International Journal of Health Sciences and Research
www.ijhsr.org ISSN: 2249-9571

Original Research Article

Short-Term Perceptual Training of Music and Its Effect on Neural Encoding

Devi. N[1], Ajith Kumar U[2], Hijas Mohamed[3]

[1]Lecturer in Audiology, [2]Reader in Audiology,
All India Institute of Speech and hearing Manasagangothri, Mysore-570 006.
[3]Clinical Audiologist, Coimbatore.

Corresponding Author: Devi. N

Received: 16/03/2015 *Revised: 15/04/2015* *Accepted: 16/04/2015*

ABSTRACT

Introduction: Speech and music exhibits similar acoustic and structural properties and even its perception recruit shared computational systems. However, short term music perceptual training and its effect on neural encoding at cortical and sub cortical structures of brain still remains unanswered.
Aim and objective: To investigate the short-term perceptual musical training and its influence on encoding of speech and music evoked auditory responses for frequency following response and long latency response.
Methodology and Analysis: Pre and post perceptual musical training was recorded for harmonics of frequency following response and long latency response (LLR) for speech stimuli /da/ and music stimuli played through violin for 20 participants in the age range of 18-25 years.
Results: The results reveal that there was no significant difference for the harmonic of frequency following response where as significant difference was observed for the P2 and N2 latency and N2 amplitude of LLR.
Conclusion: The short-term perceptual musical training had an impact on plasticity which was evident at the cortical level preceding the changes at the sub-cortical level. There is a clear clinical implication that the plasticity of the organism can be strengthened which would fine tune the neural process not only for the music perception but also for speech and language remediations.

Key words: Speech evoked responses, Music evoked responses, Short - term perceptual musical training, Harmonics

INTRODUCTION

Perception of speech and music is complex as both requires precise fine processing of frequency, intensity, time and attention. There are anatomical overlap in the brain networks that process an acoustic feature used in both music and speech. The auditory perception in humans is enriched with cognitive as well as sensory processes that work through a complex interaction of corticofugal neural pathway from cochlea to cortex and vice versa. The perception of complex signals like speech and music are realized due to the dynamic modulation present per se. [1] Speech being the primary communication system, problems with speech perception (especially seen in geriatrics) can be very distressing. Recent research suggests that musical training enhances the sensory processing of speech sounds at the level of brainstem and cortex. [2] So the continuous and consistent music practice over the years helps in fine tuning the auditory system in a comprehensive manner. This in turn strengthens the cognitive and neurobiological foundations of both music and speech processing.

Experience and /or training can alter the neural processing and modify the brain structure and function both cortically and sub cortically. [3] However, changes at various levels of auditory pathway from the brainstem to the primary and surrounding auditory cortices to the areas involved in higher – order auditory cognition due to musical experience. [4,5] Long-term music training exposure results in plastic changes in sub cortical and cortical auditory pathways. At behaviour level, long term music exposure improves fine grained auditory perception, pitch coding, auditory attention and working memory. These perceptual and cognitive factors are also shown to be important for speech perception in noise. [6,7] Few studies have shown musicians have better processing of speech in noise compared to non-musicians. [8-11] These studies have found robust brainstem encoding of speech as neurobiological basis for the enhanced perception of speech in noise in musicians. [12] These positive effects have been demonstrated only on musicians who had undergone long term formal training in music. It is interesting to see whether these advantages extend to short-term perceptual musical exposure also. It is also interesting to see if changes occur, does the music training leads to changes throughout the auditory system for listening challenges beyond music processing in terms of encoding of the speech sounds. Specifically, we measured brainstem and cortical responses to speech and music stimuli after a short-term perceptual musical training on Indian classical music.

Aim and objectives: To study the pre and post perceptual musical training difference in the speech and music evoked frequency following responses and long latency responses.

