Effect of Musical Training on Psychophysical Abilities and Working Memory in Children

Chandni Jain, N. Devi, Sindhu Parthasarathy[1], S. Kavitha

Department of Audiology, All India Institute of Speech and Hearing, [1]Department of Audiology, JSS Institute of Speech and Hearing, Mysuru, Karnataka, India

Abstract

Introduction: Music involves fine modulations of intensity, frequency, and temporal aspects and musicians can distinguish these fine variations due to their extensive training. The long-term musical practice has been found to result in the improvement of various auditory and cognitive skills. The aim of the present investigation was to study the effect of musical training on psychophysical abilities and working memory in children. **Methods:** Total of 30 participants in the age range of 10 to 15 years were recruited for the study. They were equally divided into two groups. Group I had children trained in Carnatic music for more than three years and group II included 15 children with no formal musical training. Psychophysical abilities were assessed using all three frequency, intensity, and temporal parameters. Frequency discrimination and intensity discrimination was assessed through differential limen of frequency (DLF) and differential limen of intensity (DLI) at 2000 and 4000 Hz. Temporal parameters were assessed through a gap detection test (GDT), temporal modulation transfer function (TMTF), and duration discrimination test (DDT). Working memory was assessed using digit span and operation span test respectively. **Results:** Results showed that children with musical training had significantly better scores for DLI, DLF, GDT, and DDT. However, there was no significant difference in TMTF scores between the groups. Further, a significant better score for digit span task was obtained by children with musical training. But no significant difference was noted for operational span task between the groups. **Conclusion:** To conclude, the study shows the importance of musical training in fine-tuning the auditory system and its significance in ameliorating auditory psychoacoustic skills and auditory memory.

Keywords: Digit span, frequency, intensity, temporal

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Introduction

Music is a form of art and it plays an important role in human culture. Music involves fine modulations of intensity, frequency, and temporal aspects, and musicians can distinguish these fine variations due to their extensive training.[1] Long-term musical practice has been found to result in improvement of various auditory and cognitive skills such as auditory attention,[2] auditory stream segregation,[3] processing of emotion in speech,[4] working memory,[5] temporal resolution abilities,[6] and processing of prosody and linguistic features in speech.[7] Studies have also shown that musicians perform better than nonmusicians on tasks involving pitch discrimination, backward masking, forward masking, and random gap detection.[8-10] Micheyl *et al*.[11] reported that musicians had six times smaller pitch discrimination thresholds than nonmusicians.

Musicians also perform superiorly than nonmusicians on a variety of other nonauditory skills such as information processing speed, intelligence, memory,[12] problem-solving tasks,[13] and higher-level cognitive functions.[14] Individuals trained in music have enhanced processing not only for music perception, but also for linguistic and nonlinguistic cognitive processing.[15,16] Musical training has shown improved cognitive abilities such as digit span[17] and reading complex words.[18]

Furthermore, it has been shown that long-term musical training induces both structural and functional plasticity in the auditory system. Schlaug[19] reported differences in auditory, motor, and visual–spatial brain regions in trained adult musicians compared to amateur musicians or nonmusicians. It has

Address for correspondence: Dr. Chandni Jain,
Department of Audiology, All India Institute of Speech and Hearing,
Mysuru, Karnataka, India.
E-mail: chandni_j_2002@yahoo.co.in

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been reported that there are increased activations in auditory association areas of professional musicians compared to nonmusicians.[20] Thus, it can be concluded that long-term formal music training results in structural, functional, and behavioral changes in the auditory system. However, these studies have compared the auditory abilities and working memory in adults undergoing musical training. There is a dearth in literature regarding the effects of musical training on various auditory abilities and cognition in children. Thus, the aim of the present investigation was to study the effect of musical training on psychophysical abilities and working memory in children.

Methods

Participants

A total of 30 participants in the age range of 10–15 years were recruited for the study. They were divided into two groups: Group I had 15 children trained in Carnatic music for >3 years and Group II included 15 children with no formal musical training. Further, on both the groups, a questionnaire on the musical abilities[21] was administered, and all the children in Group I scored higher than 15, which ensured that these children had higher musical abilities.

All children were native Kannada speakers with English as a medium of instruction. None of the participants had a history of hearing loss, ear disease, head trauma, ototoxic drug intake, and ear surgery or speech-language problems. In addition, none of them reported any illness during the time of testing. All the listeners' participation was voluntary, and they were not paid for their participation in the study.

