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Original Research Article

Brainstem Encoding Of Indian Carnatic Music in Individuals With and Without Musical Aptitude: A Frequency Following Response Study

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ABSTRACT

Introduction: Brainstem evoked responses reflect the frequency and time-varying characteristics of sound and have been studied using click, tonal and speech stimuli as well as non-speech stimuli. However, music stimuli evoked frequency following response (FFR) will provide an in depth information on the pitch contours of its varying composition.
Aim & Objective: To investigate the music transit encoding of frequency following response for individuals with musical aptitude and without musical aptitude.
Methodology & Analysis: Sixty participants were divided into two groups as with and without musical aptitude based on the scores of *'Questionnaire on music perception aptitude'* and *'The Music (Indian music) Perception Test Battery'*. FFR was recorded for 127 ms Indian Carnatic music transit stimuli. In order to assess the participants pitch tracking to the music stimuli three measures of pitch tracking (stimulus to response correlation, pitch Strength and pitch error) were calculated.
Results: The results reveals that the scores of the participants with musical aptitude for the parameters of pitch error was lesser pitch strength was better with more stimulus-to-response correlation than the participants without musical aptitude.
Conclusion: Music is an intrinsically rewarding auditory activity, due to its activation of the brain's mesolimbic reward network, though not formally trained but still with innate capability and experience dependent plasticity might incorporate an individual's musical processing aptitude.

Key words: Transit music, Questionnaire, Pitch tracking.

INTRODUCTION

The frequency following response (FFR) is a scalp-recorded auditory brainstem evoked potential that follows the pitch contour of a complex stimulus, reflecting neural phase-locked activity. [1] The response is characterized by a periodic waveform which follows the individual cycles of the stimulus waveform. FFR can be recorded with simple stimuli such sinusoids to more complex sounds. [2] FFR has been reported majorly for, speech stimuli, speech like stimuli, tuned and detuned musical chords, speech syllables with descending and ascending pitch contours, [3] Mandarin pitch contours, [4,5] synthetic syllable continum, [6] synthetic vowel [7] or natural vowel [8] non-speech vocal sounds - baby's cry [9] and also musical sounds. Despite using music stimuli to evoke brainstem encoding is relatively a new endeavor, it has a profound influence on the experience-dependent plasticity in the auditory brainstem on how sound is processed in the brain. It is an intriguing notion that musicians could unconsciously detect smaller changes in pitch than non-musicians. [10] Comparing the music stimuli and non-music stimuli, music stimuli has differences and similarities in its compositions with varying pitch contours which actually taps the perception ability of a musical expert. Hence, the present study aimed to use a novel Indian Carnatic music transit stimulus which has a larger pitch variation as neural encoding of pitch with varying contours as it is vital in processing prosody, source identification and sound source segregation.

The music stimuli primarily relay upon the hierarchical arrangement of pitch. [11,12] In music, changes in pitch are quintessentially discrete and stair-stepped in nature despite the capabilities of many instruments to produce continuous ornamental slides. [13] Musicians also show more robust pitch encoding, relative to non-musicians, in response to speech as well as music stimuli. [14,15] Thus, musical training sharpens sub cortical encoding of linguistic pitch patterns. However, despite ample evidence the question remains whether musical training influences or the experience and environment or the innate inherit induced plasticity enhances sub cortical encoding of musical pitch patterns. Hence, the present study investigates if there are any differences in music transit encoding of frequency following response for individuals with musical aptitude and without musical aptitude.

MATERIALS AND METHODS

Participants: The participants involved in the study comprised of two groups in the age range of 18 to 40 years. Group I consists of thirty individuals (mean age range of 25.27, SD=3.88) with musical aptitude and group II consists of thirty individuals (mean age range of 29.93, SD=5.39) without musical aptitude. Musical aptitude of the participants were tested based on the administration of a 'Questionnaire on music perception aptitude' (Appendix A) which had questions related to different parameters of music like pitch awareness, pitch discrimination & identification, timber identification, melody recognition and rhythm perception and Music (Indian music) Perception Test Battery [16] which assesses different parameters of music like pitch discrimination, pitch ranking, rhythm discrimination, melody recognition and instrument identification. 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.