Participants

A total of 20 normal hearing adults (16 males, 4 females) in the age range of 18-25 years (mean age = 21.29 years, SD = 2.65 years) participated in the study. These participants were same as those participated in our previous study. [13] Participants had their air conduction and bone conduction hearing thresholds within 15 dB HL at octave frequency from 250 Hz to 8 kHz. Participants also had speech identification scores of 90% and above in both the ears. All participants showed 'A' type tympanogram with acoustics reflex at normal sensation levels. None of them reported any history of middle ear pathology, ototoxic drugs usage or exposure to occupational noise. Participants did not have any complaints of difficulty in understanding speech in presence of background noise.

MATERIALS AND METHODS

All the participants were amateur or rare listeners of classical music and they were informed about the purpose of the study and a written consent for their willingness to participant in the study was taken.

Phase I: Electrophysiological recording:

Brainstem and cortical responses were recorded for both speech and music stimuli. Music stimuli consisted an excerpt of Mayamalavagowla raga at A scale played by an expert violinist. Mayamalavagola is a shudh madhyam raga and 15th mela karta. [14] The output of the violin was recorded using a unidirectional microphone placed at a unidirectional microphone placed at one foot distance. The recording of the stimuli were done using Adobe Audition software (Version 3) with a sampling rate of 48000 Hz and 32 bit resolution. After recording the music stimuli was edited only to first note from the complete raga which was 100 msec. The first note was taken as the stimuli as it's the root of the octave, all the other notes are defined in relation to the root. Then the edited music stimulus was loaded into Biologic system Version 7.0. Speech stimuli was default BIOMARK /da/ provided by the Biologic system manufacturer was used. The participants were comfortably seated to ensure a relaxed posture and a minimum rejection rate. Silver chloride cup electrodes were placed after cleaning the electrode site with the preparation gel. Conducting gel was used to ensure proper conductivity; electrodes were placed on the respective site with the help of plaster. Frequency following response (FFR) and long latency response (LLR) were recorded binaurally using speech stimuli /da/ of 40 msec duration and music stimuli of 100 ms. Single channel recording was carried out with vertex positive and the ipsilateral mastoid negative. The fore-head served as the site for the ground electrode. Inter-electrode impedance was maintained below 2 kΩ. Other recording and acquisition parameters for brainstem and cortical responses were as shown Table 1.

Table 1: Speech and Music evoked electrophysiological recording and acquisition parameters

PARAMETERS	Speech FFR	Music FFR	Speech LLR	Music LLR
Stimulus Type	Biomark /da/	Violin tone /sa/	Biomark /da/	Violin tone /sa/
Duration	40 ms	100 msec	40 ms	100 msec
Rate	5.1/sec	5.1/sec	1.1/sec	1.1/sec
Polarity	Alternating	Alternating	Rarefaction	Rarefaction
Level	70 dB nHL	70 dB nHL	70 dB nHL	70 dB nHL
No. of Sweeps	1500	1500	200	200
Band pass filters	100-2000 Hz	100-2000 Hz	1 – 30 Hz	1 – 30 Hz
ACQUISITION				
Analysis time				
Pre stimulus	15 msec	40 msec	75 msec	75 msec
Post stimulus	70 msec	120 msec	450 msec	450 msec

The auditory evoked potentials were recorded before and after the short term perceptual musical training.

Phase II: Short-term perceptual musical training

An expert violinist who passed 'senior level' examination and practices 2 to 3 hours daily played the song in two Ragas Kalayani Raga and Mayamalavagola Raga. These two ragas were chosen as it is one of the basic raga in Indian Carnatic Music and they both differ in terms of frequency of 1st note (ri), 3rd note (ma) and 5th note (da). Eight samples of both the ragas (four for each) were recorded each lasting for about 15 minutes. All the participants were asked to listen to violin song played in Kalyani Raga for 15 minutes and Mayamalavagola Raga for another 15 minutes with the help of personal computer through high fidelity headphones (Sennheiser HD 449). After each training session participants were made to listen to small music excerpts from both the ragas and were instructed that whenever they hear the excerpts from *Kalyani* raga they had to identify the raga as *Kalyani*. Similar task was performed for *Mayamalavagola* raga, too.This training was provided every day for a period of 8 sessions. An identification task using the excerpts of raga was also carried out immediately after training. Feedback was provided immediately after the response during the training sessions. Figure 1 depicts the mean identification scores for both the ragas after the music perceptual training sessions on each day.