Procedure

Psychophysical abilities were assessed using all three frequency, intensity, and temporal parameters. All tests were carried out using maximum likelihood procedure (mlp) toolbox, implemented in Matlab. The MLP employs a large number of candidate psychometric functions and after each trial calculates the probability of obtaining the listener's response to all 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 MLP usually converges on a reasonably stable approximation of the most likely psychometric function, which can then be used to estimate the threshold.[22,23] Stimuli were generated at 44,100 Hz sampling rate. A three-interval, alternative 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 the 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. For all the tests, 5–6 practice items were given before the commencement of the actual test. The stimulus was presented through a Sennheiser 449 high-fidelity headphone at the most comfortable level binaurally.

Frequency discrimination and intensity discrimination were assessed through differential limen of frequency (DLF) and differential limen of intensity (DLI) at 2000 Hz and 4000 Hz. Temporal parameters were assessed through gap detection test (GDT), temporal modulation transfer function (TMTF), and duration discrimination test (DDT). TMTF was done for 8 Hz, 16 Hz, 64 Hz, and 128 Hz modulated white noise, and DDT was carried out for a 1000 Hz tone.

Working memory was assessed using digit span and operation span test. In digit span task, backward and descending digit span tests were carried out through Smriti-Shravan V1.0 software (Mysuru, Karnataka, India).[24] Participants were presented with cluster of numbers and asked to repeat them in either reverse order or decreasing order depending on the task. The maximum number of digits recollected correctly was documented.

In the operation span task, each element consisted of a mathematical operation and a word (e.g., Is $[8 \times 5] - 25 = 21$ yes or no?/mara/). Mathematical problem was true in half of the trials, and it was false in the other half of the trials which were presented randomly. The size of each trial varied from 2–5 mathematical problem–word items. Three trials of each length were presented for a total of 12 trials. The participant's task was to read the mathematical problem aloud, say "yes" or "no" to indicate whether the given answer is correct or incorrect, and then say the word. After all the elements in an item are presented, the participant was required to repeat the words in correct serial order. The difficulties of the items were randomized such that the numbers of the elements were unpredictable at the outset of an item. A score of "1" was assigned when all the words were correctly recalled, and a score of zero was given if the words were either not recalled or if recalled in the wrong serial order. Furthermore, proportion correct score for each trial was calculated (e.g., if one element was recalled correctly in a trial of two elements, a proportion correct score of 0.5 was obtained). These scores were averaged across all the 12 trials, and therefore, maximum possible score was 12.

Results

The mean and one standard deviation of all psychophysical abilities and working memory tasks of the two groups is shown in Figure 1. From Figure 1, it is evident that musicians had better scores for all the psychophysical abilities compared to that of nonmusicians. Further, in working memory tasks, musicians performed better in backward digit span and descending span tasks compared to nonmusicians.

A Mann–Whitney U-test was carried out to assess the difference in various psychophysical abilities and working memory between the two groups. The results showed a significant difference between the two groups for DLI at 2000 Hz ($U = 57.00$, $z = -2.30$, $P < 0.05$), DLI at 4000 Hz ($U = 62.50$, $z = -2.07$, $P < 0.05$), DLF at 2000 Hz ($U = 14.50$, $z = -4.06$, $P < 0.01$), DLF at 4000 Hz ($U = 5.00$, $z = -4.46$, $P < 0.05$), DDT ($U = 39.00$,

