Short-term musical training and pyschoacoustical abilities

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Abstract

The aim of the study was to assess the effect of short-term perceptual training of music on some psycho-acoustical measures. The study was carried out in three phases. In first the phase pre-training evaluation was done which included raga identification and various psycho acoustical tests. Psycho-acoustical tests included measurement of differential limen of frequency and intensity, duration discrimination, gap detection, modulation detection, backward masking and duration pattern test. In the second phase, auditory perceptual training was given for raga identification and in the third phase post- training evaluation was done though same tests as mentioned in pre-training phase. A total of 10 normal hearing adults (7 males, 3 females) in the age range of 18-25 years participated in the study. The results revealed that all the subjects performed significantly better on raga identification after training. However; there was no significant difference in psycho-acoustical measures in pre and post-training.

Introduction

A multitude of evidences suggests that long term musical training has benefits on sensory and cognitive processing.[1,2] Music involves

fine modulations of amplitude, frequency, and temporal aspects and musicians are trained to recognize these fine variations due to their extensive training. As a result of this practice a well-trained musician will have rich auditory experience. Due to their auditory experience musicians are considered as auditory experts and they are thought to have better auditory skills than non-musicians.[3] Musicians perform better than non-musicians, both on music specific as well as general auditory skills.[4]

Psychoacoustic research on musicians using behavioral measures suggests an enhancement of various psycho-acoustical skills. It has been reported that musicians perform better than non-musicians on tasks involving pitch discrimination, backward masking, forward masking and random gap detection.[5-9] Micheyl et al.[10] reported that musicians had pitch discrimination thresholds that were six times smaller than non-musicians. Similarly, Ishii et al.[6] reported that gap detection thresholds of trained musicians were better when compared to non-musicians. Furthermore, significant enhanced performance on the backward masking and backward masking with a gap were also reported in musicians compared to non-musicians.[11] It was also observed that there was a correlation between years of musical practice and performance on backward masking, which suggests that musical training influences temporal resolution.[12] Furthermore, it has also been shown that long-term musical training induces both structural and functional plasticity in the auditory system.[13,14] Schlaug[14] reported differences in auditory, motor and visual-spatial brain regions in trained adult musicians compared to amateur musicians or non musicians. More specifically, professional musicians had a larger gray matter density in the pre-central gyrus, Heschl's gyrus and right superior parietal cortex. Gaab and Schlaug[15] reported increased activations in auditory association areas of professional musicians compared to non-musicians. Music induced structural and functional plasticity changes have also been reported in the auditory brainstem.

Taken together, from the above studies, it can be concluded that long-term formal music training results in structural, functional and behavioral changes in the auditory system. It has also been shown that, positive effects of music can be transferred on auditory processing as well as speech and language.[16] However, the positive effects of music have been demonstrated only on those musicians who have undergone long term formal training in music.[5-10] It would be interesting to see whether these advantages would extend for short-term perceptual musical exposure also. Therefore, the present study was taken up to evaluate the perceptual changes in the auditory system, if any, due to short-term perceptual music training. Short-term musical training was operationally defined as non-formal perceptual listening to music for 8-10 sessions. This study measured the effect of short-term auditory perceptual training of two Carnatic Ragas on auditory system using various psycho-acoustical abilities (frequency, intensity and temporal abilities).

Materials and Methods

Participants

A total of 10 normal hearing adults (7 males, 3 females) in the age range of 18-25 years participated in the study. All the participants had their hearing thresholds less than or equal to 15 dB HL at octave frequencies from 250 Hz to 8000 Hz and A type tympanogram. It was also ascertained from a structured interview that these listeners did not have any history of neurologic or otologic disorder. All the participants did not have any complaints of difficulty in understanding speech either in quiet or in the presence of background noise and were amateur or rare listeners of music. All the listeners' participation was voluntary and they were not paid for their participation in the study. Ethical clearance was obtained from the ethics committee of the institute prior to commencement of the experiment.