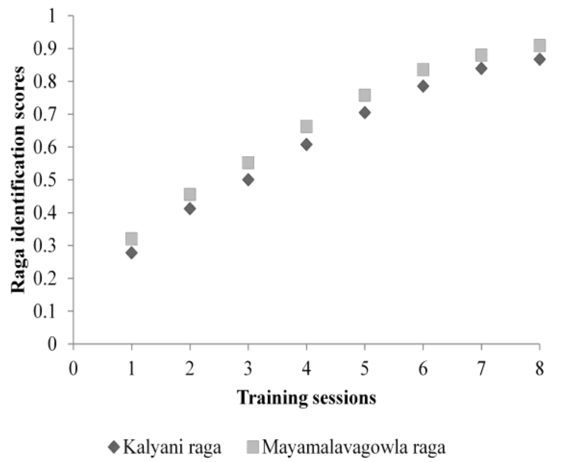

Figure 1: Mean identification scores for both the ragas after the music perceptual training sessions on each day.

Figure 1 reveals that the scores of identification of the raga increased gradually with increase in the number of training sessions.

Analysis:

Before analysis all wave forms were base line corrected. Brainstem responses were analysed using brain stem tool box. [15] Cortical responses were analysed by measuring the peak amplitude and peak latencies of N1, P1, N2 and P2 peaks. Furthermore, a point wise paired t - tests were carried out between pre and post training evoked potential waveforms. This identifies the timing of the differential responses between the pre and post training waveforms. These analyses were carried out using the Cartool 3.55 software (Brunet, 1996) (http:/brainmapping.unige.ch/Cartool.htm).

RESULTS

The mean and standard deviation in terms of its respective amplitude of F0, H1, H2, H3 and H4 for speech evoked frequency following response and music evoked frequency following response were calculated for all the participants and shown in Figure 2a and 2b.

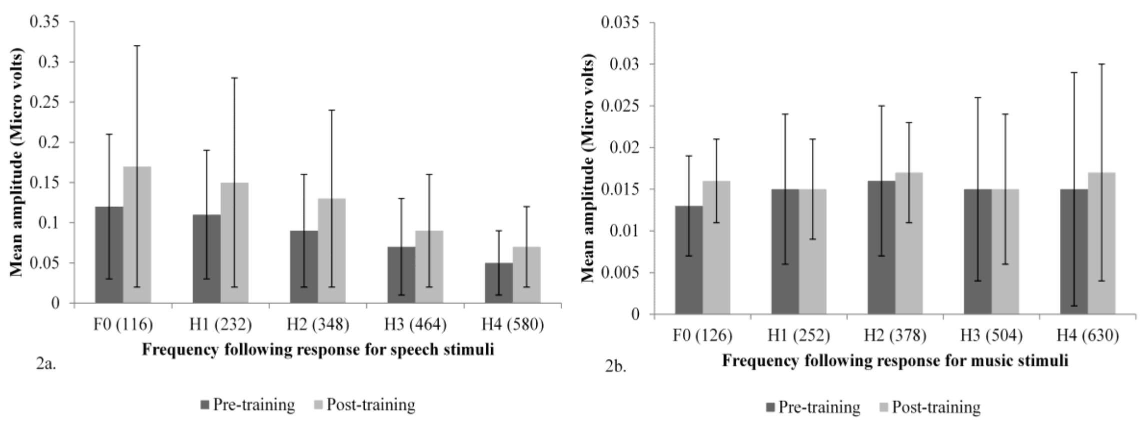

Figure 2: a. Pre and post training mean and standard deviation amplitude of F0, H1, H2, H3 and H4 for speech stimuli. b. Pre and post training mean and standard deviation amplitude of F0, H1, H2, H3 and H4 for music stimuli