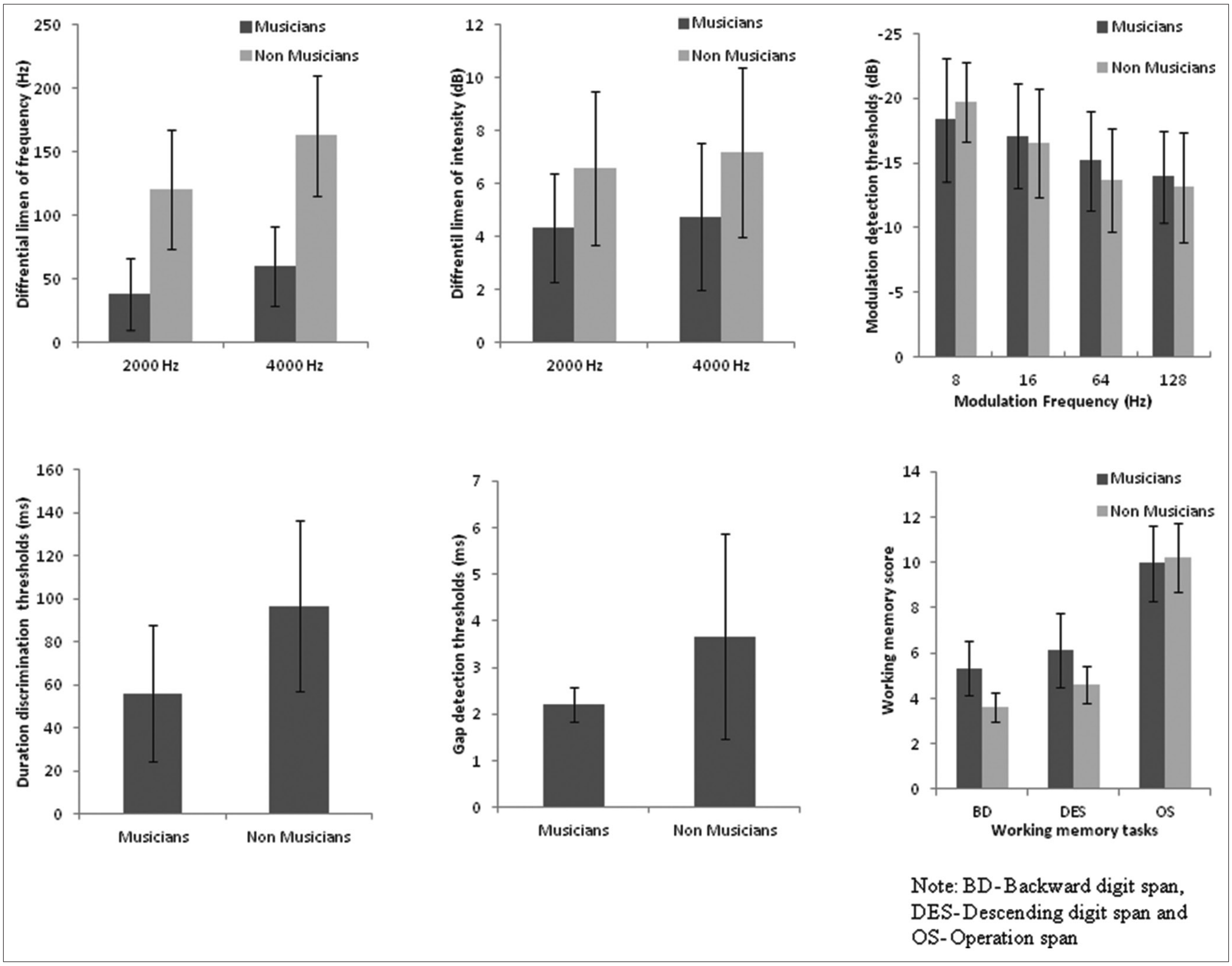

Figure 1: Mean and one standard deviation of various psychophysical abilities and working memory measures

$z = -3.04$, $P < 0.05$), and GDT ($U = 64.50$, $z = -1.99$, $P < 0.05$). However, there was no significant difference between the scores of TMTF between the groups.

Further, a significant difference was obtained between the groups for digit span task. The scores of backward digit span ($U = 20.50$, $z = -3.90$, $P < 0.01$) and descending number span ($U = 49.00$, $z = -2.73$, $P < 0.01$) were significantly higher for children who underwent musical training. However, no significant difference was noted for operational span task between the groups.

Discussion

The present study showed that children with musical abilities had better frequency discrimination, intensity discrimination, temporal processing skills, and working memory with respect to auditory stimuli. The scores of operation span did not reveal a significant difference which could be attributed to the fact that the presentation of stimuli in this test was in visual mode. This shows that musical training improvises the auditory system and does not show an effect on visual storage of information. Similar results related to auditory abilities have been reported in adults.[9,11] Spiegel and Watson[25] reported that pitch discrimination ability was three times smaller for musicians compared to nonmusicians. Studies have also shown that the temporal processing abilities of musicians are superior to nonmusicians. Ishii *et al*.[26] in their study reported that the gap detection thresholds were better in trained musicians when compared to nonmusicians. In a study on children, Sangamanatha *et al*.[27] reported that with 1 to 2 years of musical training, children were able to perform like adults on all the temporal resolution tasks measured, except modulation detection at 200 Hz. Further, while most of the studies in the literature have examined either one of the abilities in musicians, the present study has examined all three frequency, intensity, and temporal parameters and working memory in children who have undergone musical training. Thus, the study shows the importance of musical training in fine-tuning the auditory system and its significance in ameliorating psychophysical skills and auditory working memory in children.

Conclusion

The present study showed that children with musical training have better frequency, intensity, temporal resolution abilities, and higher working memory. This could be because music training results in an efficient neural mechanism for performing various auditory tasks. Future research may aim to study the number of years of music training which will show an improvement in auditory and cognitive abilities.

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Conflicts of interest

There are no conflicts of interest.

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