EFFECT OF MUSICAL TRAINING ON TEMPORAL RESOLUTION ABILITIES AND SPEECH PERCEPTION IN NOISE

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MANASAGANGOTHRI, MYSORE – 570 006
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To my beloved Parents,
Brother
&
To Rajalakshmi ma'am

CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Musical Training on Temporal Resolution Abilities and Speech Perception in Noise"*** is a bonafide work submitted in part fulfilment for the degree of Master of Science (Audiology) of the student Registration No: 09AUD007. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore
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CERTIFICATE

This is to certify that this dissertation entitled ***"Effect of Musical Training on Temporal Resolution Abilities and Speech Perception in Noise"*** has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this master's dissertation entitled ***"Effect of Musical Training on Temporal Resolution Abilities and Speech Perception in Noise"*** is the result of my own study under the guidance of Dr. K. Rajalakshmi, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any diploma or degree.

Mysore **Register No. 09AUD007**

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CHAPTER 1

INTRODUCTION

"Music is forever; music should grow and mature with you, following you right on up until you die." -Paul Simon

Music perception involves complex brain functions underlying acoustic analysis, auditory memory, auditory scene analysis and processing of musical syntax. Moreover, music perception potentially affects emotion, influences autonomic nervous system, the hormonal and immune systems and activates (pre)motor representations.

Many studies have reported that musicians have better auditory perception skills when compared to non-musicians. There are many studies in literature which have documented that musical training improves basic auditory perceptual skills resulting in enhanced behavioral (Jeon & Fricke, 1997; Koelsch et al., 1999; Oxenham et al., 2003; Tervaniemi et al., 2005; Micheyl et al., 2006; Rammsayer & Altenmuller, 2006) and neurophysiological responses (Brattico et al., 2001; Pantev et al., 2001; Schneider et al., 2002; Shahin et al., 2003 & 2007; Tervaniemi et al., 2005; Kuriki et al., 2006; Kraus et al., 2009). Musicians' life long experience in detecting melodies from background harmonies can be considered as a process analogous to speech perception in noise. Studies report that musicians had a more robust sub- cortical representation of the acoustic stimulus in the presence of noise (Kraus et al., 2009). Musical practice not only enhances the processing of music related sounds but also influences processing of other domains such as language (Marques et al., 2007; Moreno et al., 2009; Parbery-Clark et al., 2009a; Schon et al., 2004). Because of their musical training, musicians have learned to pay more attention to the acoustic details of the stimulus than non-musicians.

Carnatic music (Sanskrit: Karnataka samgita) is a system of music commonly associated with the southern part of the Indian subcontinent, with its area roughly confined to four modern states of India: Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. It is one of two main sub-genres of Indian classical music that evolved from ancient Hindu traditions; the other sub-genre being Hindustani music, which emerged as a distinct form due to Persian and Islamic influences in North India. In contrast to Hindustani music, the main emphasis in Carnatic music is on vocal music; most compositions are written to be sung, and even when played on instruments, they are meant to be performed in *gayaki* (singing) style.

Although there are stylistic differences, the basic elements of *sruthi* (the relative musical pitch), *swara* (the musical sound of a single note), *raga* (the mode or melodic formulæ), and *tala* (the rhythmic cycles) form the foundation of improvisation and composition in both Carnatic and Hindustani music. Although improvisation plays an important role, Carnatic music is mainly sung through compositions, especially the kriti (or kirtanam), a form developed between the 16th and 20th centuries by composers such as Purandara Dasa and the Trinity of Carnatic music (Tyagaraja, Muthuswami Dikshitar, & Syama Sastri).

Carnatic music is usually performed by a small ensemble of musicians, consisting of a principal performer (usually a vocalist), a melodic accompaniment (usually a violin), a rhythm accompaniment (usually a mridangam), and a tambura, which acts as a drone throughout the performance. Other typical instruments used in performances may include the ghatam, kanjira, morsing, veena & flute.

Musical training involves discrimination of pitch intonation, onset, offset and duration aspects of sound timing as well as the integration of multisensory cues to perceive and produce notes. Because of their musical training, musicians have learned to pay more attention to the details of the acoustic stimuli than non-musicians (Musacchia et al., 2007). Music is a complex auditory task and musicians spend years for fine tuning their skills. It is no wonder that previous research has documented neuroplasticity to musical sounds as a function of musical experience (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2005; Koelsch, Schroger, & Tervaniemi, 1999; Musacchia, Sams, Skoe, & Kraus, 2007; Pantev et al., 1998; Pantev, Roberts, Schulz, Engelien & Ross, 2001).

More surprising, however, are findings that music training benefits auditory processing not only in the musical domain, but also in the processing of speech stimuli (Musacchia et al., 2007; Schon, Magne, & Besson, 2004; Wong, Skoe, Russo, Dees, & Kraus,2007). Consistent findings across a range of studies that use methods spanning from neurophysiology to behavior indicate that music training improves a variety of verbal and non verbal skills. This include working memory (Chan, Ho, & Cheung, 1998; Forgeard, Winner, Norton & Schlaug, 2008), processing of prosody and linguistic features in speech (Chandrasekaran, Krishanan & Gandour, 2009; Wong et al., 2007), phonological skills (Forgeard, Schlaug, et al, 2008), processing emotion in speech (Strait, Kraus, Skoe, & Ashley, 2009), auditory attention (Strait, Kraus, Parbery- Clark, & Ashley, 2010) and auditory Stream segregation (Beauvois, & Meddis, 1997).

Temporal Resolution is defined as the perception of a short interval of time that each individual can discriminate between two auditory signals of about 2-3 ms. The studies suggest that exposure to sound during the first two years of life is important for the maturation of the structures of the central nervous system. The different studies on musicians suggest that musical training diary, used by professional musicians, can induce functional reorganization of the cerebral cortex. Therefore the contact with the music before the age of seven could contribute to the development of the primary auditory cortex more precisely the planum temporale. The musicians surveyed had an increase in the left temporal plane identified by investigations of magneto encephalography. Musicians have better neural activation due to long term musical training.

Other research points out that to be a better development of planum temporale, the musical training should begin before the age of nine. In the comparison of experienced musicians with non-musicians, the first responded differently to musical stimuli compared with the brains of non-musicians. This fact was also observed in musicians who started their musical activity early (Ohnishi et al. 2001). However, other studies argue that musical ability is innate and that musical training is not responsible for the improvement of planum temporale. However, it is confirmed that there is improvement of the planum temporale in relation to individuals who were exposed to early musical stimulus (Pantev et al. 2001). Another study by Ishll et al. (2006) shows that music has a positive influence on the development of the planum temporale, because according to their study, subjects were exposed to musical training (singing) over four years compared to amateur musicians without professional guidance, performed better on temporal resolution through the test Random Gap Detection Threshold (RGDT).

Speech perception in noise is a complex task requiring the segregation of the 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 (Brandt & Rosen, 1980). Whereas children with language-based learning disabilities (Bradlow et al., 2003; Ziegler et al., 2005) and hearing impaired adults (Gordon- Salant & Fitzgibbons., 2005) are especially susceptible to the negative effects of background noise, musicians are less affected and demonstrate better performance for SIN when compared to non-musicians (Parbery-Clark et al., 2009). Compared with non-musicians, musicians exhibit enhanced subcortical encoding of sounds with both faster responses and greater frequency encoding. These enhancements are not simple gain effects. Rather, musical experience selectively strengthens the underlying neural representation of sounds reflecting the interaction between cognitive and sensory factors (Kraus et al., 2009), with musicians demonstrating better encoding of complex stimuli (Wong et al., 2007) as well as behaviorally relevant acoustic features (Lee et al., 2007).

In order to extract the target acoustic signal, our auditory system must resolve two issues. First, there must be a process that partitions the acoustic input into separate auditory units. Second there must be a mechanism for appropriately organizing these acoustic units over time. Auditory scene analysis is the term given to the internal process of segregating and subsequent grouping of an auditory stream (Bregman, 1990). Auditory scene analysis is based on the notion that pre-attentive processes use the Gestalt laws of organization (Koffka 1935) - physical similarity, temporal proximity, and good continuity- to group sounds. In acoustic terms, sounds with similar frequency and spatial location are more likely to be grouped together as auditory units. Indeed listeners take advantage of both frequency and spatial location cues to assist in the perception of SIN. Perceptual streaming, or the ability to hear two streams, is facilitated when concurrently presented complex tones are separated by as little as one semitone. For example, when asked to identify simultaneously presented vowels, performance improved when the fundamental frequencies were different (Scheffers., 1983; Assmann & Summefield., 1990). This phenomenon can help to explain why speech recognition in noise is more difficult when the target and the background speakers are of the same sex, and the fundamental frequencies of different voices are consequently closer in frequency. Even small frequency differences between speakers' voice can be used as cues to aid speaker differentiation. (Treisman., 1964; Brkox & Nooteboom., 1982).