Table 2: Results of Wilcoxon signed ranks test for pre and post Speech and Music evoked frequency following response (Harmonics)

Pre-post Speech evoked FFR (Harmonics)			Pre-post Music evoked FFR (Harmonics)		
Conditions	'Z' Value	p (>.05)	Conditions	'Z' Value	p (>.05)
PF0S - F0S	-.682	.495	PF0M - F0M	-1.667	.096
PH1S - H1S	-.883	.377	PH1M - H1M	0.000	1.000
PH2S - H2S	-.805	.421	PH2M - H2M	-.535	.593
PH3S - H3S	-1.025	.305	PH3M - H3M	-.165	.869
PH4S - H4S	-1.087	.277	PH4M - H4M	-.402	.688

Wilcoxon signed ranks test was carried to find if there is any significant difference between the pre and post perceptual musical training.

The results of table 2 reveals that there was no significant difference for all the parameters of F0, H1, H2, H3 and H4 for speech and music evoked frequency following response between pre and post perceptual musical training. Cartool was used to find out the waveform modulations if any, between pre and post perceptual musical training for speech and music evoked frequency following response.

A series of paired t-tests between waveforms of pre and post FFR at every data point was calculated to find out the significant waveform modulations. To minimize the family wise errors, results of the paired t-test (at an alpha criterion of 0.05) were evaluated against the randomized distribution. The result of this test provides an overview regarding the time points at which the response differed. Correction was made by applying a temporal criterion of 20 continuous time frames for the persistence the differential effects. Results of this analysis showed that there was no significant difference between the FFRs of pre and post training at any of the data points.

In order to analyse the long latency response, P1, N1, P2 and N2 peaks were marked by two experienced audiologist and then latency and amplitudes were extracted. In case of differences the mean of the two judges mean values were taken. Figure 3a and 3b shows the pre and post mean and standard deviation of latency and figure 4a and 4b shows the pre and post mean and standard deviation of amplitude for LLR different components respectively for speech and music stimuli.

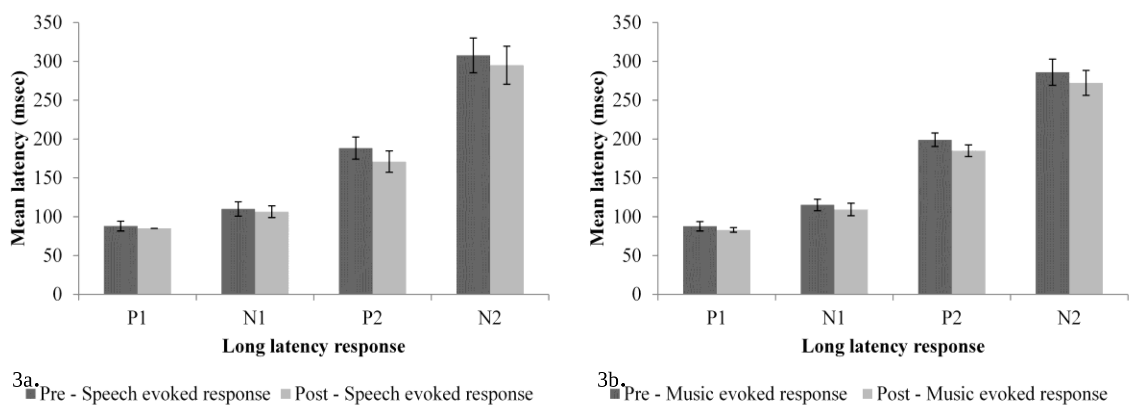

Figure 3a and 3b shows the pre and post mean and standard deviation of latency for different LLR components for speech and music stimuli respectively.

