SOME AUDITORY EFFECTS OF SHORT-TERM PERCEPTUAL TRAINING OF MUSIC

Hijas Mohamed N

Register Number: 11AUD009

A Masters Dissertation Submitted in Part Fulfilment of Final Year

Master of Science (Audiology)

University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MANASAGANGOTHRI, MYSORE – 570006

MAY, 2013.

Dedicated To

Umma, Uppa & my Guide

CERTIFICATE

This is to certify that this dissertation entitled "**Some Auditory Effects Of Short-Term Perceptual Training Of Music**" is a bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student (Registration No: 11AUD009). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any of the University for the award of any other Diploma or Degree.

Mysore

May, 2013

Dr. S. R. Savithri
Director
All India Institute of Speech and Hearing
Manasagangothri, Mysore – 570006.

CERTIFICATE

This is to certify that this dissertation entitled "**Some Auditory Effects of Short-Term Perceptual Training of Music**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in other University for the award of any Diploma or Degree.

Mysore

May, 2013

Dr. Ajith Kumar. U.
Guide
Reader in Audiology
All India Institute of Speech and Hearing
Manasagangothri, Mysore – 570006.

DECLARATION

This is to certify that this dissertation entitled “**Some Auditory Effects Of Short-Term Perceptual Training Of Music**” is the result of my own study under the guidance of Dr. Ajith Kumar U, Reader in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier in other University for the award of any Diploma or Degree.

Mysore Register No: 11AUD009

May, 2013

ACKNOWEDGEMENT

"It is our choices...that show what we truly are, far more than our abilities."

- Albus Dumbledore

At the outset I am very grateful and thankful to ***Almighty Allah*** *for making me get through tough times and making me what I am today. Oh Allah, I bow to u every day. Please bless me so that I will be always happy and let all virtues come to me. It is all possible because of your blessings.*

*'**Gu**' represents Darkness, '**Ru**' acts like an obstacle to the darkness and shows the path of knowledge.* ***Guru*** *is the one who leads us from darkness to the light of knowledge.*

My Guide and Teacher, ***Dr. Ajith Kumar. U,*** *Reader, Department of Audiology, All India Institute of Speech and Hearing has been and continues to be my Guru in many ways. It is said that, "teachers teach more by what they are, than what they say". Sir, your words ("Be a good human being before becoming a professional") had a great impact on me. I humbly acknowledge with great respect for his guidance, comments, patience and untiring effort in steering me through every aspect of the study, providing me with the opportunity to learn from his expertise, in music. I am indebted to him for the completion of this work. In spite of his busy schedule, he spent many of his precious hours for correcting this. He was friendly and patient in solving problems. I am not finding words to thank u sir. I am grateful to u Sir, you have always been patient to me even*

though I did many mistakes. I owe him for his flexible scheduling, relaxed demeanour and letting me work independently without questioning my abilities.

I would like to render my thanks to **Prof. S. R. Savithri,** *the Director of AIISH, for permitting me to carry out this study.*

I would also like to thank the **Dr. Animesh Barman,** *HOD, Dept. of Audiology for permitting me to use the instruments and facilities available for my study.*

I am proud of you **UPPA** *and* **UMMA** *for being such adorable parents. A lifetime of thanks is not enough for the care, concern and affection that you bestowed on me. Your unconditional love and support has made me who I am. Your prayers protect me, your wisdom leads me, and your love builds me! I wish I could always stay curled up within your arms! I assure you that I will always be there for you like you have always been there for me!*

UMMA, *I can't just thank for the sacrifices you have made and for the enthusiasm you have shown for all the challenges I have taken up. 'A mother's love is something we keep locked deep in our hearts, always knowing it will be there to comfort us'.*

UPPA, *I want to thank you from the bottom of my heart for the sacrifices you have made and for having the faith in me, all the time. Your motivating words have always encouraged me and have helped me achieve my dreams. Thanks for teaching me* *how important it is to have moral values and to lead a principled life.*

Thank you **Pachu (Faiz)**!!! *You are a wonderful brother and a good friend. Love you loads....*

Thank you **Unnimol (Fathima)**!!! *You are a wonderful sister... enjoyed the silly fights with you.. Love you loads....*

A hearty thanks to **Dr. K. Rajalakshmi** *for being so awesome, very caring and for your love towards us. Thank you Mam.*

I thank **Sandeep Sir** *for being such an inspirational teacher in my career. You are a perfect lecturer clubbing knowledge and interest in learning sir.*

Thank you **Sreeraj Sir** *and* **Jijo Sir** *for all the support... It was nice for being your junior and a student later.*

I thank all the faculty members of AIISH.

The dissertation would not have come to this form without the melodic tunes of **Violinist Chetan. C.** *Thank you sir for your timely help.*

I extend my sincere appreciation to **Ms. Usha Shastri,** *for her critical contributions to this dissertation and helping me with the statistics. Thank you mam!!!*

I thank **Vasanthalakshmi mam** *for teaching me statistics in a wonderful manner without which it would have been difficult for me to do statistical analysis.*

*I am grateful to all my close relatives and friends (**Merry, Seby, Rhea** and **Sara)** for raising my confidence and lending support in my hour of personal crisis. Thanks for being with me for all the long 6 years….The friendship with you guys helped me move on in this place of loneliness and finally gave me an album of everlasting sweet memories. No words to express your love and care…I will always remember the best times we had….I wish that we are always together….. I just pray to GOD for your happiness…. All the best guys…Miss you….*

***Nishu**! What do I say? How can I thank you enough? This is the toughest task! Thanks is not enough for the care, concern and love that you showed towards me. Thanks for being my sister and part of my life. 'Sisters always share a special bond, which includes unconditional love and support, filled with the occasional healthy competition and silly fights'. I just pray to GOD for your happiness.*

*Special thanks to **Guddu chechi** for being my part of my life and supporting me in my hard times.. Thanks is not enough for you.. I just pray to GOD for your happiness.*

*Thank u **Khushbu** for being part of my life. At the same time sorry.. Didn't have any other way. You have taught me many things.. Will remember all the times spent together.. Miss you..* ☹

*Hands that help are holier than the lips that praise. Yes my friends **Prajeesh, Nandu, Sachidanand, Bharathidasan, Saravanan, Mittali**. You all have proved it right. I am indebted to them for all their support and help life at AIISH. I have* *always loved to spend time with you all and going out together on weekends and holidays.*

Danny, Chinkan, Prinkan, Gangan *and* **Vivek,** *my brothers who have made my years in AIISH colourful! Thank you guyzz!!!*

My special thanks to **Ramees, Zebu, Sudhanshu, George, Hemaraj, Jobish, Prasad, Vipin, Sreelakshmi, Yashu, Aparna, Rithu, Sushma** *for being my friends. Enjoyed the time with you…*

Thank u all for helping in various ways. Time flies memories don't. Thank u all for being part of my memories and being the reason for my smile.

A million thanks to all the participants of taking part in my study!

Thanks to my entire classmate, you guys are awesome. I cannot describe your love and good deeds that you have done for me, else it will become an essay book, but with few words ill end up saying you guys meant so much to me. Thank you all for your immense help throughout the year. I cherish every moment spending with you all. Love you, always & forever.

Thanks to **Ganapathi sir, Hemanth sir, Ruben sir, Roshni mam, Nike sir** *and other staffs for opening the department for our data collection.*

My sincere thanks to **Jim, Bharathi, Varun, Anchala, Pancham, Mangal, Vibhu, Jesnu, Varsha, Sneha, Revathi, Arathi, Thareeque, Fathima, Azeez,** *for being good juniors….*

Thank you everyone and be a blessing when reading this book. May God bless you.

*Thanks for the staffs of **AIISH Library** for helping me find books and article…*

I thank everyone I have met along life's journey! Forgive me if I have accidently missed out anyone!

Thank you all!

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Introduction

Music and speech share a number of properties. Comprehension of both music and speech depends on the modulations of the acoustic parameters. Furthermore, both of them are characterized by their multiplicative nature. That is, complexity is built up by the rule based permutations of limited number of discrete elements (Nowak, 2002). The elements can be phonemes in case of speech whereas in case of music it can be notes (Krumhansl, 1990). Apart from this, there are other similarities between music and speech. For example, both show relatively fixed and specified developmental time course (Trehub, 2001).

The auditory perception in humans is enriched with cognitive as well as sensory processes that work through a complex interaction of corticofugal neural pathway from cochlea to cortex and vice versa. The human perception of complex signals like speech and music are realized due to the dynamic modulation present per se (Zatorre, Belin, & Benhune, 2002). Speech being the primary communication system, problems with speech perception (especially seen in geriatrics) can be very distressing. Recent research suggests that musical training enhances the sensory processing of speech sounds at the level of brainstem and cortex (Strait & Kraus, 2011). So the continuous and consistent music practice over the years helps in fine tuning the auditory system in a comprehensive manner. This in turn strengthens the cognitive and neurobiological foundations of both music and speech processing.

Musicians have enhanced pitch and temporal discrimination abilities (Kishon-Rabin, Amir, Vexler, & Zaltz, 2001; Micheyl, Delhommeau, Perrot, & Oxenham, 2006; Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011; Strait, Kraus, Parbery-

Clark, & Ashley, 2010). The increased sensitivity in musicians to temporal and pitch components of language and music can be attributed to fine-tuned auditory perception (Chobert, Marie, Francois, Schon, & Besson, 2011; Marie, Magne, & Besson, 2011; Marques, Moreno, Castro, & Besson, 2007; Schon, Magne, & Besson, 2004; Tervaniemi, Ilvonen, Karma, Alho, & Naatanen, 1997; van Zuijen, Sussman, Winkler, Naatanen, & Tervaniemi, 2005). Even the subcortical representation of the auditory stimuli in musicians is superior when compared to the non-musicians which is demonstrated as an enhancement in the auditory brainstem response to music (Lee, Skoe, Kraus, & Ashley, 2009; Musacchia, Sams, Skoe, & Kraus, 2007), speech (Bidelman, Gandour, & Krishnan, 2011; Bidelman & Krishnan, 2010; Musacchia et al., 2007; Parbery-Clark, Skoe, & Kraus, 2009; Wong, Skoe, Russo, Dees, & Kraus, 2007) and emotional communication sounds (Strait, Kraus, Skoe, & Ashley, 2009).

Extensive musical training helps to facilitate the processing of pitch contour not only in music but also in language. Wong, Skoe et al., (2007) reported that musicians had more robust and faithful linguistic pitch encoding than non-musicians. This was attributed to reflect the positive effect of context general corticofugal tuning of the afferent system which implies that long term music training can shape basic sensory circuits. Wong, Parson, Martinez, and Diehi (2004), showed musicians had shorter latency and larger amplitude brainstem responses than non-musicians to both speech and music stimuli. Phase locking to stimulus periodicity, which is thought to be responsible for the pitch perception was enhanced in musicians and was correlated strongly with the duration of music training (Musacchia et al., 2007).

Apart from subcortical and cortical functional enhancements, music training may shape functions of the peripheral auditory structures such as cochlea. It has been demonstrated that efferent neural pathway in musicians control outer hair cell activity to a greater extend when compared to non-musicians (Brashears, Morlet, Berlin, & Hood, 2003; Perrot, Micheyl, Khalfa, & Collet, 1999). Improving sound processing at low level sensory centres is an important function of the efferent neural system. This is achieved by tuning them to relevant auditory input (Bajo, Nodal, Moore, & King, 2010; Suga, 2008). How well individuals hear in difficult listening situation such as listening in background noise can depend on the strength of the efferent system (Strait & Kraus, 2011). Individuals with stronger efferent system may have better listening in difficult listening situations. Such neural and perceptual enhancements in musicians can be attributed to the enhanced auditory cognitive skills such as working memory (Chan, Ho, & Cheung, 1998; Ho, Cheung, & Chan, 2003; Pallesen et al., 2010; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Parbery-Clark, Strait, Anderson et al., 2011) and auditory attention (Tervaniemi et al., 2009; Strait et al., 2010).