General procedure

Written consent was taken from all the participants for willingly participating in the study. The study was carried out in three phases. In first phase pre-training evaluation was done on raga identification and various psycho-acoustical measures, including frequency and intensity discrimination, duration discrimination test, gap detection test, modulation detection test, backward masking and duration pattern test. In the second phase, auditory perceptual training with music was given and in third phase post-training evaluation was done using the same tests as mentioned in the pre-training phase. The order of the psychoacoustic tests was randomized among the participants.

Phase I involved raga identification and assessment of various psycho-acoustical abilities.

Phase I: Raga identification

This was assessed by determining: i) minimum number of notes required to identify a Raga; and ii) identification of Raga by listening to small excerpts of music.

Minimum number of notes required to identify Raga

Stimuli and procedure: Stimuli consisted of violin compositions from two Carnatic Ragas [Kalyani (Audio 1) and Mayamalavagola (Audio 2)]. These two are the basic ragas of South Indian classical music wherein Mayamalavagola is a *shudh madhyam raga* and Kalyani is a *prati madhyam raga*. Also Mayamalavagola is a 15th *mela karta* and Kalyani is 65th *mela karta*.[17] A Carnatic violinist with an experience of more than 15 years, who had passed *senior level* examination and practices for at least 2 to 3 h daily played the two Ragas. Musical notes of two Ragas were played in the octave scale where the distance between the first note (*sa*) and the last note (*sa*) is one octave. The notes consisted of *sa re ga ma pa dha ni sa* played either in Kalyani or Mayamalavagola Raga. Eight stimuli were constructed using this composition for each Raga. The first stimulus had only one note, second stimulus had 2 notes, third stimulus had 3 notes and so on, 8 stimuli had all 8 notes. Testing consisted of two phases: familiarization and identification. In the familiarization phase, participants were asked to listen to violin notes played in octave notes for Kalyani Raga and were instructed that hereafter whenever they hear the notes in this particular fashion they had to identify the Raga as *Kalyani*. A similar exercise was done for Mayamalavagola Raga. In identification phase, participants were asked to identify the Raga after listening to notes by pressing the appropriate key on the keyboard. The presentation of the stimuli and a collection of the responses were controlled using DMDX[18] software. Stimuli were presented randomly using a scrambling code of DMDX. During each stimulus trial, participants were presented with different number of notes of a Raga (either Kalyani or Mayamalavagola) along with words Kalyani and Mayamalvagola on the computer screen, *i.e.*, Participants were asked to identify the stimulus by pressing the button 1 or 2 on the keyboard of the computer, where 1 and 2 represented Kalyani and Mayamalavagola respectively. The participants were given 3 s after the stimuli to respond. Till then the letters remained on the computer screen. Each stimulus was repeated 10 times in order to reduce the chance factor. This resulted in a total of 80 stimuli for each Raga. The minimum number of notes that were necessary to identify the Raga with 50% accuracy was found through linear regression. Hereafter, this test will be referred to as NOTE-50.

Identification of Raga by listening to small excerpts of music

Stimuli and procedure: The same violinist who participated in the earlier experiment played stimuli in this experiment. He was asked to play several sample songs in both Kalayani Raga and Mayamalavagola Raga each lasting for about 15 min. Pilot study done using NOTE-50 had revealed that the minimum number of notes required to identify a Raga by professional musicians is around 5 notes. Therefore, 10 different, 5 notes excerpts were extracted from one of the songs in each Raga and were used as stimuli. Each stimulus was repeated 10 times, which sums to a total of 100 stimuli in each Raga. This was done in order to reduce the chance factor.