The ability to properly group, represent, and store auditory units over time is fundamental to forming auditory streams and is therefore an essential aspect of SIN perception. Concurrently presented auditory units may be represented as separate, parallel sensory traces that are not completely independent of each other (Fujioka et al., 2005, 2008). This not only highlights the auditory system's ability to represent simultaneously presented auditory units as both separate yet integrated sensory traces (Fujioka et al., 2005,2008) but also support the idea that stream segregation is an active, rather than a passive process (Alain & Brenstein 2008).

Musicians spend hours attending to and manipulating complex auditory signals that comprise multiple streams. In addition to processing concurrent auditory units (i.e., simultaneously occurring melodies), musicians must also analyze the vertical relationships between streams (i.e., Harmony). In addition to this online auditory scene analysis musicians also hone their abilities to conceive, plan, and perform music in real time. Previous work has documented that musical training improves basic auditory perceptual skills resulting in enhanced behavioral (Jeon & Fricke, 1997; Koelsch et al, 1999; Oxenham et al. 2003; Tervaniemi et al. 2005; Rammsayer & Altemuller 2006) and neurophysiological responses (Brattico et al. 2001; Pantev et al. 2001; Schneider et al. 2002; Tervaniemi et al. 2005; Kraus et al. 2009). Moreover, it would seem that musicians are able to use these perceptual benefits to facilitate concurrent sound segregation (Zendel & Alain 2009). Musical training not only enhances aspects that are specific to musical perception, but these enhancements also cross over to other domains, particularly language, suggesting shared neural resources for language and music processing (Patel 2003, 2007; Kraus & Banai 2007; Kolesch et al. 2008). For example, lifelong musical experience is linked to improved subcortical and cortical representations of acoustic features important for speech encoding and vocal communication (Magne et al. 2003; Schon et al. 2004; Marques et al. 2007; Musacchia et al. 2007, 2008; Chandrashekaran et al. 2008; Strait et al. 2009). Likewise, musical experience has been shown to improve verbal ability (Forgeard et al. 2008), verbal working memory and verbal recall (Chan et al. 1998; Brandler & Rammsayer 2003; Ho et al. 2003; Jackobsen et al. 2003). As a consequence of the musician's extensive experience with auditory stream analysis within the context of music, more honed auditory perceptual skills as well as greater working memory capacity, musicians seem well equipped to cope with the demands of adverse listening situations such as Speech in Noise.

Emotion perception in both speech and music relies on shared acoustic (Scherer, 2003) and neural mechanisms (Nair et al., 2002, Price et al., 2005), suggesting that extensive experience in one domain may lend perceptual benefits to the other. Musical experience has been shown to enhance sensitivity to emotion in speech in both children and adults, with musicians more accurately identifying emotions expressed in speech samples (Thompson et al., 2004; Dimitrieva et al., 2006). Enhanced sensitivity in musicians is not surprising that musicians must attend to the detailed acoustic properties of sound on a daily basis, monitoring their output to express precisely defined musical intentions. Due to wide frequency range and large variations in tone durations, music serves as an extremely effective vehicle for auditory training (Saunders, 1996; Zaltorre et al., 2002). Musicians heightened sensitivity to emotion in speech may be related to well-documented structural and functional reorganization at cortical levels (Schlaug, 2001; Hutchinson et al., 2003; Costa-Goimi, 2005; Schlaug et al., 2005; Shahin et al., 2007). In fact, professional musicians have a stronger capacity for neural plasticity- even for functions not related to musical tasks (Ragert et al., 2004). Subcortical influences of musical training have also been observed, including stronger phase-locking to fundamental pitch and earlier onsets in evoked responses to linguistic and musical sounds with limited acoustic complexity (Musacchia et al., 2007, 2008; Wong et al., 2007). These observations suggest that auditory expertise, here demonstrated by musicians, results in subcortical sensory processing malleability of two acoustic properties shared by language and music (pitch and timing). These acoustic properties, along with time-varying harmonic structures (Timbre), contribute to the perception of emotion in both speech and music and are fundamental to human communication (Justlin & Laukka, 2003). Through our use of a complex emotionally charged stimulus, it is possible to explore musicians' subcortical sensitivity to acoustic features fundamental to human communication, including features not previously shown to be affected by musical training.

Need for the Study

The studies have documented better auditory perceptual skills in trained musicians when compared to non-musicians. But there are only very few studies which were done on the temporal resolution and speech perception abilities in trained musicians, as the experience increases in terms of years of training and practice. Recent study has shown that individuals with western instrumental musical training have enhanced speech perception ability in noise and working memory (Krauss et al 2009). As a combined consequence of their extensive experience with auditory stream analysis within the context of music; more honed auditory perceptual skills and temporal resolution, musicians seem well equipped to cope with the demands of adverse listening situations such as speech in noise.

Aim of the Study

The aims of the present study were:

- To find the temporal resolution abilities in trained Carnatic Vocal musicians over the years of musical training and practice.
- To find the speech perception abilities in the presence of background noise at different signal to noise ratios (SNR) for the same group.

CHAPTER 2

REVIEW OF LITERATURE

The following section provides a brief review of literature regarding the effect of musical training and/or practice on the different aspects of hearing, especially the temporal resolution abilities and speech perception in noise. The review has been divided into five sections mainly: 1) Effect of music training on language related skills, 2) Effect of music training on emotional and cognitive processes, 3) Effect of music training on perception in noise, 4) Effect of music training on temporal abilities,5) Effect of music training on structural and functional changes in the nervous system.

Effect of Music Training on Language Related Skills

The domains of music and language share many features, the most direct being that both exploit changes in pitch patterns to convey information. Music uses pitch contours and intervals to communicate melodies and tone centers. Pitch patterns in speech convey prosodic information; listeners use prosodic cues to identify indexical information, i.e., information about the speaker’s intention as well as emotion and other social factors. Further, in tonal languages, changes in pitch are used lexically; that is, in differentiating between words. A significant body of research has focused on the extent to which musical experience provides benefits in language abilities; the results unambiguously suggest that musicians show enhanced processing of prosodic and linguistic pitch. Musicians show an enhanced ability to detect subtle incongruity in prosodic pitch as well as consistent neural differences relative to nonmusicians (Besson, Schon, Moreno, Santos & Magne, 2007; Magne, Schon, & Besson, 2006). Differences between musicians and nonmusicians show up even during pre-attentive stages of auditory processing (Chandrasekaran, Krishnan et al., 2009; Musacchia et al., 2007; Wong & Perrachione, 2007). Frequency following responses (FFR), which ensemble neural responses originating at the auditory brainstem that reflect phase-locking to stimulus features, were recorded from musicians and non-musicians who were listening to the speech syllable /da/ (Musacchia et al., 2007). Relative to non-musicians, musicians showed more robust encoding of timing and pitch features in the speech signal at the level of the brainstem. Using FFR as an index, musicians showed a superior representation of dynamic pitch contours, as reflected by improved pitch tracking accuracy at the level of brainstem (Wong et al., 2007). The ability to track non-native pitch contours correlated positively with number of years of musical training, suggesting that it was musical experiences that improved lower level representation of non-native pitch. Musicians showed superior cortical representation of linguistic pitch in a non-native language relative to non-musicians (Chandrasekaran et al., 2009). In this study, native tone-language speakers showed the strongest representation of pitch, suggesting that the context of long term training matters. From a functional perspective, the enhanced cortical and brainstem representations are indeed relevant. Musicians showed a superior propensity to use pitch in lexical contexts during a language learning task, relative to non-musicians (Wong & Perrachione, 2007). Musician’s enhancement is not just restricted to pitch features. Studies also have demonstrated that musicians show superior brainstem representation of timing and harmonic structure in speech, features that are important for differentiating speech sounds (Musacchia et al., 2007; Parbery-

Clark, Skoe, et al., 2009). Taken together these studies demonstrate that musicians show a distinct advantage in the early auditory processing of speech features.

In a hallmark study, Chan and colleagues showed that participants with music training exhibited superior verbal memory relative to non-musicians, as indicated by greater number of words recalled in a list learning task (Chan et al., 1998). Children who received instrumental training not only showed enhanced processing of skills related to music, but also showed enhanced vocabulary relative to untrained controls (Forgeard, Winner et al., 2008) in typically developing children with normal reading ability, musical discrimination skills significantly predicted phonological and reading skills (Forgeard, Schlaug et al., 2008).

Effect of Music Training on Emotional and Cognitive Processing

Perception of emotion in speech and music relies on shared acoustic and neural mechanisms (Nair, D et al., 2002), suggesting that extensive experience in one domain may lend perceptual benefits to the other.