In summary long-term music training exposure results in plastic changes in subcortical, cortical and efferent auditory pathways. At behaviour level, long term music exposure improves fine grained auditory perception, pitch coding, auditory attention and working memory. These perceptual and cognitive factors are also shown to be important for speech perception in noise (Parbery-Clark, Skoe, Lam, & Kraus, 2009; Parbery-Clark, Strait, Anderson et al., 2011; Strait et al., 2010). Few studies have shown musicians have better processing of speech in noise compared to non-musicians (Heinrich, Schneider, & Craik, 2008; Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Skoe, Lam et al., 2009; Parbery-Clark, Skoe, & Kraus, 2011; Strait & Kraus, 2011). Subcortical auditory processing studies have found neurobiological basis for the enhanced perception of speech in noise in musicians.

Need for the Study

From previous studies, it is clear that there exist a functional and anatomical difference in auditory system between musicians and non-musicians. Musicians have better fine grained auditory perception and speech perception in noise. However, these positive effects have been demonstrated only on musicians who had undergone long term formal training in music. It is interesting to see whether these advantages extend to short-term perceptual musical exposure also. Therefore, present study was taken up to evaluate the physiological and perceptual changes in the auditory system, if any, due to short term perceptual music training. This study measured the effect of short term bi-sensory (auditory and visual) and uni-sensory (auditory only) perceptual training of two Carnatic Ragas on auditory system. Furthermore, this study also measured the effect of perceptual training of music on speech perception in noise and functioning of efferent auditory pathway.

Aim of the Study

The aim of the present study was to investigate the effect of short-term bi-sensory (auditory and visual) and uni-sensory (auditory only) musical exposure on speech perception in noise and contralateral inhibition of otoacoustic emissions.

Objectives of the Study

- To evaluate the effect of short-term bi-sensory (auditory and visual) and uni-sensory (auditory only) musical exposure on identification of two Carnatic music Ragas.

- To evaluate the effect of short-term bi-sensory (auditory and visual) and uni-sensory (auditory only) musical exposure on perception of speech in noise.

- To evaluate the effect of short-term bi-sensory (auditory and visual) and uni-sensory (auditory only) musical exposure on contralateral inhibition of transient evoked otoacoustic emissions (TEOAEs).

- To evaluate the relationship among short-term musical exposure, contralateral inhibition of TEOAEs and perception of speech in noise.

Chapter-2

Review of Literature

The auditory system is integrative and interactive. The two auditory experiences that can alter the brain highly are speech and music. Listening to and understanding both speech and music is a complex task that involves a variety of sensory, cognitive and language processes and interactions between them. The precise neurobiological mechanisms that bring about musical training induced neuronal enhancements remain undetermined. But it is sure that the musical training induces plastic changes in the subcortical and cortical auditory system. It is well established that long-term musical training strengthens cortical and subcortical mechanisms of auditory processing.

Auditory Cortical System and Music

The investigations on cortical representation of speech as well as music has gained the attention of many researchers (Abrams et al., 2010; Brown, Martinez, & Parsons, 2006; Rogalsky, Rong, Saberi, & Hickok, 2011; Zatorre et al., 2002). Even though there are specialized areas in brain for processing music and speech (Abrams et al., 2010; Brown, Martinez, & Parsons, 2006; Rogalsky et al., 2011; Zatorre et al., 2002), shared mechanisms are also used to process sound in both domains (Fedorenko, Patel, Casasanto, Winawer, & Gibson, 2009; Koelsch et al., 2002; Patel, 2003; Slevc, Rosenberg, & Patel, 2009; Zatorre & Gandour, 2008). These shared mechanisms can account for the structural (Gaser & Schlaug, 2003a, 2003b; Hutchinson, Lee, Gaab, & Schlaug, 2003; Schlaug, Forgeard, Zhu, Norton, & Winner, 2009; Schmithorst & Wilke, 2002; Schneider et al., 2002) and functional (Marques et al., 2007; Moreno et al., 2009; Musacchia et al., 2007; Schon et al., 2004; Wong, Skoe et al., 2007) enhancements for auditory processing of music and language. It is clear that the processing of both music and speech takes place through similar mechanism (Koelsch et al., 2002; Patel, 2003; Rogalsky et al., 2011; Zatorre & Gandour, 2008).

There are variety of differences between the brains of musicians and non-musicians both structurally (Gaser & Schlaug, 2003a, 2003b; Hyde et al., 2009; Pantev et al., 1998; Schlaug, 2001; Schneider et al., 2002) and functionally (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2004; Kraus & Chandrasekaran, 2010; Parbery - Clark, Strait, Anderson et al., 2011; Shahin, Bosnyak, Trainor, & Roberts, 2003; Strait, Chan, Ashley, & Karus, 2012; Strait & Kraus, 2011; Trainor, Shahin, & Roberts, 2009).

Musical training enhances the sensory processing of speech sounds at the level of auditory cortex (Abrams et al., 2010; Brown et al., 2006; Koelsch et al., 2002; Patel, 2003; Rogalsky et al., 2011; Zatorre et al., 2002). So continuous and consistent music practice over the years fine-tunes the auditory system in a comprehensive fashion, which strengthens cognitive and neurobiological foundations of both music and speech processing. Professional musicians with normal hearing have demonstrated superior performance on a wide variety of psychoacoustic, electrophysiological, cognitive tasks and on different anatomical and functional imaging studies of brain compared to untrained listeners (Janata, Tillmann, & Bharucha, 2002; Popescu, Otsuka, & Ioannides, 2004; Strait et al., 2009). Therefore, music plays a major role in neurorehabilitation (Sarkamo et al., 2008).

It has been reported that musicians have increased sensitivity to spectral and temporal components of language and music and enhanced cortical evoked potentials to deviances in pitch and rhythm of a sound stream which could be attributed to fine-tuned auditory perception (Chobert et al., 2011; Marie et al., 2011; Marques et al., 2007; Schon et al., 2004; Tervaniemi et al., 1997; van Zuijen et al., 2005). Musicians demonstrate enhanced auditory brainstem responses to music (Lee et al., 2009; Musacchia et al., 2007), speech (Bidelman et al., 2009; Bidelman & Krishnan, 2010; Musacchia et al., 2007; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Wong, Skoe et al., 2007), and emotional communication sounds even subcortically (Strait et al., 2009).

Professional musicians have performed better, demonstrated shorter reaction times, and exhibited larger amplitudes of cortical responses than non-musicians on tasks of timbre perception (Chartrand & Belin, 2006; Pitt, 1994; Shahin, Roberts, Pantev, Trainor, & Ross, 2005; Zendel & Alain, 2008), pitch perception and frequency discrimination (Akin & Belgin, 2009; Besson, Schon, Moreno, Santos, & Magne, 2007; Nikjeh, Lister, & Frisch, 2008, 2009; Tervaniemi, Just, Koelsch, Widmann, & Schroger, 2005), contour and interval processing (Fujioka et al., 2004; Hantz, Crummer, Wayman, Walton, & Frisina, 1992; Pantev et al., 2003; Tervaniemi, Castaneda, Knoll, & Uther, 2006), spatial ability (Douglas & Bilkey, 2007; Schellenberg, 2005; Sluming, Brooks, Howard, Downes, & Roberts, 2007), and vocabulary and verbal sequencing (Piro & Ortiz, 2009).

It has been found that long term music exposure can induce a positive effect on brain regions such as sensorimotor brain areas (Elbert, Pantev, Wienbruch, Rockstroh, & Taub, 1995; Gaser & Schlaug, 2003a; Hund-Georgiadis & von Cramon, 1999; Schlaug, 2001), auditory areas (Bermudez & Zatorre, 2005; Gaab & Schlaug, 2003a; Lappe, Herholz, Trainor, & Pantev, 2008; Pantev et al., 1998; Schneider et al., 2002; Zatorre, 1998), and multimodal integration areas (Bangert & Schlaug, 2006; Gaser & Schlaug, 2003b; Lotze, Scheler, Tan, Braun, & Birbaumer, 2003; Munte, Kohlmetz, Nager, & Altenmuller, 2001; Sluming et al., 2002; Sluming et al., 2007; Zatorre, Chen, & Penhune, 2007). Some researchers have investigated the effect of musical training on the brain functioning in children as well (Fujioka, Ross, Kakigi, Pantev, & Trainor, 2006; Koelsch, Fritz, Schulze, Alsop, & Schlaug, 2005; Overy et al., 2004; Shahin, Roberts, Chau, Trainor, & Miller, 2008).

The ability to extract the auditory message from the background noise depends on various sensory and cognitive skills like auditory attention and working memory. There are evidences suggesting that musicians depend on extra cortical areas which are responsible for attention and working memory during challenging auditory tasks to a higher extent (Baumann, Meyer, & Jancke , 2008; Haslinger et al., 2005; Stewart et al., 2003). This increased dependence on extra cortical areas that are responsible for attention and working memory can account for the enhanced pitch discrimination, sound recall and hearing speech in noise (Kishon-Rabin et al., 2001; Parbery-Clark et al., 2009; Parbery-Clark, Strait, Anderson et al., 2011; Strait et al., 2010).

The enhancement of memory in musicians is postulated to have a basis in functional cortical activation. In a pitch memory task, musicians rely more on cortical areas which are devoted to short-term memory where as non-musicians depends on auditory sensory areas (Gaab & Schlaug, 2003b). This increased dependence on the short-term memory in musicians can be as a result of rehearsals during musical training.

As individuals undergo musical training, there are plastic changes occurring in the cortical structures as studied by various non-invasive procedures (Schlaug, et al., 2009). Longitudinal studies that assess different aspects of brain function before and after music training have indicated the experience related and innate factors of musicianship (Fujioka et al., 2006; Hyde et al., 2009; Moreno et al., 2009; Norton et al., 2005; Schlaug, Forgeard, Zhu, Norton, & Winner, 2009).

Instrument of practice also has an effect on neural processing which indicates the effectiveness of music training in shaping the brain function. The cortical and subcortical brain structures in musicians are highly tuned to the instrument of practice (Pantev, Roberts, Schulz, Engelien, & Ross, 2001; Shahin et al., 2003; Shahin, Roberts, & Trainor, 2004; Margulis, Mlsna, Uppunda, Parrish, & Wong, 2009).

In order to understand the relationship between musicianship, perceptual expertise, and speech learning, training on an artificial vocabulary in which words were distinguished by lexical tones was given for English speaking adults (Wong & Perrachione, 2007). Most of the participants who mastered the vocabulary were musicians and most of them who did not master were non-musicians. There is a correlation between the level of mastery of vocabulary and individuals’ performance on a pitch pattern identification task. Musicians outperformed the non-musicians on a pitch pattern identification task. Differences in the auditory pattern of neural activity as measured by fMRI during pitch pattern identification task gave indications of the level of mastery (Wong, Perrachione, & Parrish, 2007). There was greater activation in the regions of posterior superior temporal lobe bilaterally associated with sound pattern classification for successful learners. Whereas for less-successful learners there was greater activation in the regions of frontal lobe such as anterior cingulate which are associated with attention and decision making. After training on the lexical tone based vocabulary, successful learners showed greater activation in the left posterior superior temporal gyrus, which is consistent with patterns of neural activity in native tone language speakers during a similar task (Xu et al., 2006). In less successful learners, there was greater activation in a diffuse network of frontal regions associated with attention and decision making after training. Successful learners showed larger volumes of both grey and white matter in the left Heschl’s gyrus when compared to less successful learners. There was a significant positive correlation between the volume of grey matter in left Heschl’s gyrus and level of vocabulary mastery. Similar finding was also observed in successful learning of non-native consonants (Golestani & Pallier, 2007).

