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Original Research Article

Exploring Music Induced Auditory Processing Differences among Vocalists, Violinists and Non-Musicians

Priyanka Vijaya Kumar[1], Rajalakshmi Krishna[1, 2]

[1]All India Institute of Speech and Hearing, University of Mysore, Mysore, India
[2]Audiology India, Mysore, Karnataka, India

Corresponding Author: Priyanka Vijaya Kumar

ABSTRACT

Music is a highly complex sensory stimulus and is structured in several dimensions. This richness makes music an ideal tool to investigate the functioning of the human brain. This study aimed to understand the differences in auditory processing skills like auditory memory and speech perception in noise between vocalists, violinists and non-musicians. Fifteen participants from each of the group were subjected to two auditory memory tests (forward and backward digit span tests) and a speech in noise perception test (QuickSIN). On statistical analysis, overall results indicated that both in auditory memory and speech in noise perception abilities, musicians (both vocalists and violinists) outperform non-musicians. However, no significant difference was noticed between violinists and vocalists. The results of the study are in congruence with other literature report indicating musical experience as an important factor inducing enhancements in the overall auditory perceptual abilities. Further, the study results lead to the possible speculations that type of music (vocal vs instrumental) does not influence music induced differences in the auditory processing skills.

Keywords: Music, Auditory Memory, Speech in noise perception, Neuroplasticity, Auditory perception.

INTRODUCTION

Music is one of the socio-cognitive domains of human species; in every human culture, people have played and enjoyed music. [1] Music perception and even more, music creation or production is considered as one of the most demanding tasks for the human brain engaging virtually all cognitive (sensory and motor) processes and precise monitoring of performance. [2-6] Performing music at a professional level is one of the most complex tasks of human accomplishments. For example, a pianist has to bimanually coordinate the production of up to 1,800 notes per minute. Music is a highly complex sensory stimulus and is structured in several dimensions. [7] This richness makes music an ideal tool to investigate the functioning of the human brain. [8]

Neural plasticity is a term used to describe alterations in the physiological and anatomical properties of neurons in brain as a result of any stimulation or deprivation. Depending on experience, mechanism of plasticity can involve synaptic changes that occur rapidly or slowly over a period of time. [9] Everyday learning and training involves continuous improvement of our abilities at the sensory, cognitive and behavioral levels. [10] Music being a complex auditory task and also as musicians spend years in fine-tuning their skills, it is no wonder that previous research has documented neuro-plasticity to musical sounds as a function of experience. [11-16]

There are many studies in literature which have documented that musical training affects auditory processing abilities resulting in both altered behavioral. [17-25] and electro-physiological responses. [5,12, 15-17,26-29] Amongst behavioral skills, differences have been mainly reported in temporal processing abilities, speech perception in noise, auditory memory, frequency discrimination and categorical perception. [17-25]

Speech in noise perception differences between musicians and non-musicians

Speech perception in noise (SPIN) is a complex task requiring segregation of a target signal from the competing background noise. This task is further complicated by the degradation of the acoustic signal, with the noise particularly disrupting the perception of the fast spectro-temporal changes. [20] Musicians, as a consequence of training that requires consistent practice, online manipulation, and monitoring of their instrument, are experts in extracting relevant signals from the complex sound scape (e.g., the sound of their own instrument in an orchestra). The effect of such musical experience is believed to be transferred on the skills that sub serve successful perception of speech in noise. Here are a few studies to support this hypothesis. Parbery-Clark et al. [20] found a distinct speech in noise advantage for musicians as measured by Quick Speech Perception in Noise (QuickSIN) test. They found that years of consistent practice with a musical instrument correlated strongly with performance on speech in noise perception along with auditory working memory and frequency discrimination. Thomas et al. [21] checked the ability to perceive speech in noise at three Signal to Noise Ratios (SNR); 0 dB, -5 dB & -10 dB and found that the perception got better as the experience of the musicians increased especially at lower SNRs. Abhishek et al. [22] used QuickSIN to assess speech perception abilities in the presence of background noise in mridangam players. Results showed that QuickSIN scores were better in mridangam players when compared to the control group.