Stimuli were presented bilaterally through a high fidelity headphone (Sennheiser HD 449) at a comfortable level. Testing consisted of two phases- familiarization and identification. In the familiarization phase, participants were asked to listen to an audio sample of a song played on violin in Kalyani Raga for around 15 min. Participants were instructed that hereafter whenever they hear the excerpts from this Raga they had to identify the Raga as *Kalyani*. After that, the participants were asked to listen to a song played on violin in Mayamalavagola Raga for 15 min and were asked to name the Raga as *Mayamalavagola*. After this initial familiarization phase, the identification phase began. Presentation of stimuli and collection of the responses were controlled via the software DMDX.[18] Stimuli were presented in a random manner using a scrambling code of DMDX. During each stimulus trial, participants were presented with 5 notes excerpt from a Raga (either Kalyani or Mayamalavagola) along with words Kalyani and Mayamalavagola on the computer screen. Participants were asked to identify the stimulus by pressing the button 1 or 2 on the keyboard of the computer, where 1 and 2 represented Kalyani and Mayamalavagola respectively. The participants were given a 3 s time after the stimuli to respond. Till then the letters remained on the computer screen. The accuracy in identification was measured. Hereafter, this would be referred to as a Music-test.

Psycho-acoustical assessment

This involved administration of a group of tests to assess frequency, intensity and temporal perception. All psycho acoustic tests except duration pattern test was carried out using maximum likelihood procedure (mlp) toolbox, which implements an mlp in Matlab.[19] The maximum likelihood procedure employs a large number of candidate psychometric functions and after each trial calculates the probability (or likelihood) of obtaining the listener response to all of the stimuli that have been presented. The psychometric function yielding the highest probability is used to determine the stimulus to be presented at the next trial. Within about 12 trials, the maximum likelihood procedure usually converges on a reasonably stable approximation of the most likely psychometric function, which then can be used to estimate threshold.[20] Stimuli were generated at 44,100 Hz sampling rate. A three-interval, alternate forced-choice method using mlp was employed to track a 79.4% correct response criterion. During each trial a stimulus was presented in each of three blocks where two blocks contained the reference stimulus and the other interval randomly chosen had the variable stimulus. The participant task was to indicate which block contained the variable stimulus. All the psycho-acoustical tests were

administered as per procedure mentioned above and stimulus presentation and response acquisition were controlled by mlp toolbox. For all the tests 5-6 practice items were given before the commencement of the actual test.

The test stimulus for all psycho-acoustical tests was kept at 80 dB SPL. Stimuli for all the tests were presented via a laptop (Asus) connected to Sennheiser HD- 449 earphones. The output of the earphones was calibrated to produce 80 dB SPL for a 1000 Hz pure tone in a 2 cc coupler.

Difference limen of frequency

Difference limen for frequency (DLF) for pure tones was measured using a three-block forced-choice procedure as mentioned through mlp procedure. On each trial, two of the three observation blocks contained pure tones at a reference frequency and one selected at random had a pure tone of variable frequency, which was always higher than the reference frequency. The participant's task was to identify that block. It was done at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.[21]

Difference limen of intensity

Difference limen of intensity (DLI) for pure tones was measured using a three-block, forced-choice procedure. It was obtained for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.[21] The rest of the procedure was same as mentioned in DLF testing.

Duration discrimination test

Duration discrimination was done for a 1000 Hz[22] tone at anchor duration 250 ms.[23] The rest of the procedure was same as mentioned in DLF testing.

Gap detection thresholds

The participant's ability to detect a temporal gap in the center of a 500 ms broadband noise was measured.[24] The noise was 0.5 ms cosine ramps at the beginning and the end of the gap. In a three-block alternate forced-choice task, the standard stimulus was always a 500 ms broadband noise with no gap whereas the variable stimulus had the gap.

Modulation detection thresholds

A 500 ms Gaussian noise was sinusoidal amplitude modulated at modulation frequencies of 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz and 128 Hz.[25] A noise stimulus was two 10 ms raised cosine ramps at onset and offset. The participants were instructed to detect the modulation and determine which blocks had the modulated noise. Modulated and unmodulated stimuli were equated to total root mean square (rms) power. The depth of the modulated signal was varied according to the participant's response up to a 79.4% criterion level. The modulation detection threshold was expressed in dB by using the following relationship:

$$\text{Modulation detection thresholds in dB} = 20 \log 10 \, m \qquad (1)$$

where m= modulation detection threshold in percentage.