Auditory Brainstem and Music

The auditory brainstem is considered to be a hub of sensory cognitive interactions since it has many neuronal connections (Winer, 2006). The auditory brainstem was thought to be a passive relay stations between the cochlea and the cortex. But it is now understood that subcortical nuclei such as inferior colliculus are mutually connected with cortical areas. The inferior colliculus which is thought of as a major contributor of speech evoked auditory brainstem response (speech-ABR) not only functions as an afferent route but also receives a large number of corticofugal projections. It is considered to be important for learning (Bajo et al., 2010; Suga & Ma, 2003). It is also affected by cognitive and emotional influences, and are plastic in their response properties (Bajo et al., 2010; Gao & Suga, 2000; Marsh, Fuzessery, Grose, & Wenstrup, 2002).

Musical training enhances the sensory processing of speech sounds at the level of brainstem (Bidelman et al., 2009; Bidelman & Krishnan, 2010; Lee et al., 2009; Musacchia et al., 2007; Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Strait et al., 2009; Wong, Skoe et al., 2007; Zatorre & Gandour, 2008).

The pitch of the neural response obtained from complex auditory brainstem response can be correlated with the stimulus. Musicians have enhanced pitch and temporal discrimination abilities that can be encoded at the level of brainstem (Kishon-Rabin et al., 2001; Micheyl et al., 2006; Strait et al., 2010; Parbery-Clark, Strait, Anderson et al., 2011). Musicians also exhibit enhanced encoding of linguistic pitch at the level of the brain stem when compared to non-musicians (Wong, Skoe et al., 2007). In quiet and in presence of noise, the neural encoding of the stimulus harmonics is enhanced in musicians when compared to non-musicians irrespective of the age (Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Strait, Anderosn et al., 2011). The extent of the harmonic enhancement is correlated with auditory working memory and the years of music training (Parbery-Clark, Strait, & Kraus, 2011).The fidelity with which the speech evoked ABR mimics the stimulus is high in musicians when compared to non-musicians (Strait et al., 2012; Parbery-Clark, Skoe, & Kraus, 2009).There is a greater similarity of speech evoked ABR to the stimulus in child (Strait et al., 2012) than when compared to adult (Parbery-Clark, Skoe, & Kraus, 2009) musicians. The presence of background noise and reverberation can interfere with the neural processing at the level of brainstem which can result in a delay in the timing of neural processing. Subcortical auditory processing studies have found neurobiological basis of musicians’ enhanced perception of speech in noise. The degradation in both spectral and temporal dimensions in the subcortical encoding of speech due to the presence of background noise and reverberation which result in a delay in the neural processing of speech is smaller in musicians when compared to non-musicians (Bidelman & Krishnan, 2010; Parbery-Clark, Skoe, & Kraus, 2009; Strait et al., 2012; Parbery-Clark, Strait, Anderson et al., 2011). There is a correlation between working memory and the degree of noise induced speech-ABR timing shift

(Anderson, Skoe, Chandrasekaran, & Kraus, 2010; Parbery-Clark, Skoe, & Kraus, 2009; Strait et al., 2012). Higher the working memory the lesser will the timing shift in the neural processing due to noise and reverberation.

Music and Corticofugal System

Enhancing the sound processing at lower centres is thought to be an important function of the corticofugal neural system which is achieved by fine-tuning the lower level centres to the appropriate auditory information (Bajo et al., 2010; Suga, 2008). How well we hear in the presence of background noise depends on the strength of the corticofugal pathway. It is demonstrated that individuals having stronger efferent control over auditory processing will have greater improvement for brief duration auditory task (de Boer & Thornton, 2008). This holds good for musicians since they have demonstrated enhanced top down control over auditory processing (Kraus & Chandrasekaran, 2010; Strait et al., 2010). There is direct relationship between the duration of music training and auditory task performance (Kishon-Rabin et al., 2001; Parbery- Clark et al., 2009; Strait et al., 2010). Music training may shape functions of the peripheral auditory structures such as cochlea. It has been demonstrated that efferent neural pathway in musicians control outer hair cell activity to a greater extent when compared to non-musicians (Brashears et al., 2003; Perrot et al., 1999).

Music and Auditory Perception

The musicians demonstrate significantly better frequency discrimination ability and greater working memory capacity than non-musicians (Akin & Belgin, 2009; Gaab & Schlaug, 2003a; Micheyl et al., 2006; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Trainor, Shahin, & Roberts, 2003). On a pitch memory task, measured brain activation patterns showed that non-musicians rely on cortical pitch discrimination areas, whereas musicians recruited working memory and recall areas which suggests that musical training influences the neural networks used for such tasks (Gaab & Schlaug, 2003b). Since music has many different pitches (notes) and musicians are able to identify and discriminate these musical pitches, it is hypothesized that musicians are able to better perceive pitch contours in tonal languages when compared to non-musicians (Alexander, Wong, & Bradlow, 2005).

When compared to non-musicians, musicians’ segregation of the combined signal into auditory objects occurs differently over time (Beauvois & Meddis, 1997; Snyder & Alain, 2007). Musicians are less impaired by the presence of noise when compared to non-musicians (Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Skoe, Lam, et al., 2009; Parbery-Clark, Strait, & Kraus, 2011; Strait & Kraus, 2011; Strait et al., 2012; Zendel & Alain, 2012) and this enhanced effect can even be carried over to old age (Kraus, 2012).

Music and Cognition

The musical training requires sustained control of attention for the delicate manipulation of sound and also for the coordination with other musical instrument players. This can be the reason for the enhanced attention abilities found in the auditory modality of musicians when compared to the non-musicians (Strait et al., 2010). And also musicians demonstrate faster reaction time to a target than non-musicians (Strait et al., 2010). The subcortical and cortical networks that are responsible for attention to music do overlap with those which are responsible for general auditory functions such as language. These network overlaps among attention, language and music perception suggests that, a combination of modality specific and general attention and working memory mechanism contribute to sustained attention (Petkov et al., 2004; Zatorre, Mondor, & Evans, 1999).

Irrespective of age, the cognitive abilities such as auditory attention (Kraus & Chandrasekaran, 2010; Strait & Kraus, 2011; Strait et al., 2010), working memory (Gaab & Schlaug, 2003a; Pallesen et al., 2010; Parbery-Clark, Skoe, Lam, & Kraus, 2009; Parbery-Clark, Strait, Anderson et al., 2011; Strait et al., 2012) are also found to be enhanced in musicians when compared to non-musicians. Also musicians have reduced variability in the auditory attention performance (Strait & Kraus, 2011). The cognitive enhancements exhibited by musicians tend to be auditory domain specific (Chan et al., 1998; Ho et al., 2003). The enhanced auditory cognitive skills such as auditory attention and working memory in musicians can be as a result of perceptual and neural enhancements resulted by musical training (Chan et al., 1998; Ho et al., 2003; Pallesen et al., 2010; Parbery- Clark et al., 2009; Parbery-Clark, Strait, Anderson et al., 2011; Strait et al., 2010; Tervaniemi et al., 2009). Musicians have demonstrated enhanced audio-visual neural (Musacchia et al., 2007; Musacchia, Strait, & Kraus, 2008) and perceptual processing (Petrini et al., 2009).

There is an association between auditory attention/working memory and the perception of speech in presence of background noise (Heinrich et al., 2008; Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Strait, & Kraus, 2011; Strait & Kraus, 2011). Since long term music training enhances auditory attention and working memory, musicians will have better processing of speech in noise (Kraus & Chandrashekharan, 2010; Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Skoe, & Kraus, 2009; Parbery-Clark, Strait, Anderson et al., 2011). The perceptual enhancement of speech in noise in musicians continues into the later decades of life

(Strait & Kraus, 2011). This is particularly relevant for older adults, who experience difficulty hearing speech in noise due to aging (Parbery-Clark, Strait, & Kraus, 2011; Zendel & Alain, 2012). Ho et al. (2003) studied improvement in verbal memory in children after 1 year of music training. The results showed that there was improved verbal memory but not visual memory after music training in children. In contrast to the differences in verbal memory between the groups, their changes in visual memory were not significantly different.

Auditory Perceptual Learning

It has been well documented that auditory training result in perceptual enhancement (Amitay, Hawkey, & Moore, 2005; Johnston, John, Kreisman, Hall, & Crandell, 2009; Moore, Rosenberg, & Coleman, 2005; Mossbridge, Fitzgerald, O'Connor, & Wright, 2006; Wright, Buonomano, Mahncke, & Merzenich, 1997) as well as plasticity in single neurons (Diamond & Weinberger, 1984, 1986, 1989; Kraus & Disterhoft, 1982) and neuronal populations (Bakin & Weinberger, 1990; Edeline, Pham, & Weinberger, 1993; Gaab, Gaser, & Schlaug, 2006; Olds, Disterhoft, Segal, Kornblith, & Hirsh, 1972; Recanzone, Jenkins, Hradek, & Merzenich, 1992; Weinberger, 1993). In humans, cortical plasticity related to learning has been found after discrimination training using tones (Naatanen, Schroger, Karakas, Tervaniemi, & Paavilainen, 1993) and synthetic speech stimuli (Kraus et al., 1995; Tremblay, Kraus, McGee, Ponton, & Otis, 2001; Tremblay, Shahin, Picton, & Ross, 2009).

Song, Skoe, Wong, and Kraus (2008) studied changes in frequency following response (FFR) as native English speaking adults learn to incorporate foreign speech sounds (lexical pitch patterns) in word identification. The results showed that after training, there was increased pitch tracking accuracy, indicated by a decrease in the number of pitch tracking errors and a refinement in the energy devoted to encoding pitch.

Tremblay et al. (2001) reported that training induced changes are associated with improved VOT perception. In their study, 10 normal hearing young adults, were trained to identify VOT changes in /ba/-/pa/ continuum. After discrimination training, there were significant changes in both behavioural identification and waveform morphology and amplitude of N1-P2 complex. The authors concluded that training related changes in the neural activity in the central auditory system are reflected in the N1-P2 response.

While learning any new speech sounds, there will be marked difference between individuals. Some individuals might learn it faster whereas some individuals learn it slowly. There are anatomical differences between fast learners and slow learners (Karmarkar & Buonomano, 2003). Structural magnetic resonance imaging and diffusion tensor imaging studies show that, there was higher white matter density in left Heschl’s gyrus in fast learners compared to slow learners. Also, there was greater asymmetry between left and right (left > right) in parietal lobe compared to slow learners. Apart from this, right insula and Heschl’s gyrus are more superiorly located in slow learners compared to fast learners (Karmarkar & Buonomano, 2003). This difference indicates that, there are individual differences in learning aspects of language. The findings also show that, there is functional difference, anatomical difference and lateralization of language processing. Wong et al. (2004) studied the neural correlates of learning to use the pitch patterns in words by English speakers, who formally had no previous exposure to such usage. The blood oxygenation levels were measured using fMRI technique, while the participants discriminated pitch patterns of the words before and after training. Participants who mastered the learning program showed increased activation in the left posterior superior temporal region after training, while participants who plateaued at lower levels showed increased activation in the right superior temporal region and right inferior frontal gyrus, which are associated with non-linguistic pitch processing, and prefrontal and medial frontal areas, which are associated with increased working memory and attentional efforts. Golestani and Zatorre (2004) using fMRI investigated changes in the brain activity related to phonetic learning using Hindi dental retroflex non-native contrast in English speaking adults. The training resulted in an improvement in the identification of non-native contrast. fMRI results showed that learning of a non-native phonetic contrast resulted in the involvement of areas such as left superior temporal gyrus, insula frontal operculum, and inferior frontal gyrus. There was a correlation between the behavioural improvement and the blood oxygenation level dependent signal obtained during the post-training Hindi task. This suggests that the degree of success in learning is accompanied by efficient neural processing in classical frontal speech regions, and by a reduction of deactivation relative to a noise baseline condition in left parietotemporal speech regions.

de Boer and Thornton (2008) investigated the involvement of the medial olivocochlear bundle (MOCB) in perceptual learning as a result of auditory discrimination training. VOT discrimination training for 5 days was given for normal hearing adult listeners and MOCB activity was monitored. The results revealed an increase in MOCB activity which was correlated with an increase in contralateral inhibition amplitude of otoacoustic emissions and in speech perception in noise.

