Effect of Musical Training on Perception of Temporal Fine Structure Cues in Children

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Abstract: The aim of the present study was to assess the effect of musical training on perception of temporal fine structure cues in children. Participants included 50 typical children within the age range of 8-10 years who were divided into two groups: Group 1 consisting of 25 musicians and group 2 consisted of 25 non musicians. The participants in the first group were selected on the basis of more than one years of formal musical training in Carnatic music whereas that of group 2 had received no formal or informal musical training. Temporal fine structure perception was assessed in all the participants using TFS software package which is comprised of two modules, TFS1 (to determine TFS sensitivity at higher frequencies) and TFSLF (to determine TFS sensitivity at lower frequencies). Results showed that the mean TFS thresholds for musicians for all the frequencies were better than that of the non-musicians.

I. INTRODUCTION
Multiple acoustic cues are used to interpret and understand speech in the human auditory system. These acoustic cues are largely classified on the basis of their temporal and spectral properties. The temporal properties can be further divided into temporal envelope and temporal fine structure (TFS) cue perception. The envelope is the slow variation in the amplitude of the signal over time, whereas fine structure is the rapid variation in the spectral information (Druil1man, 1995). A speech signal can be decomposed into its constituent envelope and fine structure information using Hilbert transformation (Smith, Delgute, & Oxenham, 2002). At the level of perception, the entire auditory system is tonotopic, i.e. it acts as a band pass filter which allows a specific frequency signal to pass through at each point. Thus, spectral information of speech is processed as a result of cochlear filtering. The time signal at a specific position on the basilar membrane can be decomposed into temporal envelope and temporal fine structure. The temporal signal at each portion of the basilar membrane act as an envelope which was superimposed with rapid oscillation called as temporal fine structures (Moore, 2004). Sensitivity to TFS is the ability of the human auditory system to perceive the fine spectral cues present in the speech stimuli. This particular characteristic is very important for perception of speech. TFS helps in better perception of speech. Improved ability is useful for enhanced speech perception in individuals with hearing impairment, elderly population or auditory processing disorders, where this ability is otherwise compromised.

Musicians are a set of individuals who are trained to perceive fine structural variation in the acoustic stimuli. Researchers suggest that musical training enhances the ability of coding fast varying auditory signal ( Strait, O’Connell, Parbery-Clark, & Kraus, 2014). Since, music contains fine amplitude, frequency and temporal modulation, the musicians are trained to identify these subtle fluctuations and which in turn codes their neuron system. Studies have shown that musicians have enhanced temporal perception (Rammsayer & Altenmüller, 2006), speech perception in noise (Jain, Mohamed, & Kumar, 2015) and better fine structure abilities (Mishra, Panda, & Raj, 2015). Literature indicates that musical training improves the frequency and temporal resolution abilities (Jain, Mohamed, & Uppanda, 2014; Mishra et al., 2015; Sanju & Kumar, 2015; Silva et al., 2015). But, no specific study has been conducted in the past to assess influence of musical training on sensitivity to TFS cues, especially in children. Thus, the present study was aimed to assess the effect of musical training on perception of TFS cues in children.

II. METHODOLOGY
A standard group comparison design was adapted by considering 50 typical children within the age range of 8-10 years. The participants were divided
into two groups: Group 1 consisted of 25 musicians (14 males and 11 females) and group 2 consisted of 25 non-musicians (13 males and 12 females). The participants in the first group were selected on the basis of more than one year of formal musical training in Carnatic music whereas that of group 2 had received no formal or informal musical training.

The tests in the TFS software package were used to assess the individual's sensitivity to the temporal fine structure, which comprised of two modules, TFS1 (to determine TFS sensitivity at higher frequencies; Moore & Sek, 2009) and TFSLF (to determine TFS sensitivity at lower frequencies; Hopkins & Moore, 2010). The TFS1 test was conducted at the fundamental frequencies of 100 Hz, 200 Hz and 300 Hz, and TFSLF test was conducted at the frequencies of 250 Hz and 500 Hz.