Paired t – test was done to check if there is any difference between pre and post perceptual musical training speech evoked responses as well as music evoked responses in terms of latency and amplitudes of long latency responses. The results of the latencies of the speech evoked long latency response reveal that there is no significant difference for P1 [$F (1, 19) = 0.035$, $p>.05$], N1 [$F (1, 19) = 0.186$, $p>.05$], latencies. Whereas P2 [$F (1, 19) = .043$, $p<.05$], N2 [$F (1, 15) = 0.000$, $p<.05$] latency were significantly different. Similarly music evoked long latency response reveal that there is no significant difference for P1 [$F (1, 19) = 0.072$, $p>.05$], N1 [$F (1, 19) = 0.143$, $p>.05$], latencies. Whereas P2 [$F (1, 18) =.032$, $p<.05$], N2 [$F (1, 16) = 0.004$, p<.05] latency were significantly different (Bonferroni's correction applied for multiple comparisons). Comparatively the latencies were shorter in post training compared to pre training for both speech and music stimuli.

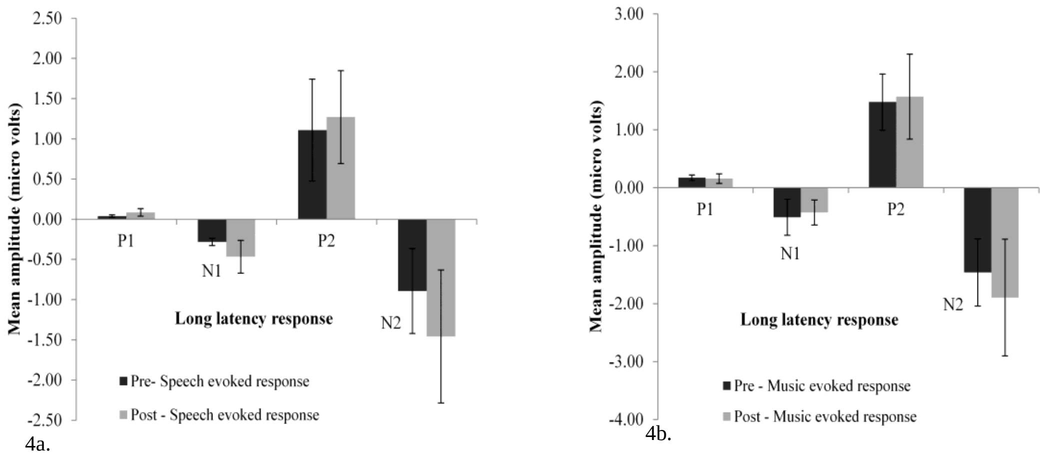

Figure 4a and 4b shows the pre and post mean and standard deviation of amplitude for different LLR components for speech and music stimuli respectively.

The results of the amplitude of speech evoked long latency response reveal that there is no significant difference P1 [F (1, 19) = .755, p>.05], N1 [F (1, 19) = 0.246, p>.05], P2 [F (1, 19) = .678, p>.05], did not reveal any significant difference but N2 [F (1, 19) = .011, p<.05] had a significant difference between pre and post perceptual musical training pre and post speech evoked long latency responses. Music evoked long latency response in terms of amplitude reveal that there is no significant difference for P1 [F (1, 19) = 0.924, p>.05], N1 [F (1, 19) = 0.125, p>.05] and P2 [F (1, 19) =.243, p>.05], where as N2 [F (1, 19) = 0.004, p<.05] was significantly different between pre and post perceptual music training.