Examining the subcortical encoding of a complex, emotionally salient stimulus (a Child’s cry) as a function of music experience, a recent study demonstrated increased neural efficiency in musicians (Strait et al., 2009; Strait, Kraus, Skoe & Ashley, 2009). They aimed to provide a biological basis for musician’s enhanced perception of emotion in speech by investigating the contribution of subcortical mechanisms to the processing of vocally communicated emotional states. 30 musicians were included in the study, who was classified into 2 groups based on 2 criteria: musicians by onset age (MusAge) and musicians by years (Mus Yrs). MusAge subjects had begun musical training at or before age of 7 years, whereas Mus Yrs subjects had received more than 10 years of consistent musical experience. Integrity of auditory brainstem was assessed using auditory brainstem responses with both click and speech (/da/). The authors suggested that musical experience has more pervasive domain-general effects on the auditory system than previously documented, resulting in fine neural timing to acoustic features important for vocal communication. The results thus provided initial biologic involvement of subcortical mechanisms in the auditory processing of communicated states of emotion.

Relative to non-musicians, musicians showed superior encoding of the most acoustically complex portion of the emotional stimuli, consistent with behavioral studies demonstrating enhanced emotional perception in musicians (Thompson, Schellenberg & Husain, 2004). Similarly musicians also demonstrated selective neural enhancement of the upper note of musical chords (Lee, Skoe, Kraus & Ashley, 2009). Music training also has been shown to improve working memory (Forgeard, Winner et al., 2008; Jakobson, Lewycky, Kilgour, & Stoesz, 2008; Parbery-Clark, Skoe, Lam et al., 2009; and executive function abilities (Bialystok & DePape, 2009). Musicians are also significantly better than non-musicians in auditory stream segregation, presumably due to their music training (Beauvois & Meddis, 1997; Zendel & Alain, 2009).

Effect of Music Training on perception in noise

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 soundscape (e.g., the sound of their own instrument in an orchestra). Literature shows that the effect of musical experience is transferred on the skills that subserve successful perception of speech in noise. A recent study found a distinct speech in noise advantage for musicians, as measured by standardized tests of hearing in noise (HINT, Hearing in- noise test; QuickSIN) (Parbery-Clark, Skoe, Lam et al., 2009). Across all participants, the number of years of consistent practice with a musical instrument correlated strongly with performance on QuickSIN, auditory working memory and frequency discrimination. These correlations strongly suggest that practice fine tunes cognitive and sensory abilities, leading to an overall advantage in speech perception in noise in musicians. The results from the study suggest that musical experience enhances the ability to hear speech in challenging listening environments. SIN performance is a complex task requiring perceptual cue detection, stream segregation, and working memory. Musicians performed better than non-musicians in conditions where the target and the background noise were presented from the same source, meaning parsing was more reliant on the acoustic cues present in the stream.

In order to find the effect of musical experience on the neural representation of speech in noise, Parbery-Clark, Skoe & Kraus (2009) compared sub-cortical neurophysiological responses to speech in quiet and noise in a group of highly trained musicians and non-musician controls. Speech evoked auditory brainstem responses were done with speech syllable /da/ on all subjects. The results indicated that musicians exhibited more robust speech evoked auditory brain stem responses in background noise. Musicians had earlier response onset timing, as well as greater phase locking to the temporal waveform and stimulus harmonics, than non-musicians. They also found that earlier response timing and more robust brainstem responses to speech in background noise were both related to better speech in noise perception as measured through HINT.

They concluded that musical experience resulted in more robust subcortical representation of speech in the presence of background noise, which may contribute to musician's behavioral advantage for speech in noise perception.

Musicians also exhibited more robust responses to the steady state portion of the stimulus in the presence of background noise. By calculating the degree of similarity between stimulus waveform and the subcortical representation of the speech sound, it was found that musicians had higher stimulus to response correlations in noise than non-musicians. A greater stimulus to response correlation is indicative of more precise neural transcription of stimulus features. One possible explanation for this musician enhancement in noise may be based on Hebbian principle, which posits that the associations between neurons that are simultaneously active are strengthened and those that are not are subsequently weakened (Hebb, 1949). Given the present results it is speculated that extensive musical training may lead to greater neural coherence. This strengthening of the underlying neural circuitry would lead to a better bottom-up, feedforward representation of the signal. It is well documented that the auditory cortex sharpens the subcortical sensory representations of sounds through the enhancement of the target signal and the suppression of irrelevant competing background noise via the efferent system (Suga et al., 1997; Zhang et al., 1997; Luo et al., 2008). The musician's use of fine grained acoustic information and lifelong experience with parsing simultaneously occurring melodic lines may refine the neural code in a top-down manner such that relevant acoustic features are enhanced early in the sensory system. This enhanced encoding improves the subcortical signal quality, resulting in more robust representation of the target acoustic signal in noise.

The improved stimulus to response correlation in the noise condition was related to greater neural representation of the stimulus harmonics (H_2- H_{10}) but not the fundamental frequency in noise. Musicians, through the course of their training, spend hours producing, manipulating, and attending to musical sounds that are spectrally rich. The spectral complexity of music is partially attributable to the presence and relative strength of harmonics as well as the change in harmonics over time. Musicians have enhanced cortical responses to their primary instrument suggesting that their listening and training experience modulates the neural responses to specific timbres (Pantev et al., 2001; Margulis et al., 2009). Likewise, musicians demonstrate greater sensitivity to timbral differences and harmonic changes within a complex tone (Koelsch et al., 1999; Musacchia et al., 2008; Zendel & Alain., 2009).

Research has indicated that musical training may serve as a useful remediation strategy for children with language impairments (Overy et al., 2003; Besson et al., 2007; Jentschke et al., 2008; Jentschke and Kolesch., 2009). Cunningham et al., 2001, indicted that clinical population known to have problems with language based learning disabilities (e.g., poor readers), may also get benefit from musical training. More specifically, the subcortical deficits in sound processing seen in this population (e.g., timing and harmonics) (Wible et al., 2004; Banai et al., 2009; Hornickel et al., 2009) occur for the very elements that are enhanced in musicians.

Effect of Music Training on Temporal Abilities

Monteiro et al., (2010) compared the temporal resolution abilities in musicians and non-musicians. The study was characterized by prospective and compared between two groups, one consisting of 20 musicians and other 20 non-musicians matched for age and education were submitted to audiological evaluation and to test Gap in Noise (GIN) to evaluate the temporal resolution. The test performance of the GIN group of musicians was not significant in the control group is in the right ear (RE) or left (LE). The correlation between the average high frequencies for the LE with the GIN test was (p= 0.001) in the control group. The average frequencies for both ears in the group of musicians was statistically significant and the highest values for RE (p= 0.0001). There was no difference between the performances of the GIN test for both groups as well as the correlation between duration of daily exposure to music and GIN.

Effect of Music Training on structural and functional changes in the nervous system

Highly trained musicians exhibit anatomical, functional and event-related specializations compared to non-musicians. From an anatomical perspective, musicians have more neural cell bodies (grey matter volume) in auditory, motor and visual cortical areas of the brain (Gaser and Schlaug, 2003) and have more axonal projections that connect the right and left hemispheres (Schlaug et al., 1995). Not surprisingly, professional instrumentalists, compared to amateurs or untrained controls, have more activation in auditory areas such as Heschl’s gyrus (Schneider et al., 2002) and the planum temporale (Ohishi et al., 2001) to sound. Musical training also promotes plasticity in somatosensory regions; with string players demonstrating larger areas of finger representation than untrained controls (Elbert et al., 1995). With regard to evoked potentials thought to arise primarily from cortical structures, musicians show enhancements of the P1-N1-P2 complex to pitch, timing, and timbre features of music, relative to non-musicians (Pantev et al., 2001).

Recent studies have suggested that playing a musical instrument “tunes” neural activity peripheral to cortical structures (Musacchia et al., 2007; Wong et al., 2007). These studies showed that evoked responses thought to arise predominantly from brainstem structures were more robust in musicians than in non-musician controls. The observed musician-related enhancements corresponded to stimulus features that may be particularly important for processing music. One such example is observed with the frequency following response (FFR), which is thought to be generated primarily in the inferior colliculus and consists of phase-locked inter-spike intervals occurring at the fundamental frequency (F0) of a sound (Hoormann et al., 1992; Krishnan et al., 2005). Because F0 is understood to underlie the percept of pitch, this response is hypothesized to be related to the ability to accurately encode acoustic cues for pitch. Enhanced encoding of this aspect of the stimulus would clearly be beneficial to pitch perception of music. Accordingly, the previous studies demonstrated larger peak amplitudes at F0 and better pitch tracking in musicians relative to non-musicians. Another example was observed with wave delta (~8ms post-acoustic onset) of the brain stem response to sound onset, which has been hypothesized to be important for encoding stimulus onset (Musacchia et al., 2006,2007). Stimulus onset is an attribute of music important for denoting instrument attack and rhythm, and therefore it is perhaps not surprising that the authors observed earliest wave delta responses in musicians than non-musicians. More importantly, FFR and wave delta enhancement in musicians was observed with both music and speech stimuli and was largest when subjects engaged multiple senses by simultaneously lip reading or watching a musician play. This suggests that while these enhancements may be motivated by music related tasks, they are pervasive and apply to other stimuli which possess those stimulus characteristics.