Stimuli and procedure: Indian Carnatic music can be either vocal or instrumental, and it is typically based on Raga and Talas. Raga is sequential arrangement of notes that is capable of invoking the emotion of a song. In order to elicit a music evoked brainstem response a basic raga - Mayamalavagowla raga from South Indian Carnatic music was taken as the stimuli. A trained violinist who has passed a senior grade in Indian Carnatic music was seated comfortably in a sound treated room and played the Mayamalavagowla raga at octave scale several times in separate recording settings. These were recorded using unidirectional microphone into CSL 4500 model (Kay PENTAX, New Jers, and USA) at a sampling frequency of 48,000 kHz and were saved into computer. The test stimuli was selected based on goodness test which was rated perceptually on a 3 point rating scale (good, fair and bad) for the quality and its naturalness by five experienced violinist. The selected stimulus was edited for the transition portion of the notes of sa-ga of the raga which had its highest pitch varying transition (118 – 147 ms) with the total duration of the stimuli of 127 ms. Figure 1 represents the waveform and spectrogram of the stimuli which reveals the shift of the fundamental frequency from 118 Hz to 147 Hz at around .055 to .077ms when the notes were shifted from sa to ga.

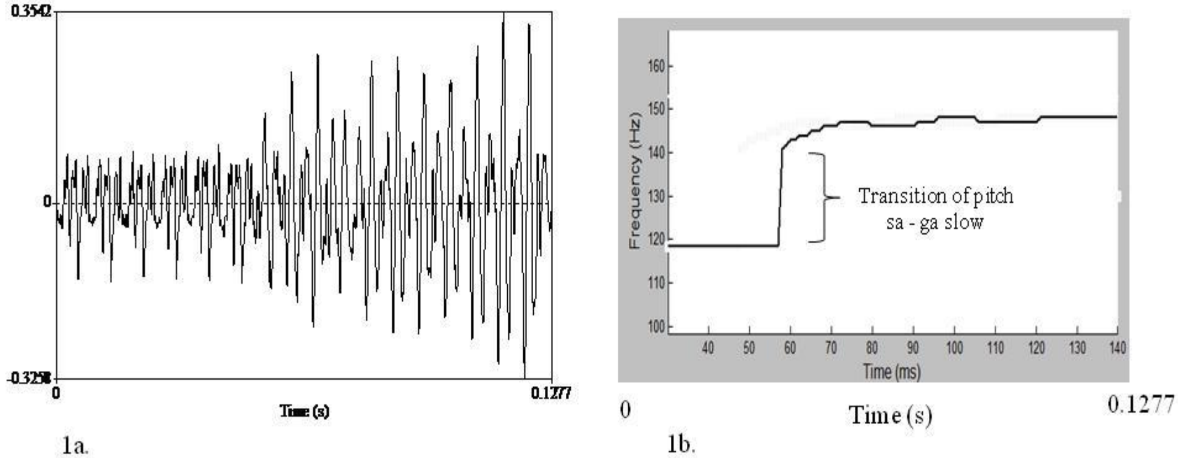


Figure 1: a. Waveform of the Indian Carnatic sa-ga music transit stimuli b. Spectrogram of the Indian Carnatic sa-ga music transit stimuli

The stimulus was delivered through insert earphones at an intensity of 85dB SPL binaurally using sound module of Stim2 software. Frequency following responses was recorded for music stimuli using Scan 4.4, Synamps2 amplifier (Neuroscan; Compumedics). Responses were recorded for 2000 alternate polarity stimulus with an inter stimulus interval of 270ms. During the recordings participants were seated comfortably in a reclining chair and watched a muted video of a movie with subtitles. Responses were recorded from silver chloride electrodes placed on Cz and M1 (left mastoid) with M2 (right mastoid) as reference. Ground electrode was placed at forehead. The electrode impedances was lesser than 5 kΩ for all the participants. A continuous EEG data was recorded at a sampling rate of 20000 Hz.