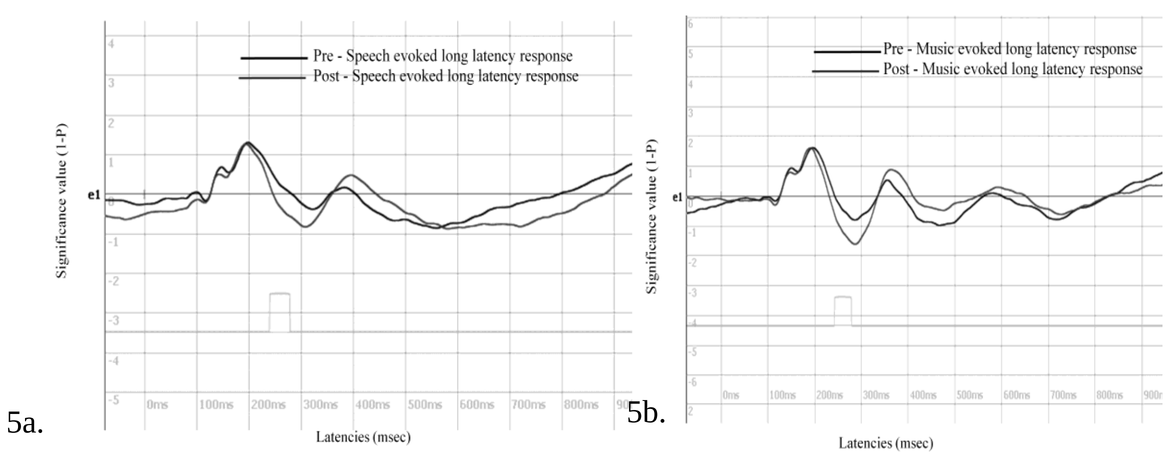

Figure 5a and 5b shows the average pre and post training LLR waveforms and *1-p* values for both speech and music stimuli respectively.

Furthermore, to study the waveform modulations more extensively series of paired t-tests between waveforms of pre and post LLR at every data point was performed. To minimize the family wise errors, results of the paired t-test (at an alpha criterion of

0.05) were evaluated against the randomized distribution. The result of this test provides an overview regarding the time points at which the response differed. Correction was made by applying a temporal criterion of 10 continuous time frames for the persistence the differential effects. The results are displayed as 1 minus the *P* value as a function of time post stimulus onset. This analysis revealed that in 236ms to 278ms and 242ms to 281 ms range pre and post stimulus responses differed significantly for speech and music evoked long latency response respectively. Figure 5a and 4b shows the average pre and post training LLR waveforms and *1-p* values for both speech and music stimuli.

DISCUSSION

Human brain is highly plastic and it can be sharpened or tuned with different experiences or training. This study was taken up to investigate if there are any changes with respect to perceptual short term musical training. The results reveals that the short-term perceptual musical training for a periods of continuous 8 days did not have any significant changes (p>.05) in the encoding of speech and music stimuli (pre and post) at the sub-cortical level through the measurement of harmonics of frequency following response. The FFR is the summed responses of electrical currents from structures including cochlear nucleus, superior olivary complex, lateral lemniscus, and the inferior colliculus. [16] The numbers of neurons involved at the various nuclear way stations undergo a progressive increase from cochlear nucleus to the cortex. There are 30,000 spiral ganglion cells in the auditory nerve, 88,000 neurons are found in one cochlear nucleus in the primate. One superior olivary complex contains 34,000 neurons, whereas the nucleus of the lateral lemniscus has 38,000 neurons, and at the inferior colliculus level there are almost 400,000 neurons on each side and at the medial geniculate body 500,000. Whereas, the auditory cortex has approximately 10 million neurons. [17] Hence the plasticity that happens at the level of the sub-cortical region may me slower and might require more intensive training for evident changes in the neural tuning compared to the cortex.

The auditory brain has an awesome capacity to change through experience. [18] But there are limits to this plasticity, in terms of the age of training, duration of training, attention, rigorous and regular practice with complex sounds. In the present study the significant changes in the amplitude of the frequency following response was not observed which could have also attributed to the number of session of perceptual musical training was lesser.

Unlike FFR responses the results of LLR analysis showed significant difference in N2 amplitude and P2 - N2 latency between pre and post short-term perceptual musical training. Paired t tests also indicated significant waveform modulations in 349ms to 504ms and 301ms to 482 ms range post stimulus for speech and music evoked long latency response. The P2-N2 areas are generators of multiple auditory areas including primary auditory cortex, secondary cortex, planum temporale and mesencencephilic reticular activating system. These components may reflect attention to sound arrival and formation of sensory memory of the sound stimuli which can be through auditory training in the auditory cortex. The P2 – N2 complex is thought to reflect synchronous neural activation of structures in the thalamic-cortical segment of the central nervous system in response stimulus discrimination and acoustic characteristics of audition. [19] as well N2 responses are highly related to attention. [20]