Musacchia, Strait & Kraus (2008) studied the relationship between evoked potentials and musical experience. They recorded simultaneous brainstem and cortical evoked potentials (EP) in musicians and non-musician controls. Because previous research showed that musician related effects extend to speech and multi-sensory stimuli, the speech syllable /da/ was presented in three conditions: when subjects listened to auditory sound alone, when the subjects simultaneously watched a video of a male speaker saying /da/ and when they viewed the video alone. The analysis focused on comparing measures of the speech evoked brainstem response that have been previously reported as enhanced in musicians with well established measurements of cortical activity (e.g., P1-N1-P2 complex). The first picture that emerged from the data is that recent musical training improves one's auditory memory and shapes composite (P1-N1) and pitch encoding (F0) in a co-coordinated manner. The EP and behavior correlations suggest that complex auditory task performance is related to the strength of the P1-N1 response. The instrumental musicians performed better in the behavioral tests and had steeper P1-N1 slopes than non-musicians.

However, it was not only the individual tests and measures that were music related. Musicians had a statistically stronger correlation between this set of brain and behavior measures than non-musicians. While it is well known that trained musicians outperform untrained controls and have more robust evoked-potentials than non-musicians, the present data showed that the accord, or relationship, between brain and behavior is also improved in musicians.

In recent years, musicians have been used as a model for experience induced plasticity, which is known to be expressed in AEPs in adults (Trembly et al., in 2001). Shahin, A, Roberts & Trainor, (2003) compared AEPs evoked by pure, violin and piano tones in young 4- to 5- year old children with age matched non-musician children. The aim of the study was to assess whether AEP components are sensitive to musical experience at this age and, if so, which components are affected. Before conducting the main study AEP responses in independent cohorts of non-musician children between 4 and 15 years of age to the same tones. Larger amplitude P1, N1, and P2 responses were found in 4-to 5-year-old musically experienced children compared with musically less experienced children. Furthermore, the P2 enhancement was specific to the instrument of practice. Thus AEPs differ between musical and control children as young as 4 years of age, and the differences reflect specific musical experience. Comparison of piano-evoked N1 and P2 responses in our 4- to 5-year-old musicians (most of whom were pianists) to cross sectional findings suggest that musical experience may have advanced the developmental trajectory for sounds of the instrument of training.

Several studies show differences between the brain of adult musicians and non-musicians. For example, structural MRI studies indicate differences in gray matter between musicians and non-musicians in motor, auditory, and visual brain regions (Gaser et al., 2003). Heschl’s gyrus, containing primary auditory area, was found to be larger in musicians than non-musicians and its size correlated with musical proficiency (Schneider et al., 2002). Furthermore, the left planum temporale, which is important for the processing of complex sounds, is relatively larger than the right planum temporale in professional musicians, especially those with absolute pitch (Schlaug, G, 2001). With respect to the integrity of directionality organized neural fibers, white matter tracts also appear to differ between pianists and non-musicians, particularly in a pathway from primary motor cortex to the spinal cord and in a region near Broca's area, which is important for complex aspects of language and music processing.

At a functional level, the brain responses of adult musicians and non-musicians also differ as measured by EEG and MEG. For example, some event related potential responses from auditory cortical areas are larger in musicians compared to non-musicians such as N1 occurring at about 100 ms after stimulus onset, N1c, occurring at about 140 ms and larger in the right hemisphere, and P2, occurring at about 170 ms after stimulus onset (Pantev et al., 1998; Shahin et al., 2003). For a sequential stimuli, occasional wrong notes in a short melody that is repeated in different keys (i.e., starting on different notes) from trial to trial, elicit a frontally negative event-related potential called mismatch negativity (MMN). While MMN to such melodic changes is present in both musicians and non-musicians, it is much larger in musicians (Fujioka et al., 2004). In terms of polyphonic music, changed notes in either of the simultaneous melodies elicit MMN responses that are larger in musicians than non-musicians (Fijioka et al., 2005). Errors in one chord of a chord sequence produce an early right anterior negativity that is also larger in musicians than in non-musicians (Kolesch et al., 2002).

The research done on musicians revealed the advantages in different aspects when compared to non-musicians. Studies had reported that music training can not only improve the skills related to music perception, but also other different aspects like improvement in linguistic skills, working memory, temporal abilities, perception of emotions and also ability to perceive speech in the presence of noise. Studies had also reported that as the experience of the musicians increases these abilities also will get improved.

CHAPTER 3

METHOD

The present study aimed to find out the effect of musical training on temporal resolution abilities and speech perception in noise in musicians with various years of Carnatic vocal musical training or practice, using Temporal Modulation Transfer Function (TMTF), Gap Detection Test (GDT) and Speech Perception in Noise (SPIN) tests.

Participants

A total of 20 professionally trained Carnatic vocal musicians were included in the study. The musicians were classified in to 4 groups; each group consisted of 5 members, based on their years of experience in terms of training and/or practice.

Group 1: Musicians who received training/ practice for 1-5.11 years.

Group 2: Musicians who received training/ practice for 6-10.11 years.

Group 3: Musicians who received training/ practice for11-15.11 years.

Group 4: Musicians who received training/ practice for 16 years and above.

An informal Questionnaire was administered to all participants in order to obtain the information like experience in the musical field.

Inclusion Criteria

All the subjects who participated in the present study met the following criteria:

- Normal air conduction and bone conduction thresholds (≤15 dB HL) at all octave frequencies from 250 Hz to 8000 Hz.
- Normal middle ear function (‘A’ type tympanogram at 226Hz probe tone with normal acoustic reflexes in both ears.)
- Speech Recognition Threshold of ±12 dB (re. PTA of 0.5, 1 and 2 KHz) in both ears.
- Speech Identification Scores of > 90% at 40 dB SL (re. SRT) in both ears.
- No indication of Retrocochlear Pathology(RCP).
- No history of neurological or Otological problems.
- No illness on the day of testing.
- All were native Kannada speakers.
- All were professionally trained in Carnatic vocal music for duration of minimum 1 year.

Environment

All testing was carried out in a sound treated double room situation as per the standards of ANSI S3.1 (1991).

Instrumentation

The following instruments were used in the present study:

1. Orbiter 922 (Madsen Electronics, Denmark), two channel audiometer, calibrated as per ISO 389, with supra-aural headphones (Telephonics TDH39) housed with MX-41/ AR ear cushions with audio cups and a bone vibrator (Radioear B71) were used to assess the pure tone threshold, for Gap detection Threshold, for Temporal Modulation Transfer Function and for Speech Perception in Noise.
2. GSI Tympstar (Grason- Stadler Inc, USA) middle ear analyzer was used for tympanometry and reflexometry.
3. A laptop (Compaq Presario CQ40) was used to deliver the stimulus for GDT, TMTF and SPIN, which were routed through audiometer.

Stimuli

- Gap Detection Test was done with stimulus developed by Shivaprakash.S and Manjula.P (2003).
- Recorded phonemically balanced (PB) word list in Kannada developed by Yathiraj and Vijayalakshmi (2005) was used for Speech Perception in Noise (SPIN) Test. It consists of 100 words divided into 4 lists (each containing 25 words). Speech noise was used as the masking stimulus.
- Sinusoidally Amplitude modulated white noise was used to find the Temporal Modulation Transfer Function (TMTF).

Procedure

Pure tone Audiometry

Air conduction thresholds for octave frequencies from 250 Hz to 8000 Hz and bone conduction thresholds for octave frequencies from 250 Hz to 4000 Hz were obtained with modified version of Hughson Westlake procedure (Carhart & Jerger, 1959).

Speech Audiometry

Kannada Spondee words (Rajashekar, B, 1976) were used to obtain the Speech Recognition Threshold (SRT) from both ears. A set of 3 spondees were presented at 20 dBSL with reference to PTA and the minimum level at which the subject correctly identified 2 out of 3 spondees were considered as SRT.

Speech Identification Scores in quiet for both ears were obtained with Kannada PB words (Yathiraj & Vijayalakshmi, 2005). PB words, recorded in the voice of a typical Kannada female speaker were presented to both ears separately at 40 dB SL with reference to SRT. A total of 25 words were presented to each ear separately. Each word was given a score of 4 % and the speech identification scores for each ear separately were calculated in percentage.

Immitance Audiometry

Immitance Audiometry was carried out with GSI Tympstar (Grason- Stadler Inc, USA) middle ear analyzer using 226 Hz probe frequency. Ipsilateral and contra lateral reflexes were measured for 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Temporal Modulation Transfer Function (TMTF)

Test Stimuli

Two stimuli, unmodulated white noise and sinusoidally amplitude modulated (SAM) white noise of 500 ms duration, with a ramp of 20 ms were used. The stimuli was generated using a 32 bit digital to analog converter with a sampling frequency of 44.1 KHz and were low pass filtered with a cutoff frequency of 220KHz. The modulated signal was derived by multiplying the white noise by a dc-shifted sine wave. The depth of modulation was controlled by varying the amplitude of modulating sine wave. Modulation depth was varied between 0 to -30 dB (where 0 dB is equal to 100% modulation depth and -30 dB is equal to 0 % modulation). Six different modulation frequencies were used (4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz, & 128 Hz).

