed poorly when compared to individuals with normal hearing, for all the subtests. Their performance was equivalent to the moderate hearing loss group with normal vision, which shows superior auditory skills for those associated with visual impairment. For pitch subtest they could not discriminate 1 semitone difference, but could successfully make out a difference of 2 semitones. For timbre subtest their scores were better than those with moderate hearing loss and almost similar to that of individuals with mild hearing loss. Melody perception and rhythm perception for these individuals were found to be better than those with moderately severe hearing loss, but was almost similar to that of those with moderate hearing loss.

Conclusions

The results of the study showed that the music perception skills of individuals with hearing loss and those with visual impairment associated with hearing loss were deviant from that of normal. Both group performances were significantly different from that of normal for all the subtests.

Even though the scores of individuals with visual impairment associated with hearing impairment performed significantly poorer than that of normal, their performance was superior to their sighted counterparts with the same degree of hearing loss.

Rhythm was the least affected parameter of music in the presence of cochlear hearing loss. Individuals with moderately severe hearing loss yielded the worst scores for all the subtests, while individuals with mild hearing loss scored the highest after normal hearing group for all the highest. Thus it can be concluded that the perceptual measures of an individual with visual impairment associated with hearing loss is different from that of their sighted counterparts. This implies that the auditory processing is different in these two groups. The frequency resolution and temporal processing abilities of an individual with associated visual impairment will be better than that which is expected from the audiological findings. Thus the rehabilitative measures taken, such as fitting of a hearing should be done by considering the factor that they have improved auditory skills. And the suggestions that can be withdrawn are, the individuals with hearing impairment and those with hearing impairment associated with visual impairment, have music perception in different ways, this could attribute to the physiological changes in the sensory pathway depending upon the impairment. Musical training can help these individuals as the suprasegmental aspects are better perceived that the segmental aspects which in turn can help them for the perception of segmental attribute of language.

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