Barlow and Foldiak (1989) attributed the training related physiological changes to several different processes including, (1) a greater number of neurons responding in the sensory field i.e. neural arborization; (2) improved neural synchrony (or temporal coherence) and (3) neural decorrelative processes whereby training decorrelates activity between neurons, making each neuron as different as possible in its functional specificity relative to the other members of the population. These plastic changes observed could be either due to duration of the training paradigm (short-term/long-term) or because of the resilience of the brainstem structures to changes post training.

The auditory system of musicians is superior when compared to that of non-musicians. The musical training can fine-tune various regions of brain. This rewiring of brain regions can be reflected in various auditory tasks such as hearing in difficult situation, pitch encoding at the level of brainstem, pitch discrimination, auditory stream segregation, auditory attention and working memory. These enhanced effects are seen in musicians irrespective of age. The increased use of shared mechanism that processes music and language in musicians can be the reason for enhanced language processing. The instrument of practice can have an effect on brain i.e., evoked potentials elicited using the sound of musical instrument of practice will be more robust. The short-term auditory training also can result in enhancement of different auditory tasks. The short-term multi-modal and uni-modal music training can have different effect on brain with effects of multi-modal training being superior. So it is the same brain which acts differently in musicians.

Chapter-3

Method

Effect of short-term perceptual training of music on auditory system was assessed using behavioural and physiological experiments. Behavioural experiments included determining minimum number of notes required to identify a Raga, identification of Raga by listening to small excerpts of music and speech identification in noise. Physiological experiment included measuring the contralateral inhibition of otoacoustic emissions.

Participants

A total of 24 normal hearing adults (14 males, 10 females) in the age range of 18-25 years (mean age = 21.29 years, SD = 2.65 years) participated in the study. These participants were randomly assigned to two training regimes. One group (N = 12) received musical training only in auditory mode while the second group (N = 12) received training in audio-visual mode. Participants in both group had their air conduction and bone conduction hearing thresholds within 15 dB HL at octave frequency from 250 Hz to 8 kHz. 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. All the participants did not have any complaints of difficulty in understanding speech either in quiet or in the presence of background noise. All the participants were amateur or rare listeners of classical music.

I. Behavioral Experiment

Raga identification. This was assessed by determining (i) minimum number of notes required to identify a Raga and (ii) identification of Raga by listening to small excerpts of music.

Minimum number of notes required to identify Raga

Stimuli and procedure. Stimuli consisted of violin compositions from two Carnatic Ragas (Kalyani and Mayamalavagola). A Carnatic violinist with an experience of more than 15 years, who has passed ‘senior level’ examination and practices 2 to 3 hours daily played the two Ragas. Musical notes of two Ragas were played in octave scale. The notes consisted of sa ri ga ma pa dha ni sa played either in Kalyani or Mayamalavagola Raga. Eight stimuli were constructed using this composition for each Raga. The first stimuli had only one note, second stimuli had 2 notes, third stimuli had 3 notes while eighth stimuli had all 8 notes. Testing consisted of two phases- familiarization phase and identification phase. In the familiarization phase, participants were asked to listen to violin notes played in octave notes either in Kalyani Raga and were instructed that hereafter whenever they hear the notes in this particular fashion they had to identify the Raga as “Kalyani”. A similar exercise was done for Mayamalavagola Raga too. In identification phase, participants were asked to identify the Raga after listening to notes by pressing the appropriate key on the key board. The presentation of the stimuli and collection of the responses were controlled using DMDX (Foster & Foster, 2004) software. Stimuli were presented randomly using scrambling code of DMDX. During each stimulus trial, participants were presented with a note/sequence of notes of a Raga (either Kalyani or Mayamalavagola) along with words Kalyani and Mayamalvagola on the computer screen. Participants were asked to identify the stimulus by pressing the button 1 or 2 on key board of the computer, where 1 and 2 represented Kalyani and Mayamalavagola respectively. The participants were given a 3 seconds time after the stimuli to respond. Till then the letters remained on the computer screen. Particular note or sequence of notes was repeated 10 times in order to reduce the chance factor. This resulted in a total of 80 stimuli for each Raga. The minimum number of notes that were necessary to identify the Raga with 50% accuracy was found out through linear regression. Here after this test will be referred to as NOTE-50.

Identification of Raga by listening to small excerpts of music

Stimuli. Same violinist who participated in earlier experiment played stimuli in this experiment too. He was asked to play several sample songs in both Kalayani Raga and Mayamalavagola Raga each lasting for about 15 minutes. Pilot study done using NOTE-50 had revealed that minimum number of notes required to identify a Raga by professional musicians is around 5 notes. Therefore, 10 different, 5 notes excerpts were extracted from one of the songs in each Raga and were used as stimuli. Each stimulus was repeated 10 times which sums to a total of 100 stimuli in each Raga. This was done in order to reduce the chance factor.

Procedure. Stimuli were presented bilaterally through a high fidelity head phones (Sennheiser HD 449) at comfortable level. Testing consisted of two phases- familiarization phase and identification phase. In the familiarization phase participants were asked to listen to an audio sample of a song played on violin in Kalyani Raga for around 15 minutes. Participants were instructed that hereafter whenever they hear the excerpts from this Raga they had to identify the Raga as “Kalyani”. After that the participants were asked to listen to a song played on violin in Mayamalavagola Raga for 15 minutes and were asked to name the Raga as “Mayamalavagola”. After this initial familiarization phase, identification phase began. Presentation of stimuli and collection of the responses were controlled via the software DMDX (Foster & Foster, 2004). Stimuli were presented in a random manner using scrambling code of DMDX. During each stimulus trial, participants were presented with 5 notes excerpt from a Raga (either Kalyani or Mayamalavagola) along with words Kalyani and Mayamalvagola on the computer screen. Participants were asked to identify the stimulus by pressing the button 1 or 2 on key board of the computer, where 1 and 2 represented Kalyani and Mayamalavagola respectively. The participants were given a 3 seconds time after the stimuli to respond. Till then the letters remained on the computer screen. The accuracy in identification was measured. Here after this would be referred to as Music-test.

Speech identification in noise test. In the present study, speech intelligibility was measured using a signal-to-noise ratio required for 50% identification using the sentence list developed by Methi, Avinash, & Kumar, (2009). Seven lists were used. Each list contained seven sentences with five key words each. The signal to noise ratio decreased from +8 dB SNR to -10 dB SNR in 3 dB steps from sentence 1 to 7 in each list. Two lists were used to assess the speech perception in noise ability. In order to avoid familiarity with the test material, different lists were used for pre-training and post-training assessment. The participants were instructed that they will be presented with sentences in Kannada in the presence of multi-talker babble in the background at different SNRs and they were asked to write the target sentences in a sheet of paper. The number of correct key words identified was counted at each SNR. The SNR-50 was calculated using the Spearman-Karber equation (Finney, 1952) as

SNR-50= i + ½(d) – (d)(# correct)/(w)

Where,

i= the initial presentation level (dB S/B)

d= the attenuation step size (decrement)

w= the number of key words per decrement

correct= total number of correct key words

II. Physiological experiment

Test stimuli and instrumentation. For evaluation of medial olivo cochlear efferent activity, contralateral inhibition of transient otoacoustic emissions (TEOAEs) was measured under contralateral acoustic stimulation using broad band noise presented at 50 dB SL. TEOAEs were recorded for non-linear clicks by using Echoport ILO V6 OAE instrument. A probe with a foam tip was positioned in the external ear canal and was adjusted to give a flat stimulus spectrum across the frequency range. The response of 256 sweeps was averaged to obtain the TEOAEs, and amplitudes of TEOAEs were measured. This procedure was repeated in the presence of contralateral broad band noise of 50dB SL (ref: threshold of noise) presented through the insert receiver of the Orbiter 922 dual channel diagnostic audiometer.

Procedure. Participants were made to sit in a comfortable chair and OAE probe was placed in the ear canal with good seal, after which OAEs were recorded with the above mentioned parameters in two conditions:

(a) Without noise in the contralateral ear

(b) Without altering position of the probe, by presenting the broad noise to the contralateral ear through an insert receiver

The difference between OAE amplitudes with and without noise in the contralateral ear was considered as magnitude of inhibition.

III. Training

After behavioural and physiological tests, participants were randomly assigned to one of the two training regimes. One group i.e., audio only group (N = 12) received musical training only in auditory mode while the second group i.e., audio-visual group (N = 12) received training in audio-visual mode. During training everyday participants in the audio-visual group listened to 15 minute composition of both the Ragas with the help of personal computer through high fidelity headphones (Sennheiser HD 449). Second group of participants were asked to watch and listen to a video of violin song played in Kalyani Raga for 15 minutes and Mayamalavagola Raga for another 15 minutes. The participants were asked to listen to the song and concentrate on the finger movements of the musician carefully. After listening to these compositions, participants performed Music-test. In training sessions participants were given immediate feedback about their responses in the Music-test. Music compositions/songs used in training sessions were different from that of pre and post training test.

All the behavioural and physiological tests were re-administered at the end of 8th day of training session.

For audio-visual group both physiological and behavioural experiment were repeated at the beginning of the training program and then at the end of the training program. In audio only group two base line measurements were carried out. One at the beginning of the training sessions for audio-visual and the other at the beginning of training session for audio only. Training effects were assessed by repeating the behavioural and physiological experiments at the end of training sessions. Figure 3.1 shows the block diagram of the concise experimental protocol.

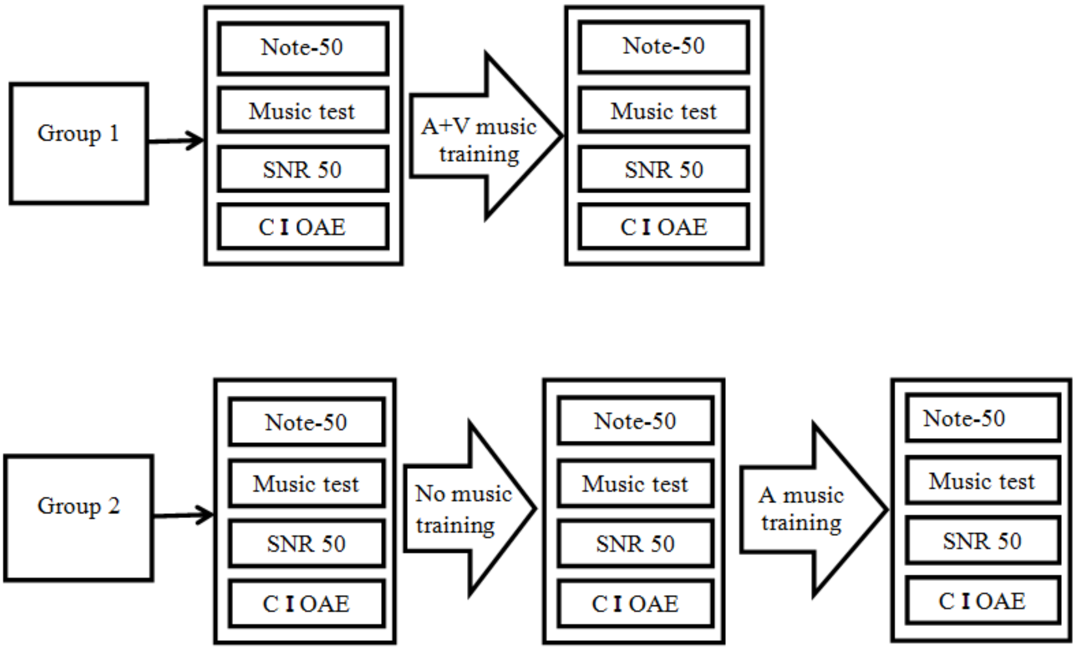

Figure 3.1. Block diagram of the concise experimental protocol

CI OAE- Contralateral inhibition of TEOAE

A+V music training: Music exposure through auditory and visual mode

A music training: Music exposure only through auditory mode.