The study reveals that the training has had an impact on the plasticity and the evident of this change in plasticity is only at the cortical level which usually precedes the changes at the sub-cortical level. [21,22] Which suggest that plasticity in sub cortical circuits could be driven by descending ("corticofugal") neural projections from cortex onto these circuits. There are many such projections in the auditory system (exceeding the number of ascending fibres), providing a potential pathway for cortical signals to tune sub cortical circuits. The processing and plasticity of the encoding of speech sounds is generally at-tribute to the neocortex [23-25] although brain-stem and thalamic structures contribute to such processing to a certain extent. The corti-cofugal system plays an important role in improving and adjusting auditory signal processing in the cortex and subcortical nuclei. [26] The reorganizations of subcortical auditory nuclei and hair cells are short term, whereas cortical reorganization evoked by auditory fear conditioning is long term. The results of the amplitude and latency analysis of the long latency response reveal significant difference only to certain cite of excitement however, further more degree and domain general enhancement would take place significantly with the amount of musical training and practice. [4,27-29]

Furthermore, the speech evoked responses and musical evoked response of both cortical and sub-cortical could not be comparable in our present study as there are difference in the parameter related to the stimuli itself. However, perceptual musical training might influence the neural encoding of speech (i.e., via plasticity driven by corticofugal projections). [30]

CONCLUSION

The study was conducted on 20 normal hearing individuals in the age range of 16 - 25 years who did not have any exposure or experience with music. Pre and post electrophysiological frequency following response and long latency response were recorded for speech and music stimuli after a short term perceptual musical training. The results revealed that there was no significant difference for the sub-cortical responses in terms of frequency following response where as there was significant difference observed for the cortical responses (long latency response) for speech and music stimuli for harmonics (FFR), latency and amplitude (LLR). The reason that the changes were not observed at the sub-cortical level might be because that the duration of the perceptual musical training was only for 8 days. Hence, if the duration of perceptual musical training increases subtle differences could be observed in sub-cortical responses also. Such training might interact over time to sustain sharpened neural processing in central auditory nuclei which may carry meaningful improvement in language skills by activating the same areas of speech language processing in the brain. There is a clear clinical implication that with short-term perceptual musical training, the plasticity of the organism can be strengthened which would fine tune the neural process not only for the music perception but also for speech and language remediation's.

REFERENCES

1. Zatorre RJ, Belin P, Penhune VB. Structure and function of auditory cortex: music and speech. Trends Cogn Sci 2002;6:37-46.
2. Strait DL, Kraus N. Playing Music for a Smarter Ear: Cognitive, Perceptual and Neurobiological Evidence. Music Percept 2011; 29(2);133-146.
3. Song H, Buhay JE, Whiting MF, et al. Many species in one: DNA barcoding overestimates the number of species when nuclear mitochondrial pseudogenes are coamplified. Proceedings of the National Academy of