DC offset correction, filtering and artifact rejection were employed offline using Edit module Scan 4.5, (Neuroscan; Compumedics) prior to averaging the responses. Continues EEG waveform was DC offset corrected with a polynomial order of two, band pass filtered from 30-3000 Hz. They were epoched from -20 to 200 ms. the epochs exceeding the voltage of ±35µV were rejected using artifact rejection and then were averaged for each polarity and added together to minimize the stimulus artifact and cochlear microphonics. To assess the participants pitch tracking to the music stimuli three measures of pitch tracking (stimulus to response correlation, pitch Strength and pitch error) were calculated. These measures were derived using autocorrelation which analyses Fast Fourier Transform (FFT) of both FFR response and stimulus. Stimulus to response correlation (SR_r) is the degree of similarity between the stimulus and response F0 contours which is calculated using Pearson‘s correlation coefficient (r). It represents direction and strength of relationship between stimulus and response. Pitch Strength refers to the mean of the ‘r’ values which denote the strength of relationship. Pitch error is the amount of deviation of response in Hz from the stimulus pitch on average. All the above analyses were done using Brainstem Toolbox (2013) in Matlab™ (Version 7.8).

RESULTS

The recorded FFR for music stimuli was subjected to autocorrelation and the mean and standard deviation for the three parameters, stimulus-to-response correlation (Serer), pitch strength (PS) and pitch error (PE) for music stimuli were measured which is represented in Figure 2. Figure 2 shows the mean and standard deviation of all the parameters of autocorrelation for participants with and without musical aptitude.

The mean pitch error (PE) was lesser (Mean= 2.63, SD=1.01), pitch strength (PS) was higher (Mean= 0.89, SD=0.6) and stimulus-to-response correlation (SR_r) was higher (Mean=.95, SD=0.06) for participants with musical aptitude when compared to participants without musical aptitude.

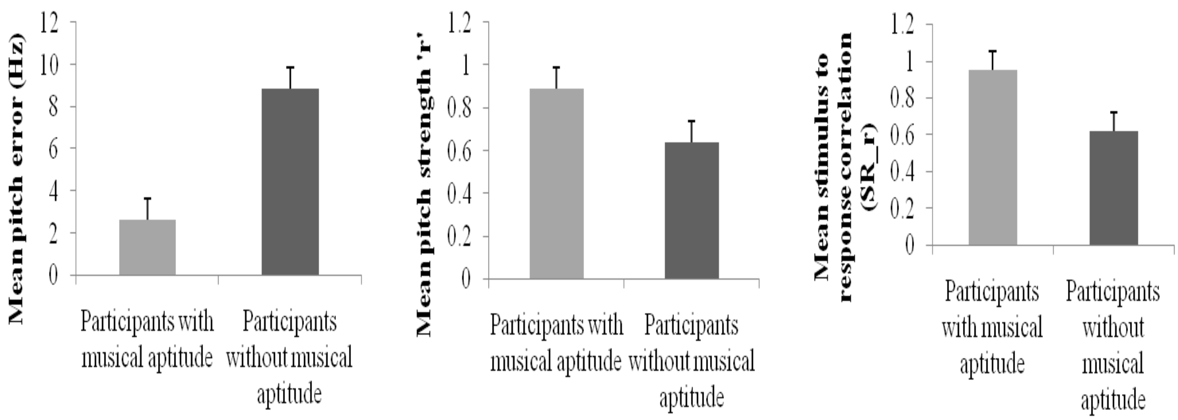


Figure 2: Mean and standard deviation of Pitch Error, Pitch Strength and stimulus to response correlation for both the group of participants

Independent t- test was done to compare the mean PE, PS and SR_r between the two groups of participants. The results revealed a significant difference for pitch error [t (60) = -12.827 ($p<0.05$)], pitch strength [t (60) = 10.761 ($p<0.05$)] and SR_r [t (60) = 13.991 ($p<0.05$)] between the two groups of participants. The grand average wave forms of FFR for both the participants with musical aptitude and without musical aptitude are represented in Figure 3.