Chapter-4

Results

The results of the present study will be discussed under the following headings:

A. Behavioural experiments

B. Physiological experiments

C. Relationship between behavioural and physiological experiments

In all the experiments there was no statistically significant difference between baseline 1 and baseline 2 obtained in audio only training group. This indicated that all the behavioural tests constructed had good test re-test reliability. Therefore, average of two baseline scores was used for all statistical analysis.

A. Behavioral Experiment

Raga Identification. This was assessed by determining (i) minimum number of notes required to identify a Raga and (ii) identification of Raga by listening to small excerpts of music.

Minimum number of notes required to identify Raga. Figure 4.1 and Figure 4.2 shows identification of Ragas with different number of notes in audio and audio-visual groups for individual participants in pre-training condition. Y-axis represents performance and X-axis represents the number of notes. As can be seen from the Figure 4.1 and Figure 4.2, the identification of Ragas even with the maximum number of notes was below chance level for all the participants in the pre-training condition. Figure 4.3 and Figure 4.4 shows identification of Ragas with different number of notes in audio and audio-visual groups for individual participants in post training condition

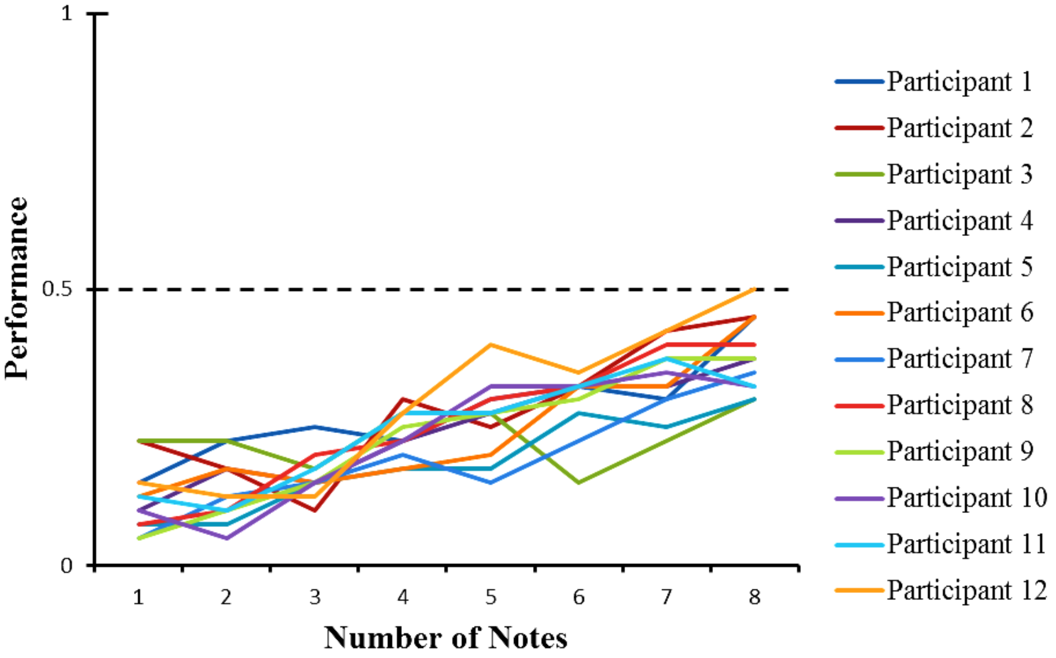

Figure 4.1. Identification of Ragas with different number of notes in audio group for individual participants in pre-training condition. Dotted line indicates chance performance

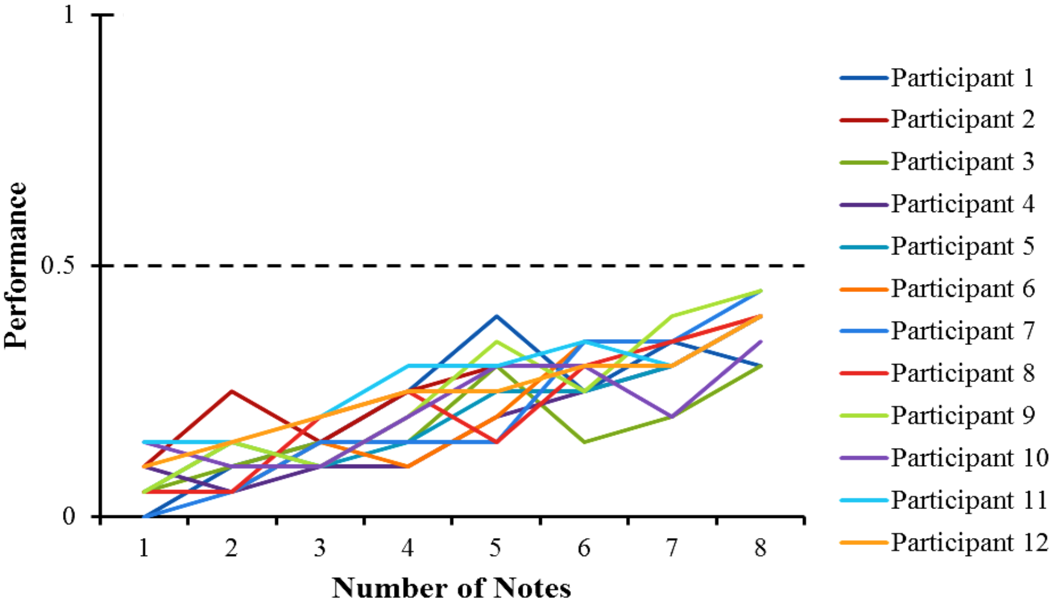

Figure 4.2. Identification of Ragas with different number of notes in audio-visual group for individual participants in pre-training condition

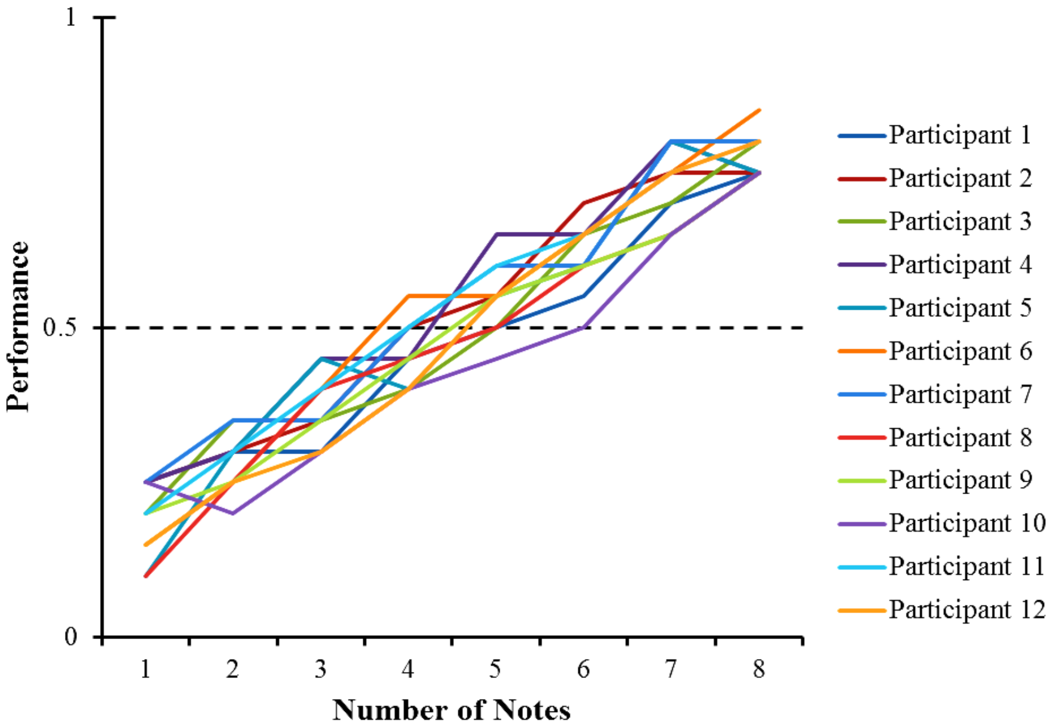

Figure 4.3. Identification of Ragas with different number of notes in audio group for individual participants in post training condition

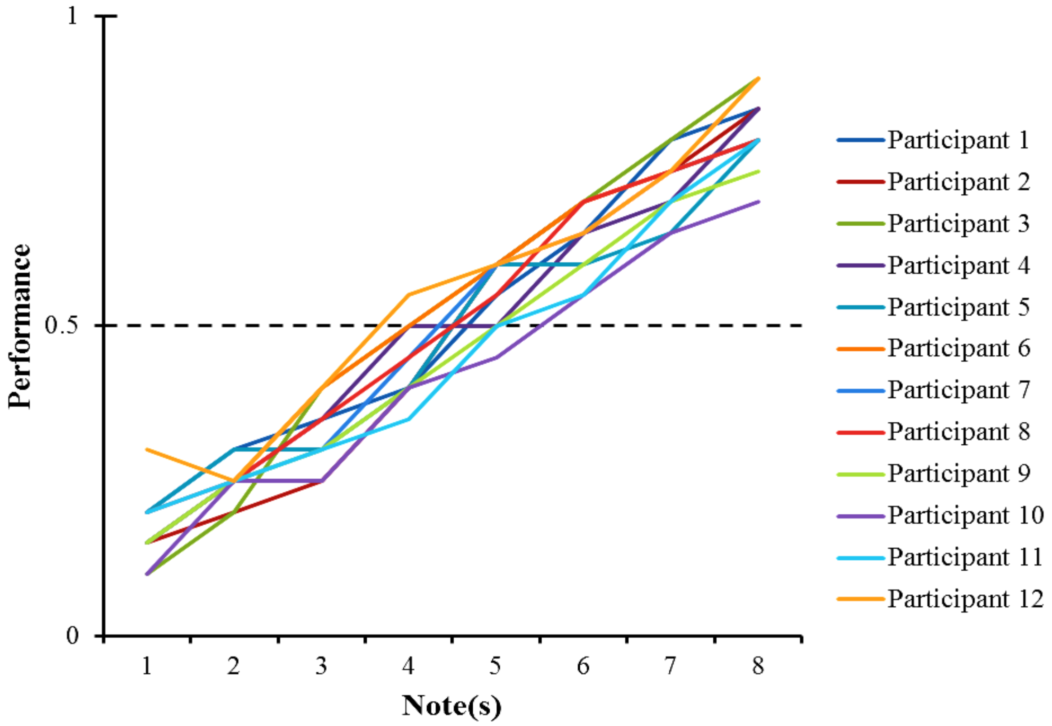

Figure 4.4. Identification of Ragas with different number of notes in audio-visual group for individual participants in post training condition

It can be inferred from the Figure 4.3 and Figure 4.4 that identification scores improved following training. Highest identification scores were obtained for the stimuli that had all 8 notes. Through linear regression curves minimum number of notes required to identify the Raga with 50% accuracy was determined. Figure 4.5 and Figure 4.6 shows minimum number of notes required to identify the Raga with 50% accuracy in audio and audio-visual groups respectively. The mean minimum number of notes required to identify the Ragas with 50% accuracy were 4.58 and 4.69 respectively for audio only and audio-visual groups.