Differences in auditory memory skills between musicians and non-musicians

Memory plays a central role in general cognition and hence it has become the focus of a rapidly growing literature that seeks to affect broad cognitive change through prolonged training on tasks. Evidences from literature have shown that music training is capable of improving memory. [23, 30-33]

Many researchers have tried to study differences in visual and auditory (verbal and non-verbal) memory between musicians and non-musicians. In a hallmark study, Chan and colleagues found that musicians had superior verbal memory but not visual compared to non-musicians. Ho et al. [30] assessed verbal memory in children with and without musical training using both cross sectional and longitudinal study design. In the cross-sectional part of the study, they found children with musical training with better verbal memory. In the longitudinal study they observed that children who had begun or continued musical training showed superior verbal memory improvement than those who discontinued. They related these findings to improvement in memory functioning which might be due to reorganized neuro-anatomic structures by music training. However, they found no differences in visual memory between musician and non-musicians.

Studies have even tried to understand if there is a neural overlap for short term memory of language and music. Williamson et al. [31] compared short term memory for verbal (letters) and musical tones (different in frequency) between musicians and non-musicians. They also aimed to study the effect of pitch proximity; distal pitch vs. proximal pitch (of musical tones) and phonological similarity (letters) on short term music and verbal memory. Non-musicians were found to have limited capacity of short term verbal and musical memory compared to musicians. Also, their memory was found to be significantly affected by pitch proximity. However, in other hand, musicians were not found have any such effect. Both groups were found to be vulnerable to phonological proximity effects. Based on their findings, they reported that, the study results reflected dissimilarities in strategies used for memory tasks by both the groups (non-musicians being dependent on pitch similarity principles). Thus, they suggested that musicians (unlike non-musicians) have lesser degree of correspondence in the way short term memory is processed for verbal and musical sounds.

Differences between Vocal vs. Instrumental Music

Vocal music is a genre of music performed by one or more singers, with or without band of instruments, in which singing is the main focus of the piece. An instrumental music is a composition without lyrics, though it might include some non-articulate vocal input; the music is primarily or exclusively produced by musical instruments. Vocal musicians practice more with the speech sounds whereas instrumental musicians practice more with non-verbal sounds.

Almost all acoustic musical instruments have highly linear resonators that determine the playing frequency whereas in voice it does not. In plucked strings (and in many percussion instruments), linear resonator alone determines the playing frequency. In contrast, some instruments that can produce sustained notes have a non-linear mechanism. For example, non-linear oscillations are produced by bow-string contact. [34] Here, resonances of the string govern the pitch. In contrast, the vocal tract acts as waveguide resonator and is highly linear. In spite of that it fails to control the pitch of the voice. Adjustments in the vocal fold parameters are necessary in-order to hold a constant pitch in a strong crescendo and decrescendo.

Another very important difference between vocal and instrumental music is that, in speech, broadband sources are vital for understanding. Further, in whispering speech can be understood only with broadband signals. In contrast, in music, broadband sources having no pitch play a secondary role. Examples include components of the starting transients of many instruments, part of the sound of un-tuned percussion and the breath sound in wind instruments; Wolfe et al. [35]

The most important difference is related to pitch control by the resonator. In instruments, parameters are almost always independently adjusted to be able to play a sequence of notes with pitches independent of loudness. Many instruments have keys, valves, frets or tone holes that give nearly digital control of pitch. But in voice, to control pitch and loudness independently, one has to control the vocal fold parameters in combination with sub glottal average pressure. Modification of several parameters is required to change pitch at the same time as loudness (or vice versa).

The above literature review highlights the existence of a few differences between vocal and instrumental music. On this basis it might be logical to hypothesize that the complexity of auditory processes involved in learning and perceiving vocal and instrumental music might also be different and thus, it might result in dissimilar organizations (and thus may be dissimilar performance in sensory tasks) in the brain between musicians compared to non-musicians. Studies in literature (few of which are discussed above), report that music training helps musicians in general perform better than non-musicians in auditory processing tasks like auditory memory and speech in noise skills. However, there are hardly any studies except Jayakumar et al [24] exploring differences in auditory processing between vocal and instrumental musicians.

Jayakumar et al [24] compared temporal resolution among guitarists, vocalists and percussionists and noted that guitarists (string instrument) performed better than the other two groups indicating better performance by instrumental musicians compared to vocalists and non-musicians.

However, there is a lack of extensive research in this regard. This sub-served as aim for this current study which intended to further explore differences within vocal and instrumental musicians in comparison to non-musicians. This study is aimed to study differences in many auditory processing skills between vocalists, violinists and non-musicians.