Procedure

The stimuli was presented at 40 dB SL (with reference to PTA) or at comfortable level. The stimuli were played with the help of Apex 3 software loaded in a laptop and were routed through the audiometer. The stimuli were presented to the participants through headphones. The subjects' task was to discriminate between modulated and unmodulated noise till they were able to identify the difference.

Three interval alternate forced choice method (3IAFC) was used. On each trial, unmodulated and modulated stimuli were successively presented with an inter-stimulus interval of 500 ms. Modulation depth was converted into decibels [20 log 10 (m), where m refers to the depth of modulation]. A step size of 4 dB was used initially and then reduced to 2 dB after two reversals. This procedure provides an estimate of the value of amplitude modulation necessary for 70.7% estimate correct responses (Levitt, 1971). The mean of eight reversals in a block of 14 will be taken as threshold. This procedure was repeated for all the modulation frequencies in both ears. The subject’s task was to identify the modulated signal among the three blocks presented.

Gap Detection Test (GDT)

Gap Detection Test was done with stimulus developed by Shivaprakash.S and Manjula.P (2003). Three Interval Alternate Forced Choice Method (3IAFC) was used to obtain the gap detection threshold. It consisted of three blocks of white noise, one of which contained gaps of variable duration. The subject’s task was to identify the gap. The presentation level of the stimulus was 40 dBSL (with reference to PTA) or most comfortable level, monaurally. The test consisted of 56 stimuli including 6 catch trials.

Before the actual test sets, four practice sets were given to the subjects for training. The gap duration of four practice sets were 20, 16, 12 and 10 ms. The test items consisted of gap intervals from 20 ms to 1 ms.

Each time when the subject detected the gap embedded in noise correctly, the size of the gap was reduced to trace the smallest gap the subject could detect using bracketing technique. The subjects were asked to detect which block of noise was having the gap in it.

The minimum gap that the subject detected was considered as the gap detection threshold. The gap detection thresholds were obtained for both the ears separately for all the four groups.

Speech Perception in Noise (SPIN)

Speech Perception in Noise test was done using the phonemically balanced (PB) Kannada word list (Yathiraj and Vijayalakshmi, 2005), recorded in the voice of a typical female Kannada speaker. The stimuli were played in a laptop and were routed through the audiometer. The presentation level was 40 dB SL (with reference to SRT) or at most comfortable level. The monosyllables and the speech noise were presented monaurally at three different SNRs (0dB, -5 dB and -10 dB). 25 monosyllables were presented for each trial. The subjects' task was to perceive the monosyllables presented in the presence of noise and repeat them back. Each word was given a score of 4 %. Number of correctly identified word at different SNRs was noted down to find the SPIN score.

CHAPTER 4

RESULTS AND DISCUSSION

The present study was aimed to compare temporal resolution abilities and speech perception in noise in Carnatic vocal musicians across their years of experience. The temporal resolution abilities were measured in terms of Temporal Modulation Transfer Function (TMTF) and Gap Detection Threshold (GDT) test. Temporal Modulation Transfer Function was done for six different modulation frequencies (4 Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz & 128 Hz) for both the ears. Gap Detection threshold was also estimated for the individual ears separately. Speech Perception in Noise (SPIN) test was done at three different SNRs (0 dB, -5 dB & -10 dB), separately for both the ears. A total of 20 trained Carnatic vocal musicians participated in the study, who were classified in to 4 groups based on their experience or training. Each group consisted of 5 subjects. The data was appropriately tabulated and statistically analyzed using SPSS (version 18) software.

The following analyses were carried out:

1. Descriptive statistics (mean and standard deviation) were obtained for all the parameters for both ears separately.
2. Kruskal-Wallis test was administered to compare the parameters across all the four groups.
3. For the parameters which showed significant results under Kruskal-Wallis test, pair wise groups comparison was done with the help of Mann-Whitney test.
4. Friedman test and Wilcoxon Signed Rank test (for pair wise comparison) were done to compare the parameters within the group.

Temporal Resolution

Temporal Modulation Transfer Function (TMTF)

Table 4.1

Mean and standard deviation (SD) of TMTF for the four groups at different modulation frequencies.

Modulation frequencies	Groups							
	1		2		3		4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
4 Hz (R)	-21.07	0.90	-21.34	2.50	-23.73	2.85	-22.27	3.64
4 Hz (L)	-22.93	3.58	-21.07	1.21	-22.00	2.87	-22.13	3.45
8 Hz (R)	-17.86	3.57	-17.73	3.48	-21.87	0.73	-21.33	1.63
8 Hz (L)	-20.00	3.09	-17.60	3.32	-12.00	18.74	-22.00	1.88
16 Hz (R)	-14.47	3.25	-14.33	3.00	-15.80	1.61	-16.40	3.82
16 Hz (L)	-14.32	4.43	-14.07	2.23	-15.87	2.56	-17.13	3.41
32 Hz (R)	-10.93	1.92	-11.34	1.25	-14.93	3.70	-16.40	2.43
32 Hz (L)	-13.47	2.96	-13.87	2.28	-14.33	3.74	-15.86	3.28
64 Hz (R)	-6.73	1.69	-10.53	2.72	-9.67	0.71	-11.20	1.88
64 Hz (L)	-7.67	2.17	-9.13	2.11	-9.93	2.24	-12.00	1.33
128 Hz (R)	-5.47	1.92	-7.27	1.57	-7.87	1.61	-9.33	1.03
128 Hz (L)	-7.53	1.30	-7.53	0.93	-7.73	1.28	-8.67	0.34

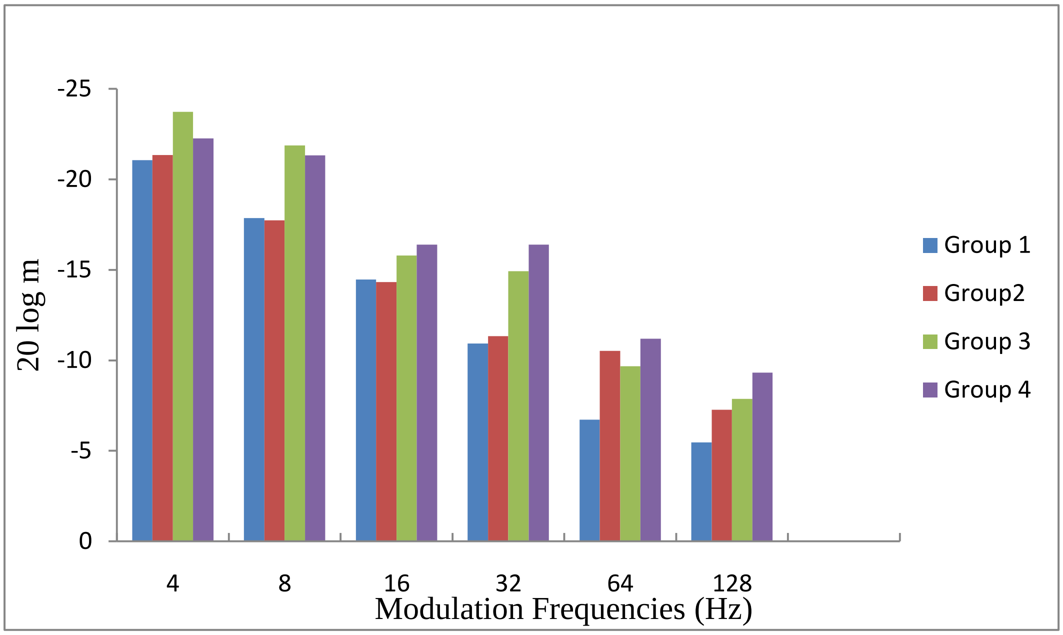

Figure 4.1. Mean values of the temporal modulation transfer function across different modulation frequencies for right ear.