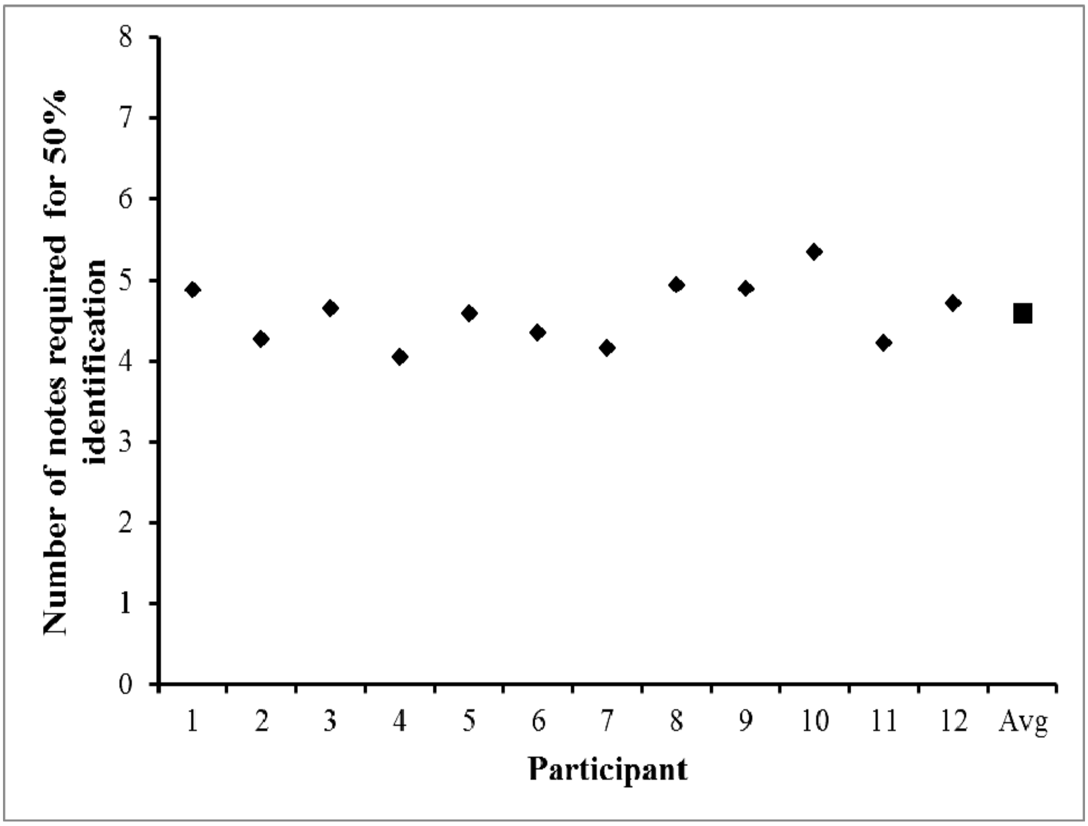

Figure 4.5. Minimum number of notes required to identify the Raga with 50% accuracy in audio group

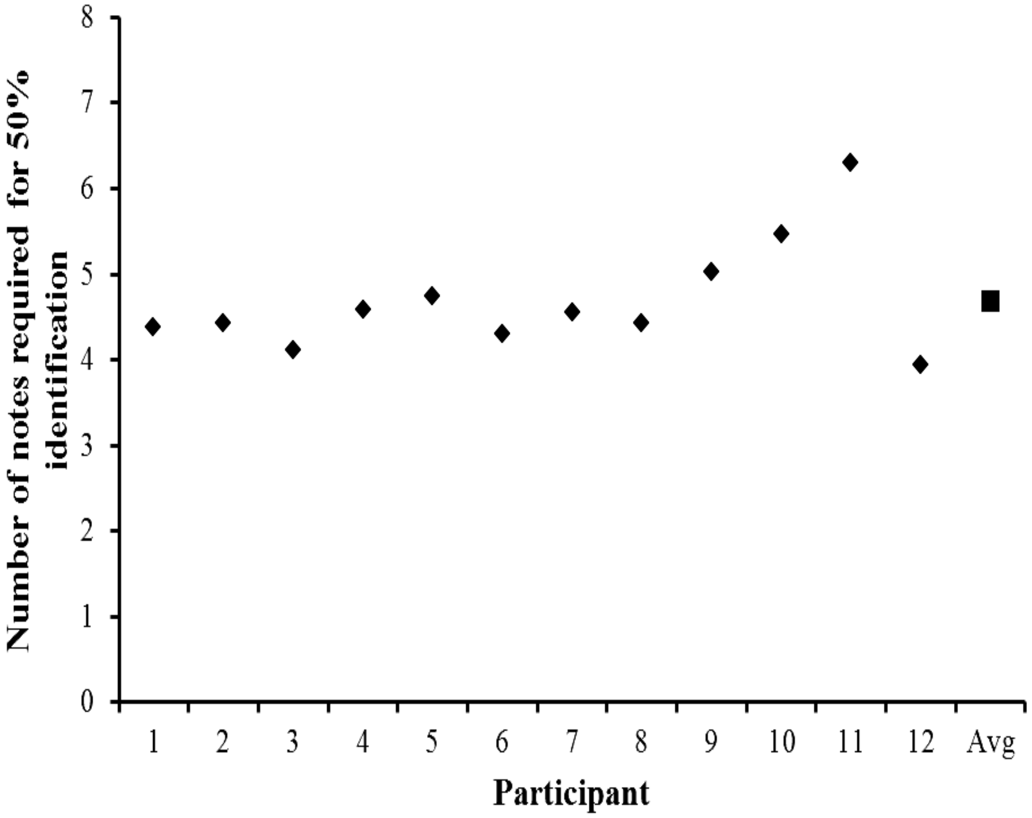

Figure 4.6. Minimum number of notes required to identify the Raga with 50% accuracy in audio-visual group

A Mann-Whitney U-test was done to find out the significance of difference in the minimum number of notes required to identify the Raga with 50% accuracy between audio only and audio-visual group. Results revealed that there was no significant difference (Z = 0.115, $p > 0.05$) in the post-training scores between the two groups.

Identification of Raga by listening to small excerpts of music. Mean Raga identification scores in pre-training and post-training conditions for audio only and audio-visual groups are shown in Figure 4.7 along with one standard deviation of error. As can be seen from the Figure 4.7 Raga identification scores improved following training. Wilcoxon Signed Rank test was performed to see the significance of difference in identification scores of Raga in pre- and post-training conditions.

Results showed that training had significantly improved the identification of Ragas in both audio only (Z = 3.061, $p < 0.05$) and audio-visual group (Z = 3.072, $p < 0.05$). Mann-Whitney U-test revealed that there was a statistically significant difference in the magnitude of improvement (post training-pre training) between two groups (Z = 3.184, $p < 0.05$). Figure 4.8 shows the magnitude of improvement (post training-pre training score) between audio only and audio-visual group with one standard deviation of error.

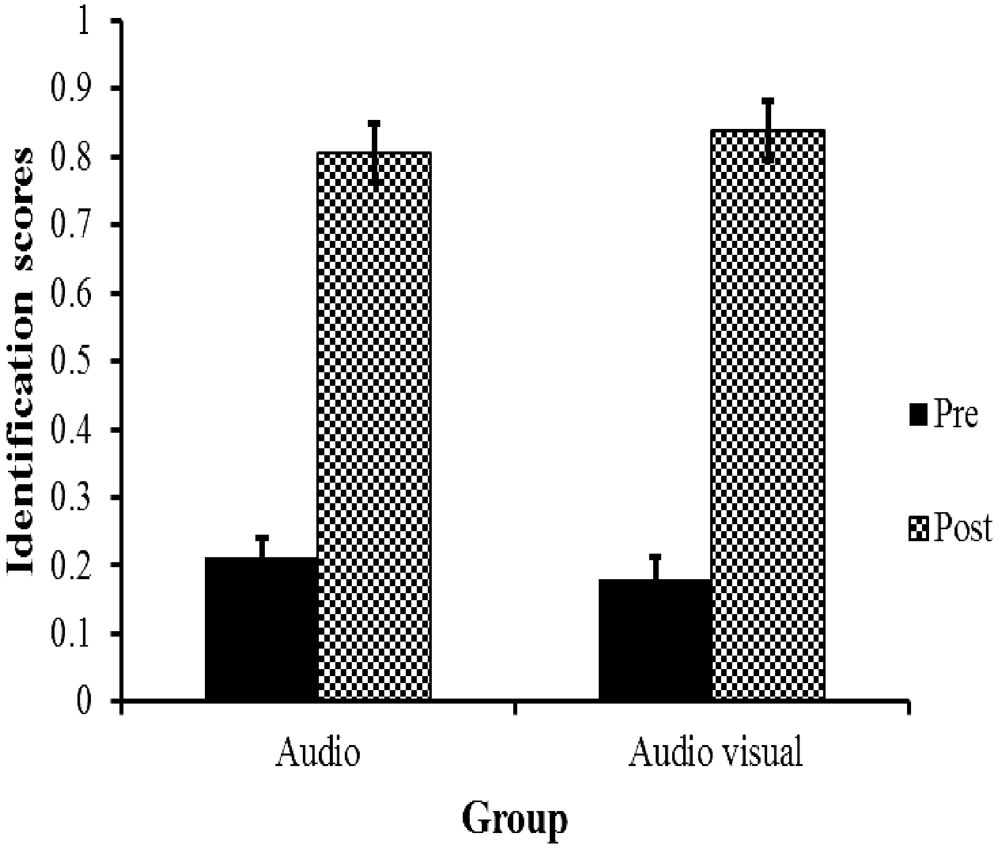

Figure 4.7. Mean Raga identification scores in pre-training and post-training conditions for audio only and audio-visual groups along with one standard deviation of error

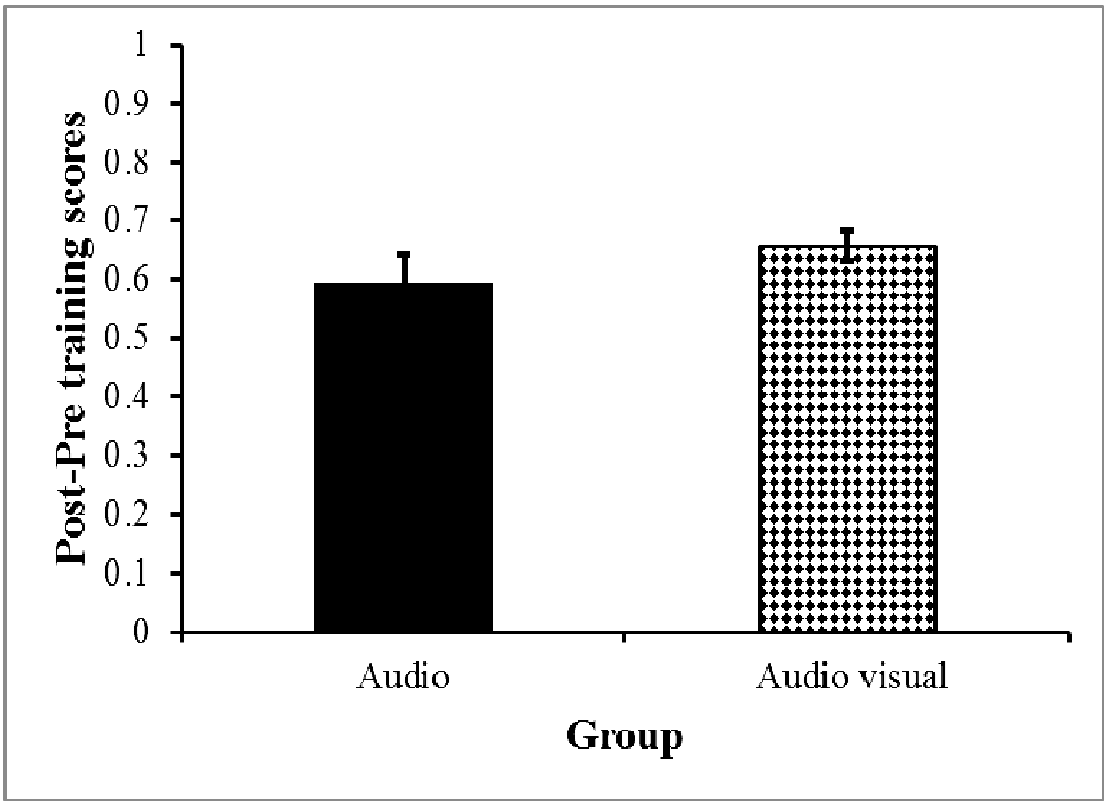

Figure 4.8. Magnitude of improvement (post training-pre training score) between audio only and audio-visual group along one standard deviation of error

Course of learning. As a part of training, music test was administered every day and feedback was provided about the participants responses after every trial. Scores obtained in this test every day was used to track the course of learning. Figure 4.9 and Figure 4.10 shows the scores obtained on music test for all the participants on every training session. From Figure 4.9 and Figure 4.10 it is clear that the identification scores for all participants in both audio only and audio-visual training group improved from training day 1 to training day 8. There were not much variations in the learning curves of different participants. Linear slope of these learning curves was calculated and is depicted in Figure 4.11 for audio and audio-visual groups. Slopes indicate pace or speed of learning process. Mann-Whitney U-test revealed no statistically significant difference in the slopes between two training groups (Z = 0.116, $p > 0.05$).