MATERIALS AND METHODS

Participants:

Fifteen professionally trained violinists, vocalists (both trained in Carnatic music) with an experience of more than five years in their respective areas of expertise (Vocal or Violin) and fifteen non-musicians participated in this study. For non-musician group, only those participants who did not receive any formal music training were considered. The details of participant's chronological age and music training initiation age (mean, standard deviation and range values) are given in table 1.

Table 1: Participants' chronological age and initiation age of musical training.

	Chronological Age (Years)			Initiation age of musical training (Years)	
	Non-musicians	Vocalists	Violinists	Vocalists	Violinists
Mean	30.4	30.4	31.53	8.8	9.87
Standard deviation	8.8	8.8	8.4	2.27	1.68
Range	18-45	18-44	19-44	7-12	5-12

There are 3 levels of proficiency in Carnatic music; Junior, Senior and Vidwath. Junior is the most basic level and Vidwath is the highest level of music proficiency. The beginners start from junior level and move to next level (i.e. Senior and then Vidwath). They have to pass the exams conducted by Karnataka Secondary Education Board to move from one level to other. Vocalist and violinist groups were matched in terms of level of proficiency. Among participants, 7 were at junior level, 5 were at senior level and remaining 3 were at Vidwath level of music proficiency in both violinist and vocalist groups.

The study involved two phases. Phase I included administering a structured questionnaire and carrying out a few audiological tests to select participants for this study. Phase II consisted of administering two working memory tests and a speech in noise test on those selected participants.

Phase I

A structured questionnaire was administered to know the musical background and general health of the participants. Questionnaire inquiries included: basic information concerning age, education, working experience, medical history (e.g. middle ear diseases, ear surgery, etc.), musical history (e.g. initiation age of training, form of musical training, music proficiency, etc), lifestyle (e.g. smoking, noisy hobbies, etc.), and their personal observation of own hearing status. A written consent was taken from all the participants and they were also informed regarding complete test procedure. All other queries, if any, by participants were answered patiently by authors.

To ascertain normal hearing sensitivity in all the selected participants, certain tests were carried out. This procedure lasted for 35 to 40 minutes. All tests were conducted in a sound treated double room set-up as per the standards of ANSI S3.1. [36] Firstly, pure tone air conduction and bone conduction thresholds were obtained using modified Hughson-Westlake procedure [37] for octave frequencies from 250 Hz to 8 kHz. Using Immittance audiometry, normal middle ear function was confirmed. Further, normal speech perception abilities were confirmed by assessing Speech Recognition Threshold (SRT) using Kannada spondee words [38] and Speech Identification Scores (SIS) using Kannada phonemically balanced word list. [39] Only those participants who were native Kannada speakers having normal hearing thresholds (≤15 dB HL) at all the octave frequencies, 'A' type tympanogram, reflexes present, SRT of ±12 dB to PTA, SIS >90% in both the ears and without any illness on the day of testing were recruited for the study second phase of this study. Participants with presence/report of any neurologic, psychiatric or structural abnormalities (ascertained by the researcher) were not considered.

Phase II

This phase included two tests of auditory working memory and one speech in noise test. For all the tests, stimuli were presented at 40 dB SL (re: PTA) or at the most comfortable level using calibrated Sennheiser HDA 200 headphones.

Tests for auditory working memory:

The two tests were chosen to assess working memory namely; forward digit span test and backward digit span test. The digit span tests are the most commonly used tests to measure short term memory.

Forward Digit Span (FDS) Test:

Bi-syllabic digits in Kannada were recorded by an adult native fluent female speaker with a clear voice and articulation. The digits were recorded with a high fidelity microphone placed 10 cm away from the speaker's mouth using the Computerized Speech Lab (CSL) systems in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44100 Hz.

Participants were presented with a series of digits (e.g., '8, 1') and were instructed to immediately repeat them in the same given order. The inter-stimulus interval between two digits was 250ms. If they could repeat it back successfully, they were given a longer list (e.g., '7, 2, 4'). This procedure would continue until the participant failed to repeat the given list. When participant fails then another list with the same number of digits would be presented. If the participant could repeat it correctly in the same order then he could go to the next series else the previous series (where he could repeat it successfully initially) would be considered as his/her digit span memory.

Backward Digit Span (BDS) Test:

In the BDS task, the procedure was similar to that mentioned above in forward digit span test but the participants had to reverse the order of the numbers in their response.