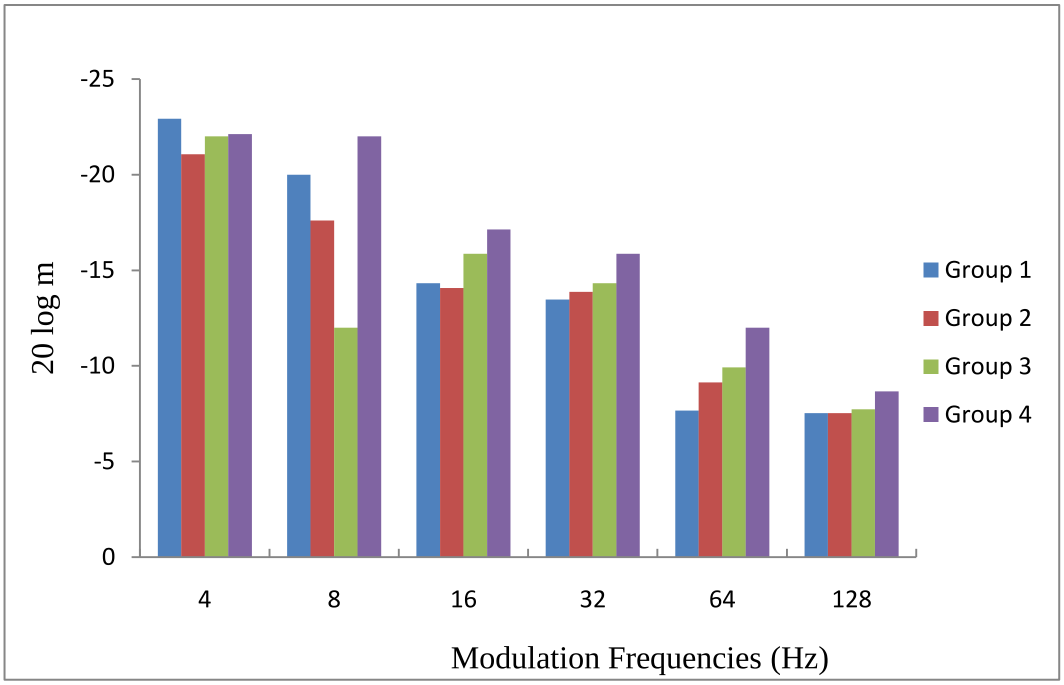

Figure 4.2. Mean values of the temporal modulation transfer function across different modulation frequencies for left ear.

Temporal modulation transfer function was measured for 6 different modulation frequencies, for both the ears separately, for all the four groups. Table 4.1 shows the descriptive statistics (mean & SD) of the TMTF of all the six modulation frequencies across the four groups.

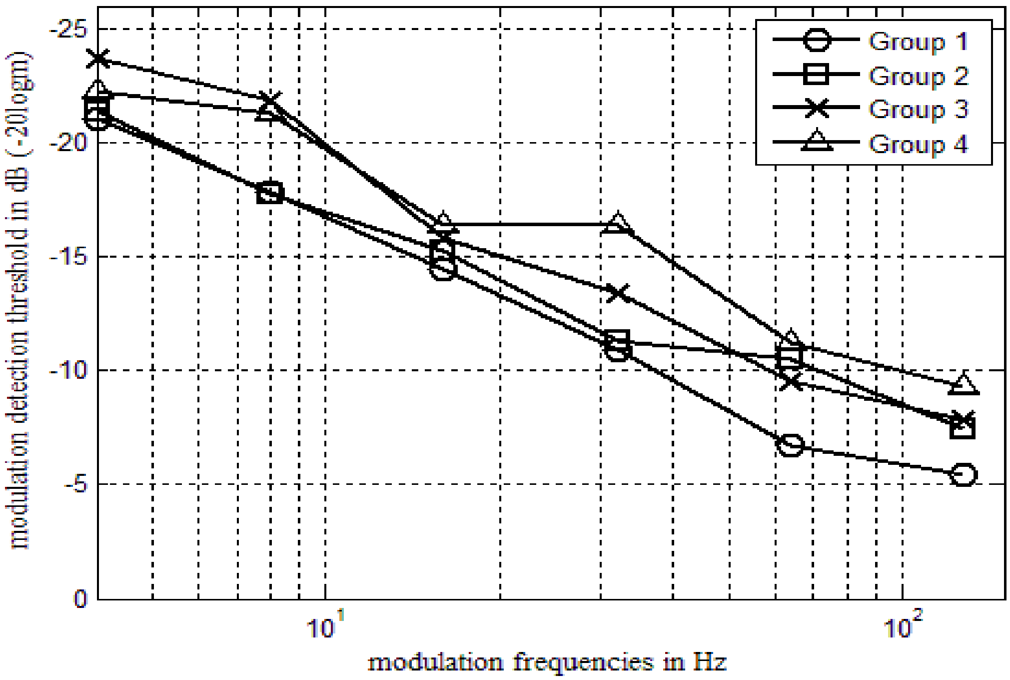

Figure 4.3. Temporal Modulation Transfer Function (TMTF) of all 4 groups for right ear.

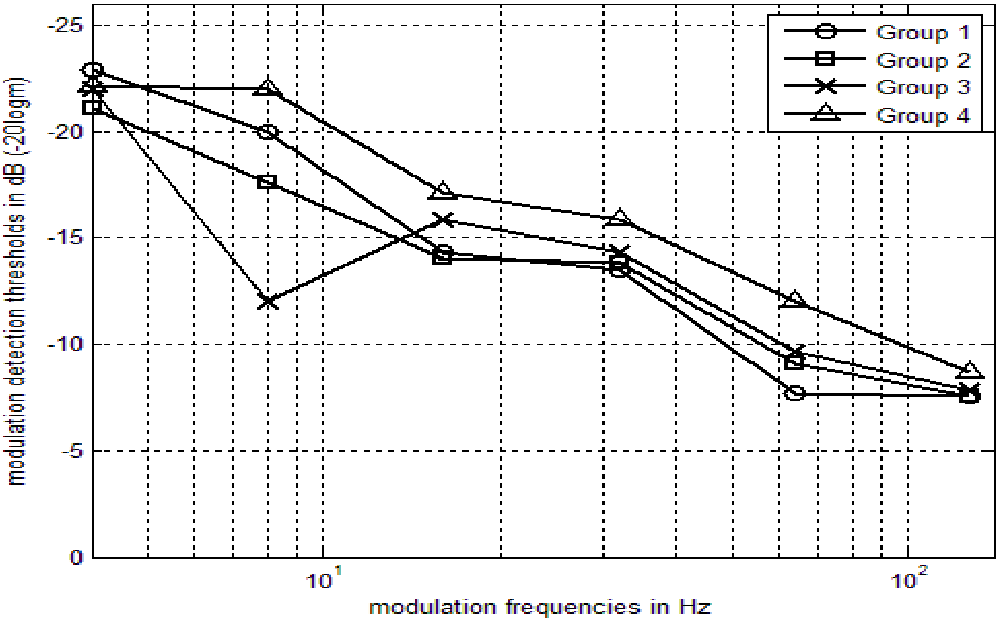

Figure 4.4. Temporal Modulation Transfer Function (TMTF) of all 4 groups for left ear.

The temporal modulation transfer functions for right ear and left ear for all the four groups were depicted in figures 4.3 and 4.4 respectively. Different modulation frequencies (in Hz) were represented in the abscissa and the modulation detection thresholds or modulation depths (as 20 log m) were represented in the ordinate. It was observed that the group with more than 16 years of musical experience (Group 4) showed better temporal modulation detection thresholds in both ears, when compared with other groups.

Across Group Comparison:

Kruskal-Wallis test was done for comparing across the four groups. It revealed no statistically significant difference for 4 Hz for both ears, 8 Hz for right ear, 16 Hz for both ears, 32 Hz for right ear, and 128 Hz for left ear. But statistically significant difference was present for 8 Hz for right ear, $\chi^2_{(3)}= 9.30$, $p< 0.05$; 32 Hz for right ear, $\chi^2_{(3)}=11.18$, $p< 0.05$; 64 Hz for right ear, $\chi^2_{(3)}= 9.00$, $p< 0.05$; and for left ear, $\chi^2_{(3)}= 7.94$, $p<0.05$ and 128 Hz for right ear, $\chi^2_{(3)}= 9.73$, $p< 0.05$.

The results of Kruskal-Wallis test revealed that there is statistically significant difference between the scores in at least any of the two groups. In order to find out which all groups are statistically different Mann-Whitney U test was administered.

When the groups 1 and 2 & 3 and 4 were compared, no significant difference ($p> 0.05$) was found for any of the modulation frequencies studied.

When groups 1 and 3 were compared, there was statistically significant difference at 8 Hz in right ear, $|Z|= 2.12$, $p< 0.05$; 32 Hz in right ear, $|Z|= 2.00$, $p< 0.05$; 64 Hz in right ear, $|Z|= 2.65$, $p< 0.05$ and at 128 Hz in right ear, $|Z|= 1.79$, $p< 0.05$. For all other frequencies there was no statistically significant difference ($p> 0.05$).

When groups 1 and 4 were compared, there was statistically significant difference at 32 Hz in right ear, $|Z|= 2.5$, $p< 0.05$; 64 Hz in right, $|Z|= 2.44$, $p< 0.05$ and in left, $|Z|= 2.51$, $p< 0.05$ ears and at 128 Hz in right ear, $|Z|= 2.62$, $p< 0.05$.

When groups 2 and 3 were compared, the results revealed that only at 8 Hz in right ear was significantly different, $|Z|= 2.38$, $p< 0.05$. Statistically significant differences were not found for all the modulation frequencies in both ears, at 5% level of significance,

For the comparison of groups 2 and 4, there was statistically significant difference at 8 Hz in both right$|Z|= 2.02$, $p< 0.05$ and left, $|Z|= 2.27$, $p< 0.05$ ears, at 32 Hz for right ear, |Z|= 2.64, $p<0.05$; and at 128 Hz for right ear, |Z|= 2.015, $p< 0.05$. For all other frequencies there were no significant differences at 5% level of significance.