The stimulus in TFS1 was a combination of complex harmonic tone with a specific fundamental frequency and an inharmonic tone. The inharmonic tone was different from the harmonic tone in the sense that in the inharmonic tone, all the harmonics were shifted upwards by a specific frequency, while keeping the envelope repetition rate equal to that of the fundamental frequency. Thus, both the tones only differ in their TFS. These tones were presented at a fundamental frequency of 100 Hz, 200 Hz and 300 Hz, passed through a fixed band pass filter centered at 9 F_0. This fixed band pass filter is used to prevent spectral cue discrimination, as the cochlea can resolve up to 8th harmonic (Moore & Gockel, 2011), thus, the 9th is the lowest unresolved harmonic.

The testing of TFS ability at the lower frequencies was carried out using TFSLF test (Hopkins & Moore, 2010). In this test, sinusoidal tone bursts were presented on the basis of interaural phase differences. One alternative of the stimulus consisted of 4 tone sequences, each in the same phase to that of the other, whereas the other alternative consisted of 4 tone sequences with alternative tones varied in phase of the other two tones. The threshold is measured as the minimum phase shift which the participants were able to determine. Both the tests were performed binaurally at 20dB SL in an adaptive 2AFC stimulus paradigm using personal computer equipped with calibrated headphones.

### III. RESULTS

The comparison between musicians and non-musicians revealed that the mean TFS thresholds for musicians for all the frequencies were better than that of the non-musicians. In TFS1 test, the mean thresholds for musicians were approximately 5.7 Hz lower than non-musicians at all the frequencies. Lower thresholds test indicate better performance. Independent sample t-test revealed statistically significant difference between musicians and non-musicians for 100 Hz (t=4.31; p=0.001), 200 Hz (t=4.99; p=0.00) and 300 Hz (t=2.94; p=0.009) fundamental frequencies. For TFSLF test, the thresholds for musicians were about 4 degree lower than non-musicians at 250 Hz and 6 degree lower at 500 Hz. The t-test signified statistically significant difference between musicians and non-musicians for 250 Hz (t=1.89; p=0.047) and 500 Hz (t=2.14; p=0.049) frequencies.

**Table 1:** The results of the independent sample t-test to identify the significance of difference in the mean TFS scores between musicians and non-musicians, both at high as well as low frequencies.

<table>
<thead>
<tr>
<th>Test</th>
<th>Frequency</th>
<th>Mean Values</th>
<th>t-values</th>
<th>p-values</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFS1</td>
<td>100 Hz F_0</td>
<td>10.54 Hz</td>
<td>21.42 Hz</td>
<td>4.314</td>
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<tr>
<td></td>
<td>200 Hz F_0</td>
<td>12.34 Hz</td>
<td>23.51 Hz</td>
<td>4.990</td>
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<tr>
<td></td>
<td>300 Hz F_0</td>
<td>18.52 Hz</td>
<td>27.76 Hz</td>
<td>2.994</td>
</tr>
<tr>
<td>TFSLF</td>
<td>250 Hz</td>
<td>6.37 degree</td>
<td>8.30 degree</td>
<td>1.893</td>
</tr>
<tr>
<td></td>
<td>500 Hz</td>
<td>12.08 degree</td>
<td>18.22 degree</td>
<td>2.147</td>
</tr>
</tbody>
</table>
IV. DISCUSSION

The present study investigated the effect of musical training on the perception of temporal fine structure cues in children. The children within the age range of 8-10 years were selected as research evidence suggested that by this age, the ability of normal hearing children to encode the fine structure cues develop like that of adults (Bertoncini, Serniclaes, & Lorenzi, 2009). The results revealed better perception of fine structure cues in musically trained children in comparison to untrained children. These results were in consonance with older findings in children (Jain et al., 2015, 2014) and adults (Zarate, Ritson, & Poeppel, 2012). These changes can be attributed to the structural and functional changes taking place in the auditory system with musical training (Elbert, Panet, Wienbruch, Rockstroh, & Taub, 1995; Panet et al., 1998). Schlaug (2001) reported that trained musicians have differences in auditory, motor and visual-spatial brain regions compared to amateur musicians or non-musicians. He specifically reported that musicians have larger gray matter density in the pre-central gyrus, Heschl’s gyrus and right superior parietal cortex.

Findings of the present study showed an improved sensitivity to temporal fine structures in musicians, and it was found that the speech perception abilities are directly or indirectly related to the temporal fine structures. Thus, musical training may be utilized as a therapeutic tool to enhance speech perception abilities in individuals with hearing impairment, auditory processing disorders, elderly population as well as many other patient groups where speech perception abilities are affected.

REFERENCES