Quick Speech in-Noise (QuickSIN) Test in Kannada:

Stimuli used for this test included 60 sentences developed for QuickSIN test in Kannada. [40] Those 60 sentences were distributed randomly to form 12 lists with 7 sentences in each list. Some of the sentences were used in more than one list. These sentences were recorded by a native male Kannada speaker using Pratt software. [41] Eight talker speech babble was used as background noise. Sentences in every list were presented at different SNRs. In each list, first sentence was at +20 dB SNR and there after SNR was reduced by 5 dB steps for the subsequent sentences. Thus, in each list, first sentence was at +20 dB SNR, second sentence at +15 dB, third at +10 dB, fourth at +5 dB, fifth at 0 dB, sixth at -5 dB and last sentence was at -10 dB SNR. These SNRs encompass the range of normal to severely impaired performance in noise. Sentences used were high probability items for which the key words were somewhat predictable based on the context. Each sentence had five key words which were scored as correct or incorrect. These sentences were presented at 70 dB HL through a personal computer. The listener's task was to repeat the sentences presented and each correctly repeated keyword was awarded one point. Thus, the total possible score was 35 (7 sentences * 5 key words) per list. To calculate SNR at which 50% scores were obtained, the following formula which was recommended in the study by Avinash et al. [40] was used.

SNR at which 50% scores = 22.5- (total words correct)

Statistical Analysis

SPSS software (version 22) was used for statistical analysis. Descriptive statistics (Mean and Standard Deviation) was carried out. To verify if the data is normally distributed, Shapiro-Wilk's test for normality was administered. Scores of tests were found to be non-normally distributed ($p<0.05$) and hence non-parametric Kruskal-Wallis test was opted. Overall, results revealed a significant difference between groups in all tests except FDS test. Further, groups were compared pair wise for all the tests (except FDS) using Mann-Whitney U test.

RESULTS

Table 2: Result of Kruskal Wallis test comparing test scores across groups.

	FDS	BDS	SPIN
Chi-Square	5.535	9.971	12.171
Df	2	2	2
Asymp. Sig.	.063	.007	.002

Tests for auditory memory:

FDS and BDS tests:

Mean and Standard Deviation (SD) values of violinists, vocalists and non-musicians for FDS and BDS tests are shown in Figures 1 and 2 respectively.

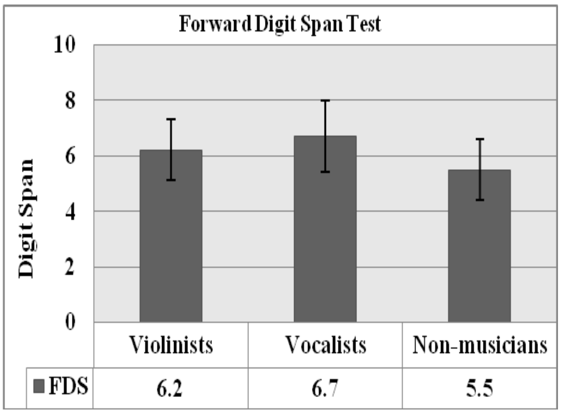

Figure 1: Mean and SD for FDS across Violinists, Vocalists and Non-musicians

For FDS test, Kruskal-Wallis test results did not reveal any statistically significant difference across the groups [table 2]. However, for BDS test, Kruskal-Wallis test results revealed a significant difference across the groups [table 2]. Further, pair wise comparison of BDS test scores using Mann-Whitney U test revealed that both vocalists [Z=-2.845, p=0.004] and violinists [Z=-2.487, p=0.013] performed significantly better than non-musicians. However, no significant difference was noted between violinists and vocalists [Z=-0.577, p=0.564].

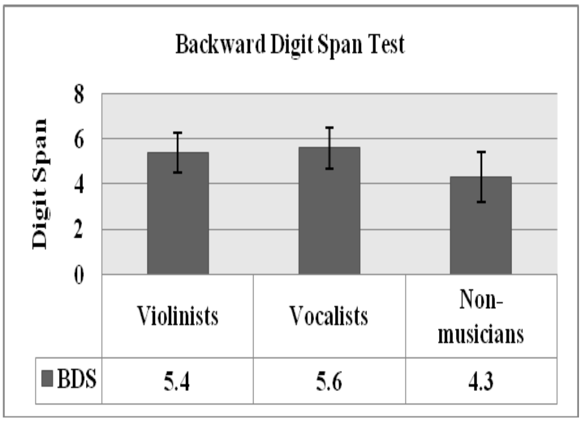

Figure 2: Mean and SD for BDS across Violinists, Vocalists and Non-musicians

Quick Speech in-Noise Test:

Mean and SD values of QuickSIN test - SNR 50 for violinists, vocalists and non-musicians are shown in Figure 3.