From figure 3 it’s evident that the responses to stimuli in FFR for the participants with musical aptitude are sharper and has better amplitude compared to participants without musical aptitude. The autocorrelation spectrograms and the pitch tracking plots were done for the two groups of participants which are represented in the Figure 4 (a, b).

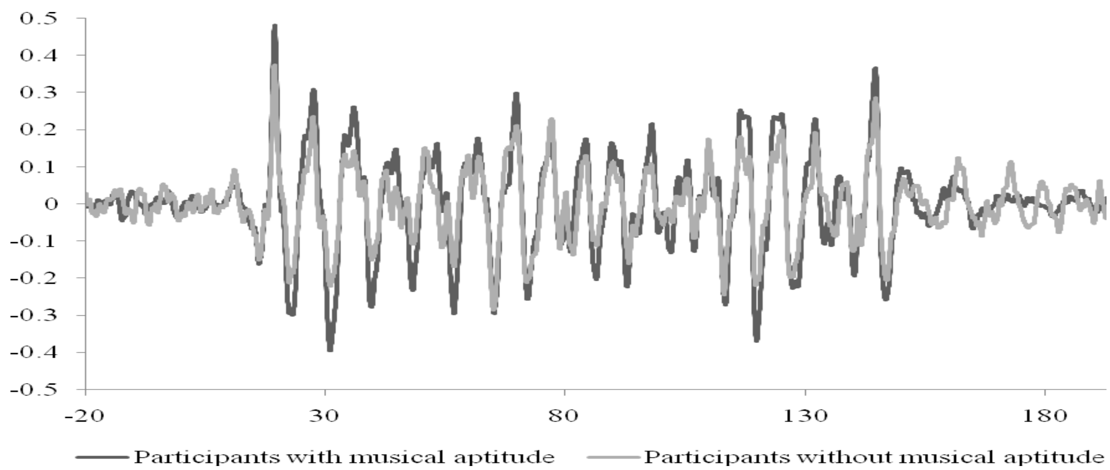
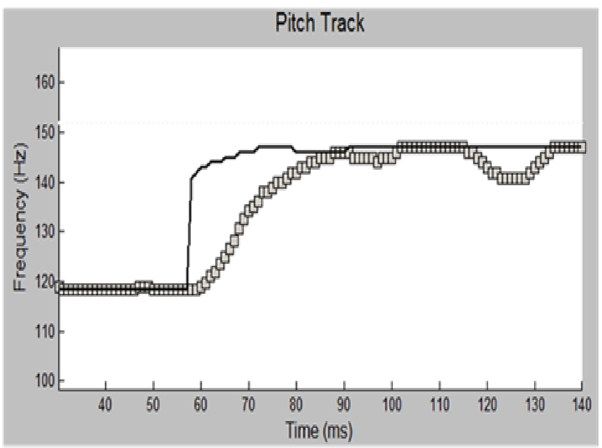
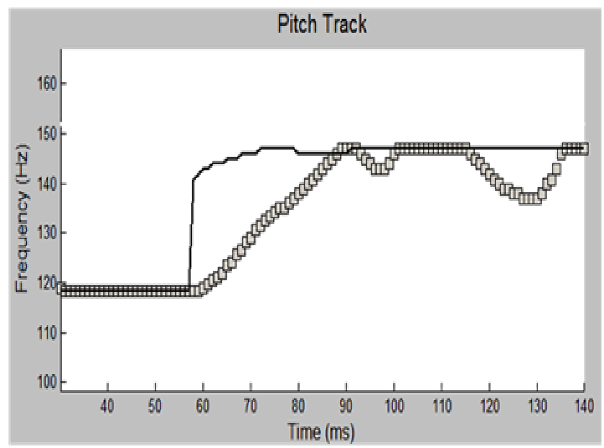


Figure 3: Grand average music evoked FFR waveform for participants with and without musical aptitude



4a.