Backward masking

A 20 ms, 1000 Hz pure tone (the signal) was presented immediately before (*i.e.*, no silent gap) a band of band pass noise of 300 ms (400-1600 Hz).[26] All sounds were onset and offset gated by means of two raised cosine onset and offset ramps of 10 ms. The participant task was to tell which block has the tone. The rest of the procedure was same as mentioned in DLF testing.

Duration pattern test

The duration pattern test was administered in the similar way as described by Pinheiro and Musiek.[27] A 1000 Hz pure tone was generated at 44,100 sampling frequency with two different durations (*i.e.* short

250 ms and long 500 ms), using Audacity software (ver. 1.3.5).[23] By combining these two durations in three tone pattern six different patterns were generated (short short long; short long short; long long short; long short short; short long long; long short long). Following practice trails, 30 test items were administered. The participants were asked to verbally repeat the sequence.

Phase II: Training

After pre-training evaluations, participants received the musical training in auditory mode. During training everyday participants listened to the 15 min composition of Kalyani and Mayamalavagola Ragas with the help of a personal computer through high fidelity headphones (Sennheiser HD 449). After listening to these compositions in the end of each session, participants performed the Music-test. In this test participants were presented with 5 notes excerpt from a Raga (either Kalyani or Mayamalavagola) along with words Kalyani and Mayamalavagola on the computer screen. Participants were asked to identify the stimulus by pressing the button 1 or 2 on the keyboard of the computer, where 1 and 2 represented Kalyani and Mayamalavagola respectively. The participants were given a 3 s time after the stimuli to respond. Till then the letters remained on the computer screen. This training was given for eight sessions. Eight sessions were selected because previous studies have shown that about eight sessions of auditory perceptual training is enough to show improvement in listening skills.[28,29]

Phase III: Post-training evaluations

All the behavioral tests mentioned in Phase I were re-administered at the end of the 8th day of the training session.

Results

Results are reported for raga identification and psycho-acoustical measures separately. Prior to the statistics, test of normality was performed using the Kolmogorav Smirnov test on all the parameters and it showed that ten parameters were significantly different (P<0.05) from the normal distribution. Hence, non-parametric tests were used for the present study.

Raga identification

This was assessed by determining: i) minimum number of notes required to identify a Raga; and ii) identification of Raga by listening to small excerpts of music.

Minimum number of notes required to identify Raga

Figure 1 shows identification of Ragas with different number of notes in participants in pre-training condition. The y-axis represents performance and the x-axis represents the number of notes. It can be noted that the identification of Ragas even with the maximum number of notes was below chance level (0.5) for all the participants in the pre-training condition. Figure 2 shows identification of Ragas with different number of notes for participants in post-training condition and it is evident from the table that the identification scores improved following training. Highest identification scores were obtained for the stimuli that had all 8 notes.

Identification of Raga by listening to small excerpts of music

Mean Raga identification scores in pre-training and post-training conditions are shown in Figure 3. It can be noted that Raga identification scores improved following training. The Wilcoxon Signed Rank test was performed to see the significance of difference in identifica-

tion scores of Raga in pre- and post-training conditions. Results showed that training significantly improved the identification of Ragas (Z=-2.805, P<0.01).

Psychoacoustic measures

Results are reported for each psychoacoustic test separately. Figures 4 and 5 shows the mean scores and one-standard-deviation error bars for differential limen for frequency and intensity at 500, 1000, 2000 and 4000 Hz in pre-training and post-training conditions. It can be noted that the scores showed improvement in post-training compared to pre-training across all frequencies except at 4000 Hz for the DLF task. Thus, in order to see the effect of training on DLI and DLF Wilcoxon Signed Rank test was performed between the pre-training and post-training conditions. Results showed that there was significant improvement in DLF and DLI after musical training at 1000 Hz in DLF task (Z=-2.497, P<0.01) and for 500 Hz in DLI task (Z=-2.805, P<0.01). Figure 6 shows the mean and one-standard-deviation error bars of the modulation detection scores at 4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, and 128 Hz across pre-training and post-training conditions. It can be noted that there was an improvement in detection threshold post-musical training with more improvement evident at low modulation frequency. To estimate whether the improvement was significant, a Wilcoxon Signed Rank test was performed between the pre-training and post-training conditions. Results showed that there was no significant difference in the score in pre- *vs* post- training at all the modulation frequencies (P>0.05). Figure 7 shows the mean scores and one-standard-deviation error bars of duration discrimination, gap detection, back-