Within Group Comparison

Within group comparison was done using Friedman test. Temporal modulation transfer function was compared across different frequencies. The results revealed that in group 1 statistically significant difference at 5% level of significance was obtained for 8 Hz, |Z|= 2.03, $p< 0.05$ and 128 Hz, |Z|= 2.03, $p< 0.05$ only. For all other frequencies there were no statistically significant differences at 5 % level of significance.

Groups 2, 3 and 4 showed no statistically significant differences at 5 % level of significance, when frequencies were compared using Friedman test.

Gap Detection Threshold (GDT) test

Gap detection threshold (GDT) test was administered for both ears separately to find the minimum temporal gap, the subject could identify. GDT test was done for all the four groups.

Mean and standard deviation (SD) of gap detection threshold for both the ears are shown in Table 4.2.

Table 4.2

Mean and SD of Gap Detection Threshold (GDT) for both ears.

	Groups							
	1		2		3		4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
GDT (R)	3.80	0.84	3.60	0.55	2.60	0.55	2.80	0.45
GDT (L)	3.60	0.90	3.60	0.55	3.00	0.00	2.60	0.55

Descriptive statistical analysis showed that the gap detection threshold reduced as the musical experience increases. Group 1 was having a gap detection threshold of 3.8±0.87 for right ear and 3.6±0.89 for left ear, where as for group 4 the threshold was 2.8±0.45 and 2.6±0.55 respectively.

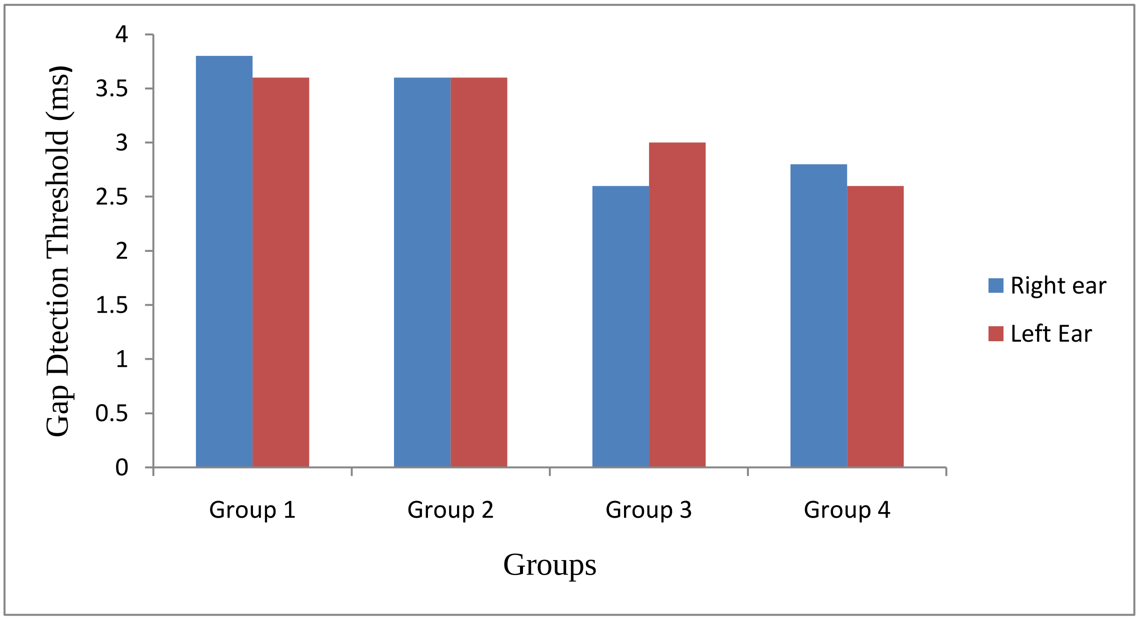

Figure 4.5. Mean values for Gap Detection Threshold for both ears across 4 groups

Across Group Comparison

Kruskal- Wallis test was done to compare the thresholds across the four groups. For both right ear, $\chi^2_{(3)} = 9.27$, $p < 0.05$ and left ear, $\chi^2_{(3)} = 8.20$, $p < 0.05$, the results were statistically significant.

Mann-Whitney test was done to compare the GDT results across two groups. The results were statistically not significant in both ears ($p > 0.05$) when groups 1 and 2, and 3 and 4 were compared.

The thresholds were statistically significant only for right ear, when groups 1 & 3, /Z/= 2.13, $p < 0.05$; groups 1 & 4, /Z/= 2.00, $p < 0.05$ and groups 2 & 3, /Z/= 2.15, $p < 0.05$.

When groups 2 and 4 were compared, the thresholds were statistically significant for both right ear, /Z/= 2.03, $p < 0.05$ and left ear, /Z/= 2.15, $p < 0.05$.

Within Group Comparison

Within group comparison of gap detection thresholds were done using Friedman test and pair wise comparison was done using Wilcoxon signed rank test. The results revealed that there was no statistically significant difference at 5% level of significance in any of the groups.

When gap detection thresholds were compared across right and left ears for all the groups using Wilcoxon signed rank test, there was no statistically significant difference at 5% level of significance.

Speech Perception in Noise

The speech perception in noise was assessed for all the 20 subjects for both the ears. The test was done at three signal-to noise ratios (SNRs): 0 dB SNR, -5 dB SNR and -10 dB SNR.

Table 4.3

Mean and SD of speech perception in noise test scores at different SNRs for both ears.

	Groups							
	1		2		3		4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
0 dB SNR (R)	92.80	3.35	93.60	2.19	95.20	1.79	93.60	2.19
0 dB SNR (L)	90.40	4.56	94.40	2.19	93.60	2.19	94.40	2.19
-5 dB SNR (R)	76.80	15.34	83.20	3.35	80.80	3.35	82.40	4.56
-5 dB SNR (L)	76.80	12.46	81.60	2.19	80.80	1.79	82.40	2.19
-10 dB SNR (R)	64.00	18.76	72.80	1.79	69.60	5.37	71.20	4.38
-10 dB SNR (L)	64.80	17.75	72.80	3.35	70.40	5.37	69.60	4.56

The descriptive statistics (Mean & SD) of the speech perception in noise (SPIN) test for the three SNRs (0 dB, -5 dB & -10 dB) for both ears are shown in table 4.3. The mean values showed that ability to perceive speech in the presence of the noise in all the three SNRs is better as the experience of the musicians increased. It was found that as the experience of musician increased the ability to perceive speech in the presence of background noise also increased, especially at lower SNRs.

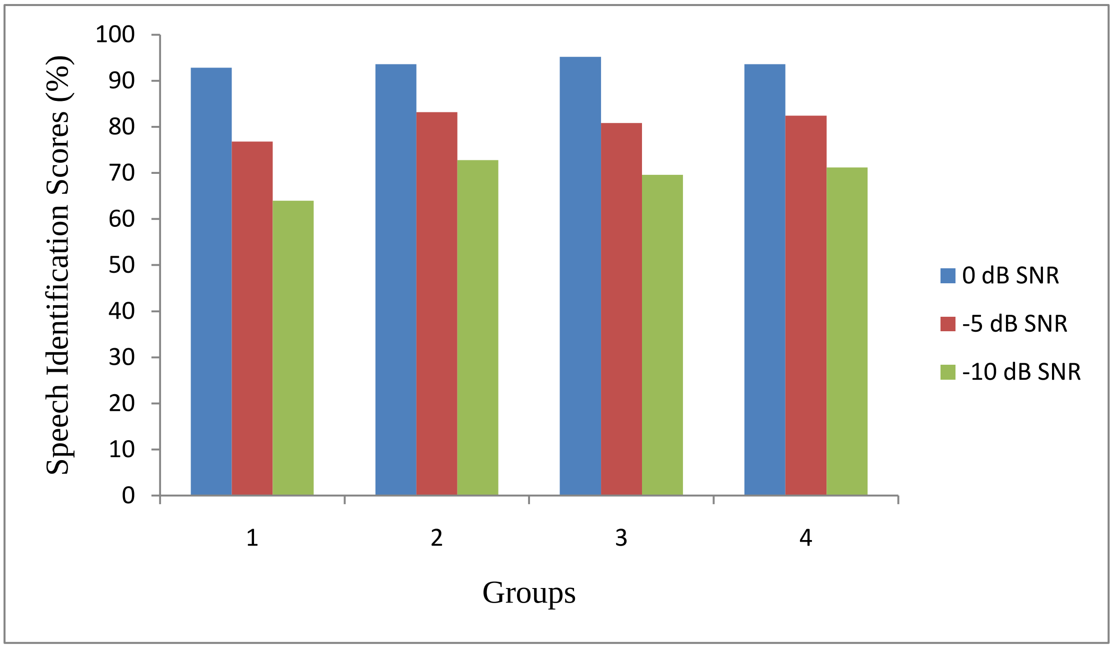

Figure 4.6. Mean SPIN scores at different SNRs for the four groups in right ear.