Sciences of the United States of America 2008;105:13486–13491.
4. Wong PC, Skoe E, Russo NM, et al. Musical experience shapes human brainstem encoding of linguistic pitch patterns. Nat Neurosci 2007; 10: 420–422
5. Lappe C, Herholz SC, Trainor LJ, et al. Cortical plasticity in-duced by short-term unimodal and multimodal musical training. J Neurosci 2008;28:9632–9639.
6. Parbery-Clark A, Skoe E, Lam C, et al. Musician enhancement for speech in noise. Ear Hearing 2009; 30(6):653-661.
7. Anderson S, Parbery-Clark A, Yi H, et al. A neural basis of speech-in-noise perception in older adults. Ear Hearing 2011; 32(6):750-757.
8. Heinrich A, Schneider BA, Craik FI. Investigating the influence of continuous babble on auditory short-term memory performance. Q J Exp Physiol CMS 2008;61(5):735-51.
9. Parbery-Clark A, Skoe E, Kraus N. Musical experience limits the degradative effects of background noise on the neural processing of sound. J Neurosci 2009;29: 14100-14107.
10. Parbery-Clark A, Skoe E, Lam C, et al. Musician enhancement for speech-in-noise. Ear Hearing 2009;30:653.
11. Parbery-Clark A, Strait DL, Kraus N. Context-dependent encoding in the auditory brainstem subserves enhanced speech-in-noise perception in musicians. Neuropsychologia 2011;49:3338–3345.
12. Parbery-Clark A, Anderson S, Hittner E, et al. Musical experience strengthens the neural representation of sounds important for communication in middle-aged adults. Front. Aging Neurosci 2012;4(30):1-12.
13. Jain C, Mohamed H, Kumar UA. Short-term musical training and Psychoacoustical ability. J Aud Res 2015; 5(111):1-8.
14. Srikanthan RK, Srinivas IMJ, Sharade T, et al. Sarvajanik shiksha iilake. Government of Karnataka; 2002.
15. Skoe E, Kraus N. Auditory brainstem response to complex sounds: A tutorial. Ear Hearing 2010;31(3):302-324.
16. Chandrasekaran B, Kraus N. The scalp-recorded brainstem response to speech: neural origins and plasticity. Psychophysiology 2010;47:236–246.
17. Richard R, Gace K, Mark R. Anatomy of the Auditory and Vestibular Systems. In Snow, BJ, Ballenger JJ. Ballengers Otolaryngology Head and Neck Surgery. 6th ed. Philadelphia: University of Pennsylvania. 2003:1-24.
18. Skoe E, Kraus N. Musical training heightens auditory brainstem function during sensitive periods in development. Front Psychol 2013;19(4):622.
19. Naatanen R The role of attention in auditory information process-ing as revealed by event-related potentials and other brain measures of cognitive function. The Behav Brain Sci 1990;13: 201–88.
20. Ponton CW, Eggermont JJ, Kwong B, et al. Maturation of human central auditory system activity: evidence from multi-channel evoked potentials. Clin Neurophysiol 2000;111(2):220-236.
21. Winer J. Decoding the auditory corticofugal systems. Hearing Res 2006;212:1–8.
22. Kral A, Eggermont J. What’s to lose and what’s to learn: development under auditory deprivation, cochlear implants and limits of cortical plasticity. Brain Res Rev 2007;56:259–269.
23. Zatorre RJ, Evans AC, Meyer E, et al. Lateralization of phonetic and pitch processing in speech perception. Science 1992;256:846-849.
24. Wong PC, Nusbaum HC, Small SL. Neural bases of talker normalization. J Cognitive Neurosci 2004;16(7):1173-1184.
25. Liebenthal E, Binder JR, SpitzerSM, et al. Neural substrates of phonemic

perception. Cereb Cortex 2005;15: 1621–1631.

26. Suga N, Xiao Z, Ma X, et al. Plasticity and Corticofugal Modulation Review for Hearing in Adult Animals. Neuron 2002;36(26):9–18.
27. Musacchia G, Sams M, Skoe E et al. Musicians have enhanced subcortical auditory and audiovisual processing of speech and music. Proc Natl Acad Sci USA 2007;104:15894–15898.
28. Musacchia G, Strait DL, Kraus N. Relationships between behavior, brainstem and cortical encoding of seen and heard speech in musicians and nonmusicians. Hearing Res 2008. 241, 34–42.
29. Strait DL, Skoe E, Kraus N et al. Musical experience and neural efficiency: Effects of training on subcortical processing of vocal expressions of emotion. Eur J Neurosci 2009; 29: 661–668.
30. Kraus N, Chandrasekaran B. Music training for the development of auditory skills. Nat Rev Neurosci 2010;11: 599–605.

How to cite this article: Devi. N, Ajith Kumar U, Mohamed H. Short-term perceptual training of music and its effect on neural encoding. Int J Health Sci Res. 2015; 5(5):347-356.

****