ward masking and duration pattern in pre- *vs* post- training condition. It can be noted from the figures that there was an improvement in scores for all the tests after musical training except for the gap detection threshold, wherein pre-training thresholds were better than post-training thresholds. To assess the difference in performance after training Wilcoxon Signed Rank test was performed and results showed that the pre- training and post- music training scores was not significant for all the tests (P>0.05).

Discussion

Perceptual learning can be defined as the improvement in the ability to perform a particular task after continuous practice. Ragas in Carnatic music have specific note sequences which can be identified by trained musicians. The results of the present study showed that with short-term perceptual training even non-musicians can learn to identify these Ragas. The main purpose of the present study was to document the differences in psycho-acoustical abilities in individuals after short-term musical training. To the best of our knowledge, the effect of short term music training on psycho-acoustical abilities has not been studied using a group of tests, including frequency and intensity discrimination, duration discrimination, gap detection, modulation detection, backward masking and duration pattern test.

The results of the present study show that there was an improvement in all the psycho-acoustical measures, including frequency, inten-
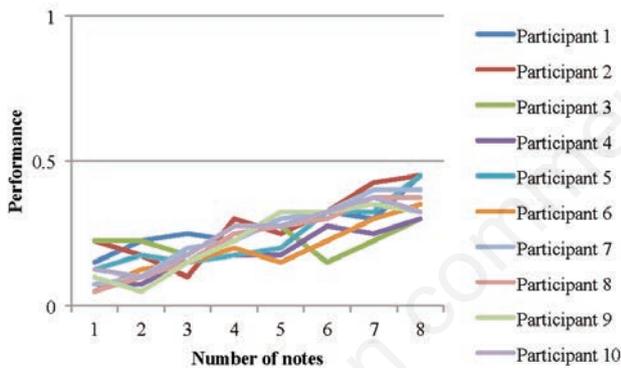

Figure 1. Identification of Ragas with different number of notes for individual participants in pre-training condition.
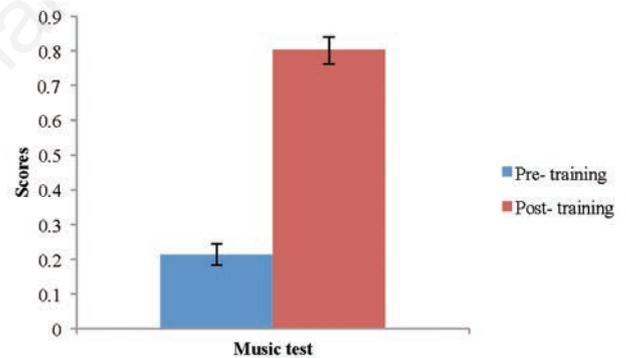

Figure 2. Identification of Ragas with different number of notes for individual participants in post training condition.

Figure 3. Identification of Ragas in pre- and post-training condition with one standard deviation error bar.
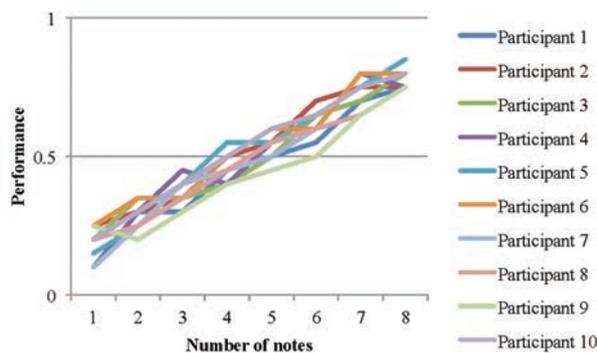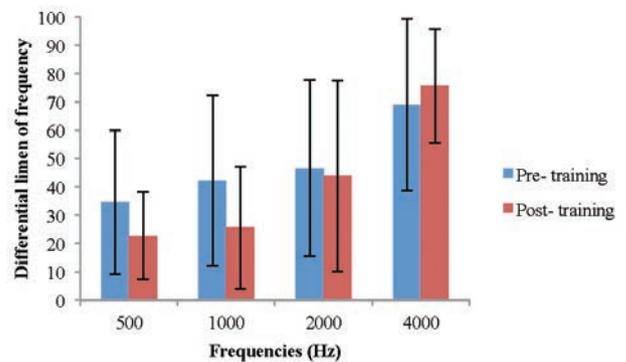