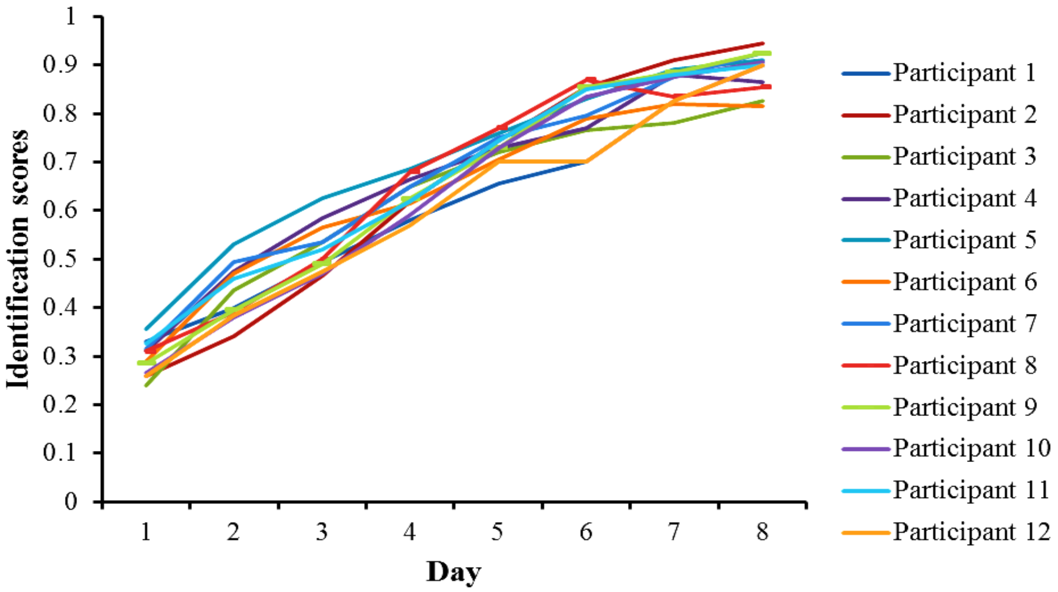

Figure 4.9. Scores obtained on music test for all the participants on every training session for audio only group

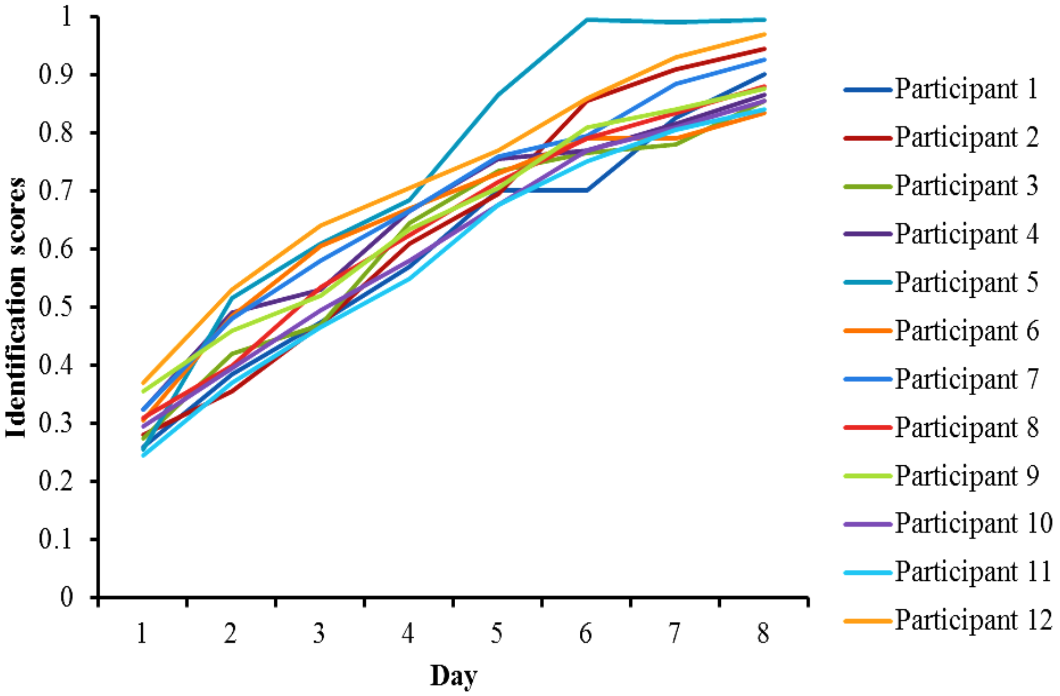

Figure 4.10. Scores obtained on music test for all the participants on every training session for audio-visual group

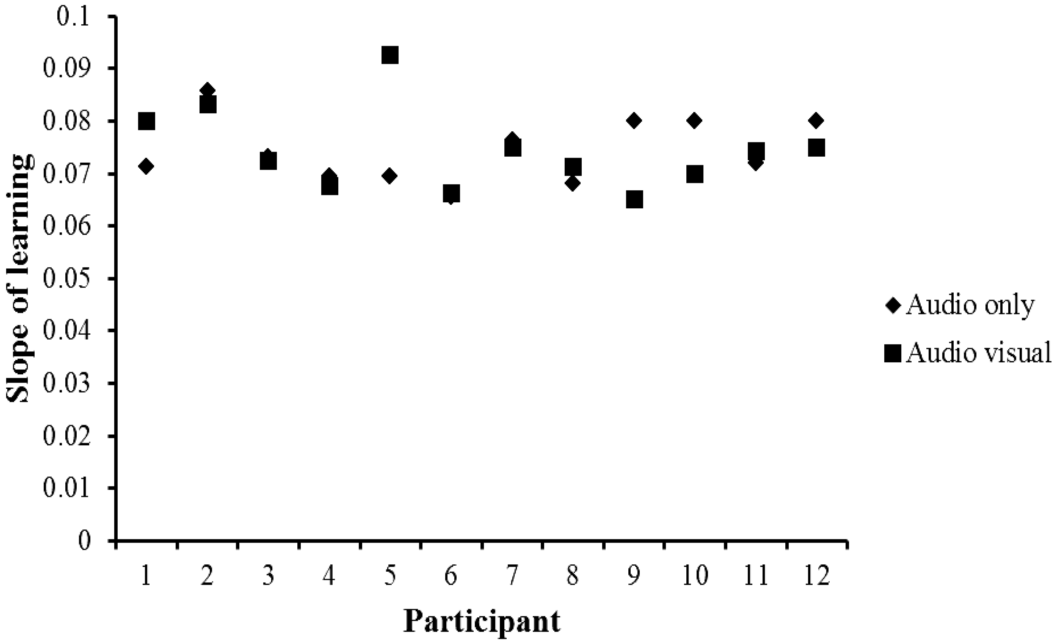

Figure 4.11. Linear slope of Slope of learning curves for both audio and audio-visual group

Effect of musical training on speech perception in noise. Figure 4.12 and Figure 4.13 shows mean word identification scores at different signal to noise ratios (SNR) in audio only and audio-visual group. From the Figures 4.12 and Figure 4.13 it can be inferred that short-term musical training improved word identification scores especially at middle SNRs (-1 dB SNR, -4 dB SNR and -7 dB SNR). SNR required for obtaining 50% correct identification scores were calculated using following formula:

$$\text{SNR-50} = i + \tfrac{1}{2}(d) - (d)(\#\ \text{correct})/(w)$$

Where,

i= the initial presentation level (dB S/B)

d= the attenuation step size (decrement)

w= the number of key words per decrement

correct= total number of correct key words

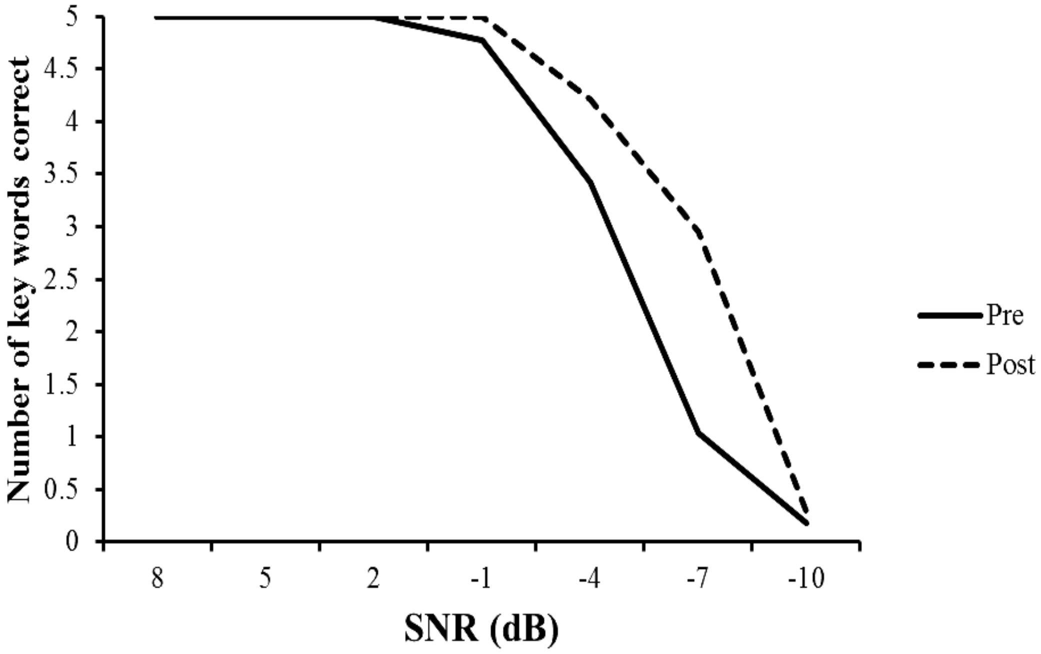

Figure 4.12. Mean word identification scores at different signal to noise ratios (SNR) in audio only group (Maximum score = 5)