4b.

Figure 4: (a) Pitch Tracking for music transit evoked FFR for participants with musical aptitude and 4 (b) Pitch Tracking for music transit evoked FFR for participants without musical aptitude(Note: The black line represents direction of pitch in stimulus and the squared grey line represents the response in Pitch Track)

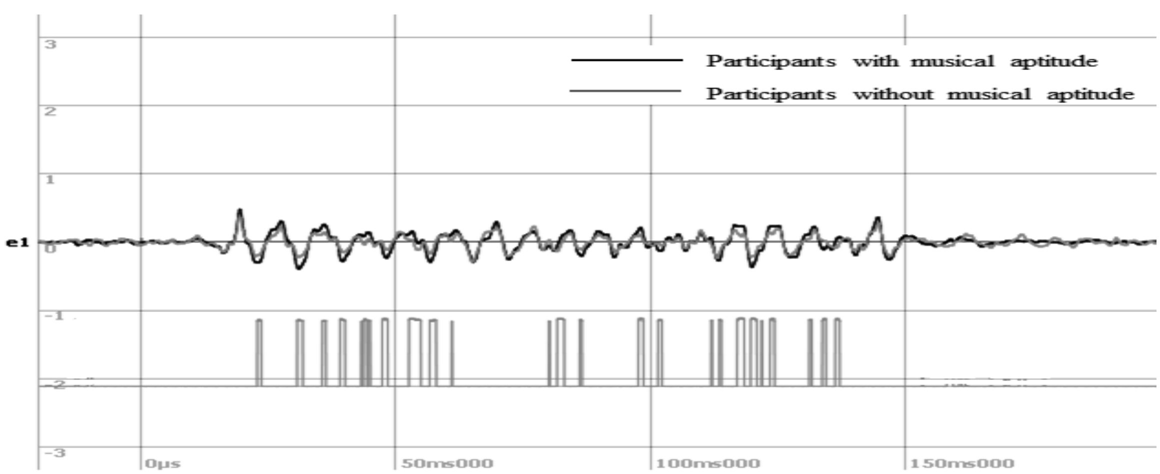


Figure 5-pvalues of frequency following response for two groups of participants (Note: The grey squared corresponds to significant differences between the two waves)

Furthermore, a point wise unpaired t - tests were carried out between the two groups of participantsat every data point to find out the significant waveform modulations. This identifies the timing of the differential responses between the groups of participant's waveforms. These analyses were carried out using the Cartool 3.55 software (Denis Brunet, Functional Brain Mapping Laboratory, Geneva, Switzerland, http://brainmapping.unige.ch/cartool.php). Figure 5 represents the results of point wise analysis.

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 significant difference between the FFRs of two groups of participants at various data points.

DISCUSSION

Musical training has been associated with significant physiological enhancements throughout the auditory system that underscore general (i.e., not music-specific) auditory processing. [17,18] The study was taken up to investigate the neural encoding of response for Indian Carnatic musical transit of a note for two groups of participants with and without musical aptitude. The results reveals that the scores of the participants with musical aptitude for the parameters of pitch error was lesser pitch strength was better with more stimulus-to-response correlation than the participants without musical aptitude. It could be attributed to enhancement of processing of the target stimulus or to neural tracking of the transit of the music by the participants who have better musical aptitude. The results of autocorrelogram and Pitch Track for music transit evoked FFR reveal that the pitch tracking was better by the participants with musical aptitude compared to the participants without musical aptitude. However, even the participants with musical aptitude did not have a 100% autocorrelation and Pitch Tracking. This could be because the participants with musical aptitude are not trained musicians, they were just selected based on the criteria that if they have a skill for music task. This highlights that, music is an inherently rewarding auditory activity, in part due to its activation of the brain's mesolimbic reward network. [19-22] This may account that the individual though not formally trained in music but still views music as one most pleasurable thing, sometimes even ranking music as their first priority, might have a better perception of the parameters of music and might be able to appreciate music to an extend as that of an trained musicians. This property of musical enjoyment which is encountered in the regular, routine life confers emotional benefits that promote its practice and performance and, by co-activating mesolimbic neuromodulatory control centers, promotes long-term musical learning success. [23] This long standing environmental / experience - dependent plasticity might incorporate an individual's musical processing aptitude without formal training.