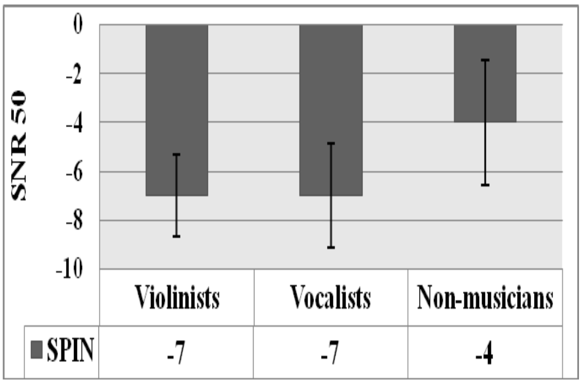

Figure 3: Mean and SD for SPIN test SNR-50 across Violinists, Vocalists and Non-musicians

The Kruskal-Wallis test results disclosed a significant difference across the groups [Table 2]. Further, on carrying out Mann-Whitney U test, statistical difference was found between violinists vs. non-musicians [Z=-3.255, p=0.001] and vocalists vs. non-musicians [Z=-2.765, p=0.006]. However, no significant difference was noted between vocalists and violinists [Z=-0.085, p=0.933].

DISCUSSION

The present study examined the auditory processing (in specific, auditory memory and speech perception in noise) similarities and differences between instrumental musicians (violinists), vocalists and non-musicians. Two auditory memory tests and a speech in noise test were used to compare the performance between groups. Overall results revealed that except FDS test, in the other two tests violinists and vocalists performed significantly better than non-musicians. However, no significant difference was noticed between violinists and vocalist. Results are discussed in detail below.

Auditory memory:

Musical competence may confer cognitive advantages that extend beyond processing of familiar musical sounds. Out of two memory tests, results of one has shown music induced enhancement of auditory memory in musicians (both violinists and vocalists) compared to non-musicians. This result is in congruence with the evidence from earlier behavioral studies reporting general enhancement of memory in musicians. [23, 30-33] Reason discussed for such a finding in these studies is simply that brain is plastic and any learning can induce structural and functional changes (neuro-plasticity) and hence probably musical experience might also lead to changes which intern may result in memory enhancements.

The FDS test did not show difference between musicians (both vocal and instrumental) and non-musicians. Lesser difficulty level in this test compared to BDS could be the probable reason for such a finding. This might draw researcher's attention towards selecting appropriate tools for evaluating the music induced differences.

Speech perception in noise

According to the finding of this study, musicians outperformed non-musicians in extracting speech from the noisy background. Sacks [42] reports music has one of the powerful sources of auditory stimulation and it is interesting to understand how music makes speech perception better in noise. Electrophysiological studies have evidenced altered neural encoding of various auditory stimuli in musicians. [20, 21, 29, 43-45] Many of those studies have shown better encoding of speech stimuli even when presented along with noise.

These findings suggest that musical experience confers an advantage resulting in more precise neural synchrony in the auditory system. According to Anderson et al. [43] musicians, probably due to music induced brain plasticity have robust temporal and spectral encoding of the eliciting speech stimulus which possibly offsets the deleterious effects of background noise. This is one of the well accepted biological explanations postulated for musicians' perceptual enhancement for speech-in-noise.

It is important to note that in the current study, between vocalists and violinists significant difference was not noted in the performance related to speech in noise perception. Hence, it might be correct to speculate that probable changes in the underlying neural circuitry (related to speech perception in noise) that occur following extensive musical experience is not influenced by the type of music (vocal vs. instrumental).

CONCLUSIONS

Considering the existing literature reports and findings of this study, it can be said that musicians clearly have an advantage over non-musicians in many auditory-cognitive performances including auditory memory and speech in noise perception. Most importantly this study findings lead to a conclusion that type of music (vocal vs. instrumental) does not have a strong influence on music induced auditory processing enhancements. In other words, both vocal and instrumental musicians perform similar and are equally better than non-musicians in auditory memory and speech perception in noise skills.

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