Figure 4. Mean scores and one-standard-deviation error bars for differential limen of frequency at 500, 1000, 2000 and 4000 Hz in pre- and post-training conditions.

sity and temporal measures, but it was not significant. The frequency discrimination abilities did not show a significant change after training which is in contrary to the studies done in the past. Speigel and Watson,[30] compared pitch discrimination ability in musicians and non-musicians and the results showed a clear separation between both the groups with a median threshold difference three times smaller for musicians. However, there are no studies examining the effect of music on intensity perception. The findings of the present study related to temporal perception also showed that with training scores improved in all temporal abilities, though it was not significant. Similar results have been reported by Monteiro et al.,[31] where they compared the temporal resolution ability using gaps in noise test in musicians and non-musicians. Results revealed that there was no difference between those groups on the performance of the gaps in noise test. On the contrary, some studies have shown that the temporal processing abilities of musicians are superior to non- musicians. Ishii et al.[6] in their study reported that the gap detection thresholds were better in trained musicians when compared to non- musicians. They also reported that the random gap detection threshold was not sensitive enough to differentiate the temporal resolution abilities. However, all the above mentioned studies have taken trained musicians to compare various auditory abilities and it has been reported that temporal resolution abilities improve as the experience in music increases.[32] In a study by Sangamatha et al.,[23] they reported that children with one to two years of musical training were able to perform like adults on all the temporal resolution tasks measured, except modulation detection at 200 Hz. This
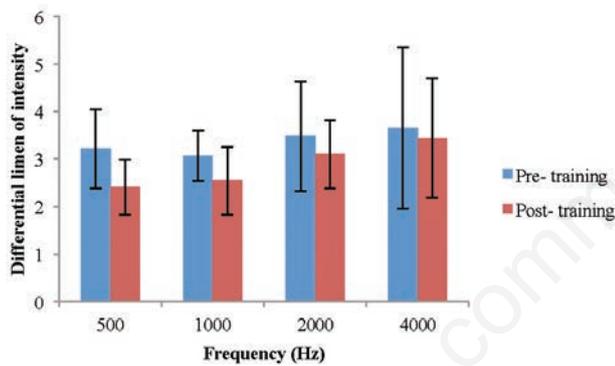

Figure 5. Mean scores and one-standard-deviation error bars for differential limen of intensity at 500, 1000, 2000 and 4000 Hz in pre- and post-training conditions.
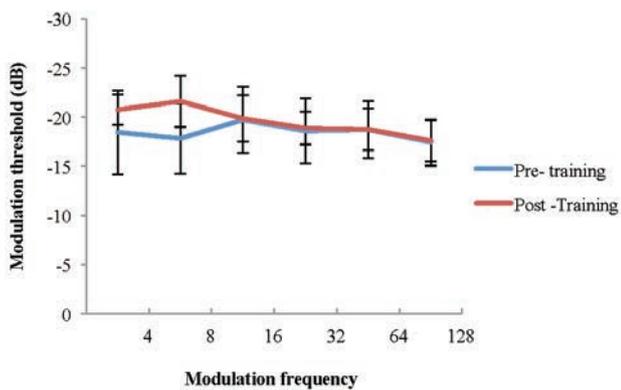