CONCLUSION

The statement which is well known that 'musicians have more precise response timing compared to non-musicians' is a training related plasticity that happens in the brain network, which might not be always true. There are individuals who are not named as 'musician' but still might have a better plasticity of the structural and physiological changes of the system which might be an innate character or might be because of the experience / environmental related. The present study reveals that the participants with musical aptitude though not trained musicians but still had the ability in appreciation and understanding of the concepts of music had better representation of the frequency following response in terms of the tracking of the pitch of the Indian music transit note with good autocorrelogram, pitch strength and stimulus-to-response correlation compared to the individual without musical aptitude who had neither been trained or experience or an innate ability to appreciate and enjoy music.

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Appendix A
'Questionnaire on Music Perception Aptitude'

PART – A

Demographic data:

1. Name-
2. Age/gender-
3. Do you like music?
4. Do you like to listen or sing music?
5. Do you have the habit of listening to music regularly? (mention how often)
6. Did you learn music?
7. Age when you started learning music
8. No. of years of experience
9. Duration of training per day
10. Duration of practice per day
11. Have you learnt music continuously or intermittently
12. Are you still learning music? If not, are you still in contact with music/dance?
13. What type of music did you learn? What is the duration of training for each of them?
    a. ---
14. Have you ever been exposed to music before training?
15. Have anyone of your family member learnt music? Who?
16. Do you learn any other performing art along with singing training?-

PART – B

Instruction: *The below questionnaire has questions related to different parameter of music like pitch awareness, pitch discrimination& identification, timber identification, melody recognition and rhythm perception. The responses are to be elicited in the form of 'Yes' or 'No'.*

Pitch awareness:

1. Is your range for speech and song same?
2. Are songs sung in different pitches?
3. Are you aware that different songs have different ragas (musical notes) and talas (beats)?
4. Do you feel that different singers sing in different pitches?
5. When we sing sa, ri, ga, ma, pa, ta, ni, sa, is there any change in pitch?
6. Have you heard of scales in music?
7. Are you aware of sapthaswaras or seven notes in music?

Pitch discrimination and identification:

1. Can you discriminate the songs sung by male voice verses female voice?

2. Can you distinguish between high and low pitch when you hear music?
3. Can you exactly find the note/scale of the music that is played?
4. Can you differentiate the ‘frequency modulations’ within the notes?
5. Can you differentiate as to whether the singer is still in pitch or has gone out of pitch?
6. Can you differentiate between singer from the song?

Timbre identification:

1. Can you identify the musical instrument played from a music that you hear?
2. If more than 3 musical instruments are played, can you identify and name all three instruments that are played?
3. When more than one instrument is played and one is out of pitch, can you make out the difference?

Melody recognition:

1. Can you exactly hum the song as you hear?
2. Can you identify if there is a change in raga or modulation with emotion?
3. Can you recognize different genres of music, like Carnatic, Hindustani, Western, jazz, Rap etc?
4. Do certain parts of a song remind you of another song?
5. Can you recognize the song when someone hums it?
6. Can you identify the melodies of different emotions?

Rhythm perception:

1. Can you differentiate if the music is slow/relaxing or fast/exciting?
2. Can you exactly count the number of beats in the song you hear?
3. Can you tap your feet / hand in the same rhythm along with the song’s beats?
4. Do you agree that music is unconsciously associated with movements made by our bodies while talking, walking, running, dancing, etc?
5. Can you make out if there is a change in beats within a song?
6. Can you recognize if someone is singing out of rhythm?

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