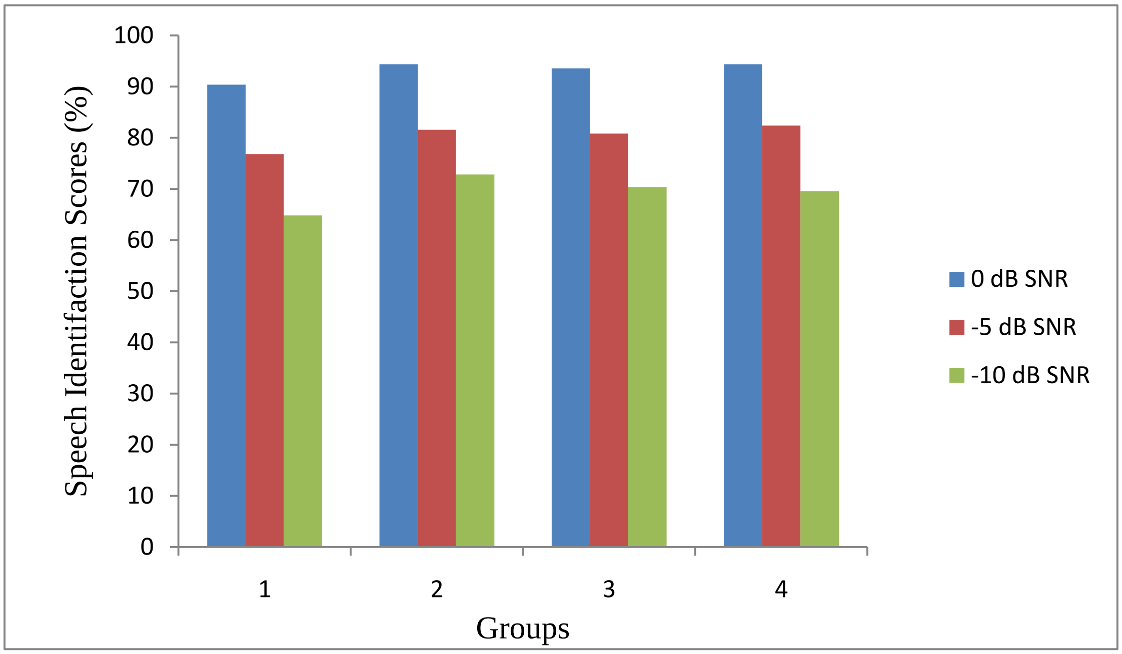

Figure 4.7. Mean SPIN scores at different SNRs for the four groups in left ear.

Across Group Comparison

The results across the four groups for three different SNRs were compared using Kruskal-Wallis test. The results revealed that there is no significant difference across the four groups at three different SNRs at 5 % level of significance.

Within Group Comparison

Within group comparison for three different SNRs (0 dB, - 5 dB & - 10 dB) were done using Friedman test. Pair wise comparisons were done using Wilcoxon signed rank test.

The comparison of SNRs in the right ear showed statistically significant difference, $\chi^2_{(2)} = 10.00$, $p < 0.05$. Wilcoxon signed rank test revealed statistically significant difference for all the three SNRs, at 5 % level of significance.

For left ear also the three different SNRs were compared using Wilcoxon signed rank test. The results revealed statistically significant difference for the three SNRs, $\chi^2_{(2)} = 10.00$, $p < 0.05$. From Wilcoxon signed rank test all the three SNRs were significantly different at 5% level of significance.

Discussion

The temporal resolution transfer function results across the four groups revealed statistically significant difference for the modulation frequencies like 8 Hz, 32 Hz, 64 Hz and 128 Hz, across different groups except for groups 1 & 2, and 3 & 4. The reason for no significant difference in these groups might be the closeness of these groups in terms of their experience. The literature which specifically explains about temporal modulation transfer function in musicians is limited. But in general, according to Ishll, C et al.

(2006), when Random gap detection test was administered on musicians and nonmusicians, the gap detection thresholds were better in trained musicians when compared to non-musicians. This concludes that temporal resolution abilities are better in musicians when compared to non-musicians. In the present study, for gap detection threshold (GDT) there was no statistically significant difference when the groups compared were closer in terms of experience or practice (i.e., Groups 1 & 2; 3 & 4). But for other group comparison there was statistically significant difference in the gap detection thresholds at 5 % level of significance. These results are in agreement with the study by Monteiro et al (2010), where it was concluded that musicians had better temporal resolution abilities when compared to non-musicians and the years of experience was a factor in deciding about the temporal resolution ability. As the experience in music increased, better temporal resolution ability was observed. Studies also reported that initiation of musical training also matters for the better abilities. According to Ohnishi et al (2001), music training can induce functional reorganization of the cerebral cortex. Therefore, the contact with music before the age of seven could contribute to the development of primary auditory cortex and more precisely the planum temporale. When the GDT was compared between the two ears within the group there was no statistical significant difference at 5 % level of significance.

When the speech perception in noise (SPIN) results were compared across the groups, there was no statistically significant difference at $p = > 0.05$, for all the three SNRs (0 dB, -5 dB, -10 dB). But this is in contrast to the previous research done in speech perception abilities in musicians. According to a study done by Parbery-Clark et al (2009), musical experience enhances the ability to hear speech in challenging listening environments. In another study Parbery-Clark et al (2009) found that musical experience resulted in more robust subcortical representation of speech in the presence of background noise. The difference in the results of the present study with the earlier studies reported in the literature can be accounted for a few reasons. First, the noise used in the previous studies were speech shaped noise or multi-talker babble. But in the present study speech noise was used to study the speech perception in noise. And it is evident that the speech shaped noise or multi-talker babble will give better results for speech perception in noise when compared to speech noise. Second, the previous studies were conducted on instrumental musicians, whereas the present study was carried out in vocal musicians. Moreover, the subjects taken in Parbery-Clark et al (2009) study were having more experience than the subjects for the present study.

When within group comparison was done for each ear at three different SNRs there was a reduction in the speech identification scores for all the subjects as the SNRs decreased which was statistically significant at 5 % level of significance. This means that when the noise level increased there was difficulty in the perception of speech.

CHAPTER 5

SUMMARY AND CONCLUSION

Many studies have reported that musicians have better auditory perception skills when compared to non-musicians. There are many studies in literature which have documented that musical training improves basic auditory perceptual skills resulting in enhanced behavioral (Jeon & Fricke 1997; Koelsch et al. 1999; Oxenham et al. 2003; Tervaniemi et al. 2005; Micheyl et al. 2006; Rammsayer & Altenmuller 2006) and neurophysiological responses (Brattico et al. 2001; Pantev et al. 2001; Schneider et al. 2002; Shahin et al. 2003, 2007; Tervaniemi et al. 2005; Kuriki et al. 2006; Kraus et al. 2009). Musicians’ life long experience of detecting melodies from background harmonies can be considered as a process analogous to speech perception in noise. Studies report that musicians had a more robust sub- cortical representation of the acoustic stimulus in the presence of noise (Kraus et al. 2009). Musical practice not only enhances the processing of music related sounds but also influences processing of other domains such as language (Marques et al. 2007; Moreno et al. 2009; Parbery-Clark et al. 2009a; Schon et al. 2004, 2008). Because of their musical training, musicians have learned to pay more attention to the details of the acoustic details of the stimulus than non-musicians.

The present study was aimed to find out the effect of musical training and/or practice in the temporal resolution abilities and speech perception in noise. A total of 20 professional Carnatic vocal musicians were participated in the study. An informal questionnaire was administered to all participants, in order to get the information regarding their experience in the musical field. The musicians were classified into four groups based on their experience and/or practice. Each group consisted of 5 subjects. Temporal resolution abilities were found out using Temporal Modulation Transfer Function (TMTF) and Gap Detection Threshold (GDT) test. Speech perception in noise was measured in three different SNRs (i.e., 0 dB, -5 dB & -10 dB). All these tests were administered at 50 dB SL or at most comfortable level, for both ears separately.

The results from the present study showed that the temporal resolution abilities and the ability to perceive speech in the presence of noise were better in musicians than in non-musicians. The results of temporal modulation transfer function results and gap detection threshold values showed that the temporal resolution abilities becomes better as the years of musical experience of the musicians increased. The results were statistically significant. But the results of the speech perception in noise were not statistically significant when the musicians were compared across their experience, though the scores were better in experienced musicians when compared to the musicians with less experience.

Implications of the Study

- To add information to the literature.
- Music training can be used as a potential remediation strategy for children requiring language training and auditory processing disorders.
- Can be implemented in Hearing Aid technology for musicians with hearing loss to improve their speech perception.

Future Directions for Research

- The present study can be replicated using more number of participants to find the difference across the experience.
- Same skills can be compared across vocal musicians and instrumental musicians.
- Can be compared between Hindustani and Carnatic musicians.
- Musicians and dancers can be compared to find whether there are differences in the temporal resolution abilities and ability to perceive speech in the presence of noise.

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