Figure 6. Modulation detectio thresholdes for pre- and post-training conditions. Error bars depict one standard deviation of error.
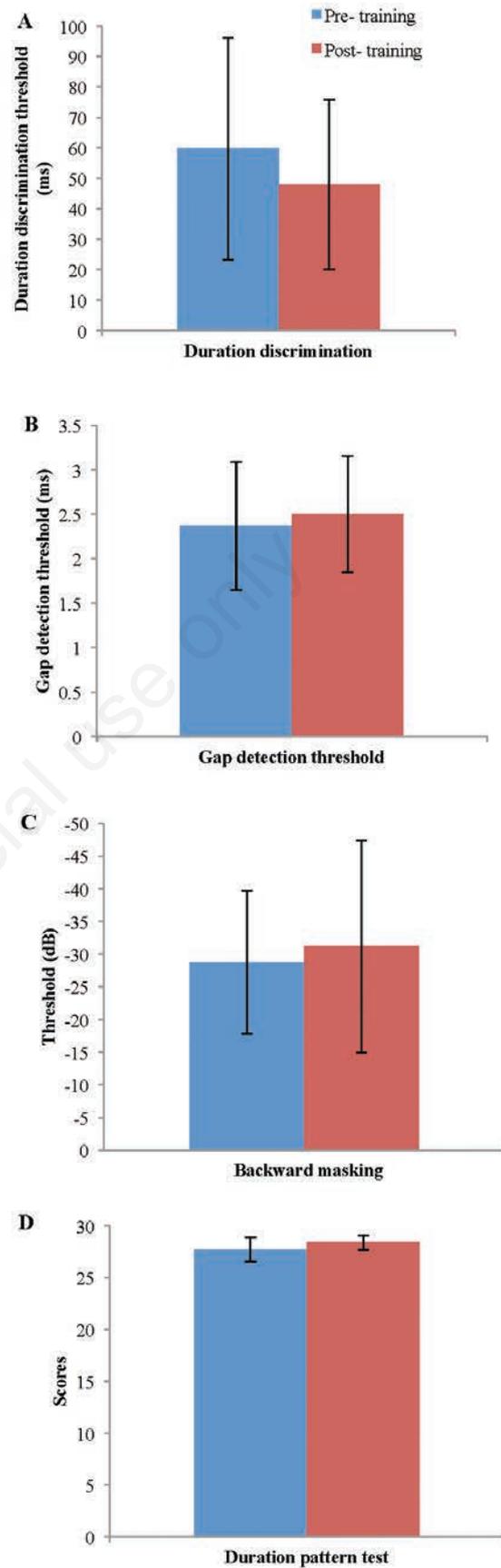
Figure 7. Mean and one-standard-deviation error for (A) duration discrimination thresholds, (B) gap detection thresholds, (C) backward masking (D) duration pattern scores in pre- and post-training conditions.

is in accordance with the present study where the improvement in the modulation detection task was more evident at low modulation frequencies (2 Hz, 4Hz, 8Hz and 16 Hz) compared to higher modulation frequencies. This result could be because music contains fine frequency and amplitude fluctuations and thus individuals with musical training are expected to have better performance on such tasks. Thus, the findings of the present study showed that with short-term musical training there was an improvement in the raga identification, but this was not generalized to the various psycho-acoustical measures. Studies done in the past have shown that with short term musical training participants exhibit superior music related perception.[33] Flohr[33] reported that children performed well on standardized rhythmic discrimination task after receiving training for 25 min twice a week across 12 weeks. Thus, it can be concluded that short term musical training shows an improvement in music perception skills; however the same improvement is not evident in various psycho-acoustical measures.

Conclusions

Short-term perceptual musical training shows an improvement in the identification of ragas but does not show a significant improvement in frequency, intensity or temporal resolution abilities. This could be because short-term music training is not resulting in an efficient neural mechanism for performing various auditory tasks. Further research is needed to explore the effect of duration of music training which can show enhancement in various auditory abilities. Moreover, whether any other type of listening training (non-music based) would also influence the psycho-acoustical abilities was not assessed as the part of the present study. Future research may aim to study pre- and post-psychoacoustic abilities in participants after receiving non-music based listening training.

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