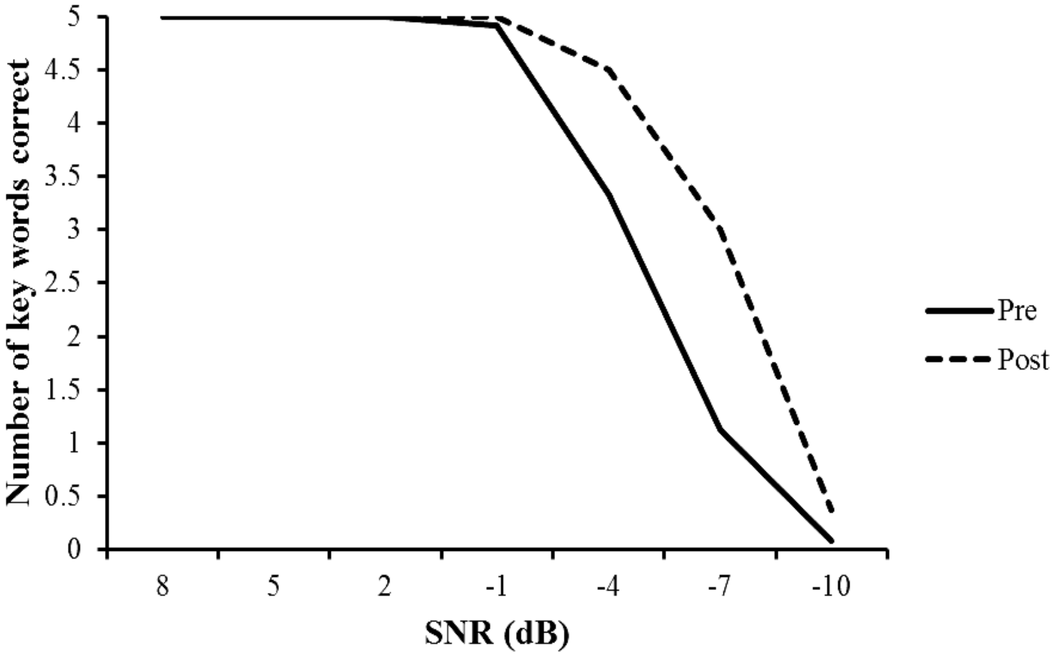

Figure 4.13. Mean word identification scores at different signal to noise ratios (SNR) in audio-visual group (Maximum score = 5)

Figure 4.14 shows mean and standard deviation of SNR-50 in pre-training and post-training conditions for both the groups. In order to find the effect of training on speech perception in noise a Wilcoxon Signed Rank test was performed between the pre-training and post-training SNR-50. Results showed that musical training had improved SNR-50 values in both the audio only (Z = 3.059, $p < 0.05$) and audio-visual (Z = 3.07, $p < 0.05$) training group. However, Mann-Whitney U-test revealed no statistically significant difference in the amount of improvement in SNR-50 (Pre training SNR-50 – Post training SNR-50) owing to training between two groups (Z = 0.609, $p > 0.05$)

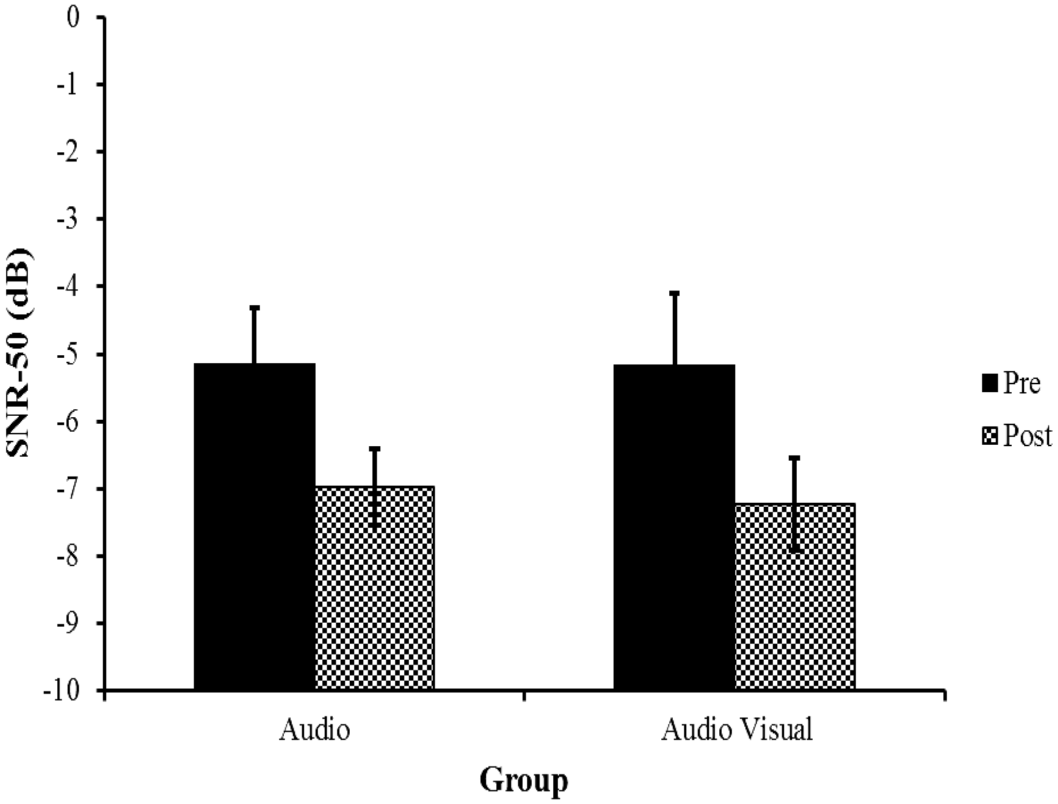

Figure 4.14. Mean and standard deviation of SNR-50 in pre-training and post training conditions for both the groups

B. Physiological Experiment

Amplitude of transient evoked otoacoustic emission (TEOAE). Figure 4.15 and Figure 4.16 shows TEOAE amplitudes in left and right ear before and after training for audio only and audio-visual group. Two way repeated measures ANOVA did not reveal a significant main effect of training on amplitudes of TEOAE [F(1,22) = 0.503, $p > 0.05$]. Also, there was no significant interaction between the TEOAE amplitudes and mode of training (audio and audio-visual training group) [F(1,22)= 4.182, $p > 0.05$].

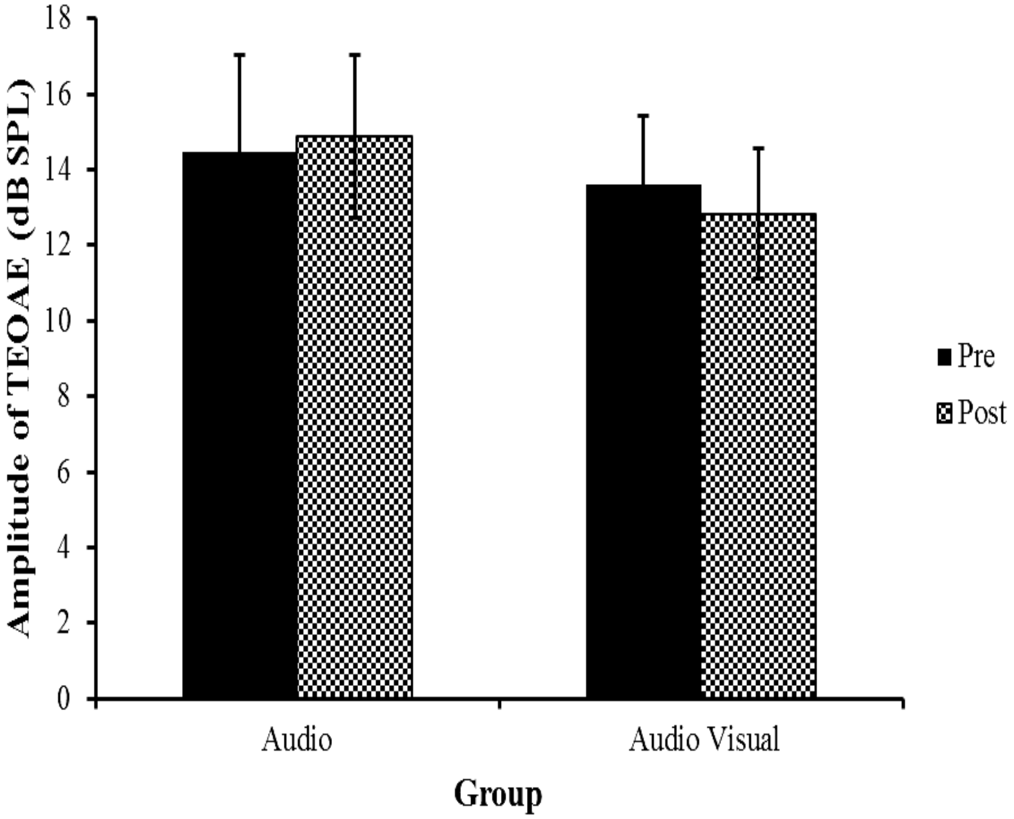

Figure 4.15. TEOAE amplitudes in left ear before and after training for audio only and audio-visual group

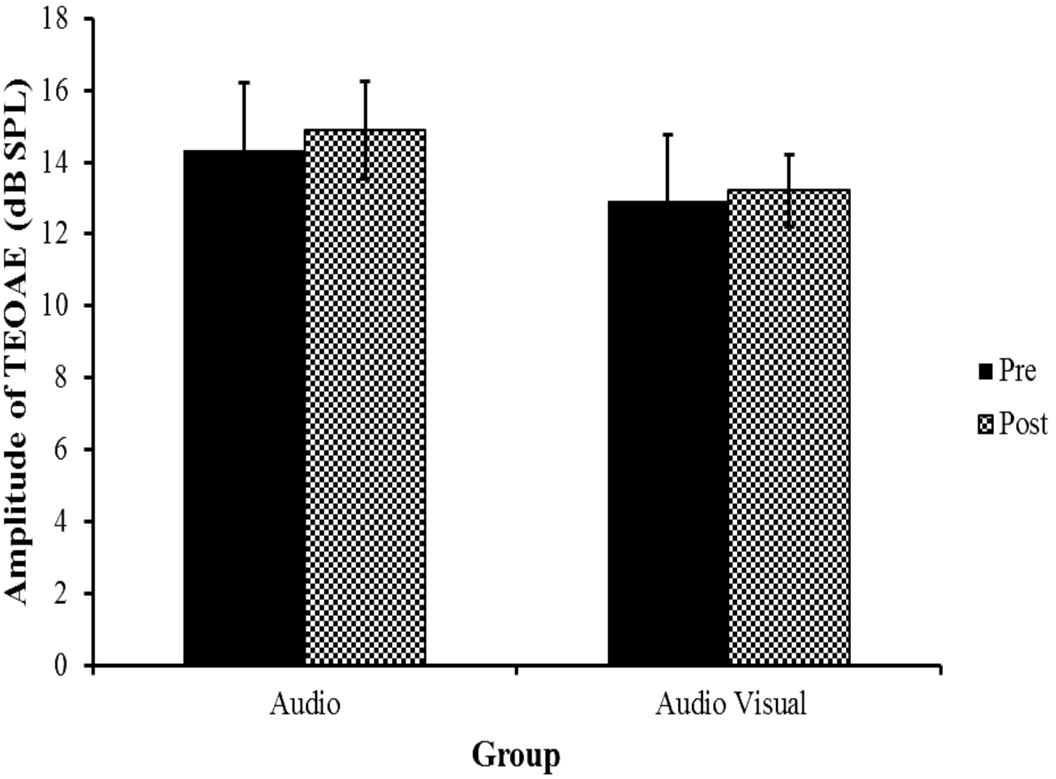

Figure 4.16. TEOAE amplitudes in right ear before and after training for audio only and audio-visual group

Contralateral inhibition of transient evoked otoacoustic emission (TEOAE). Contralateral inhibition of TEOAE was measured for both left and right ear before and after training for audio only and audio-visual group. Figure 4.17 and 4.18 represents the pre and post-training contralateral inhibition of TEOAE amplitude for both audio and audio-visual group for left ear and right ear respectively. From the Figure 4.17 and 4.18 it can be inferred that mean inhibition amplitudes were enhanced following training. Two way repeated measures ANOVA revealed that there is a significant main effect of training [F(1,22) = 277.14, $p < 0.05$] on the contralateral inhibition of TEOAE amplitude. Contralateral inhibition magnitudes were significantly enhanced following training. However there was no significant main effect of ear [F(1,22) = 0.566, $p > 0.05$] on the contralateral inhibition of TEOAE amplitude. There was no significant interaction between ear and group [F(1,22) =

0.119, *p* > 0.05], effect of training and ear [F(1,22) = 0.104, *p* > 0.04], effect of training and group[F(1,22) = 1.847, *p* > 0.05]. 3-way interaction between ear, effect of training and group [F (1,22) = 0.288, *p* > 0.05] were also not significant.

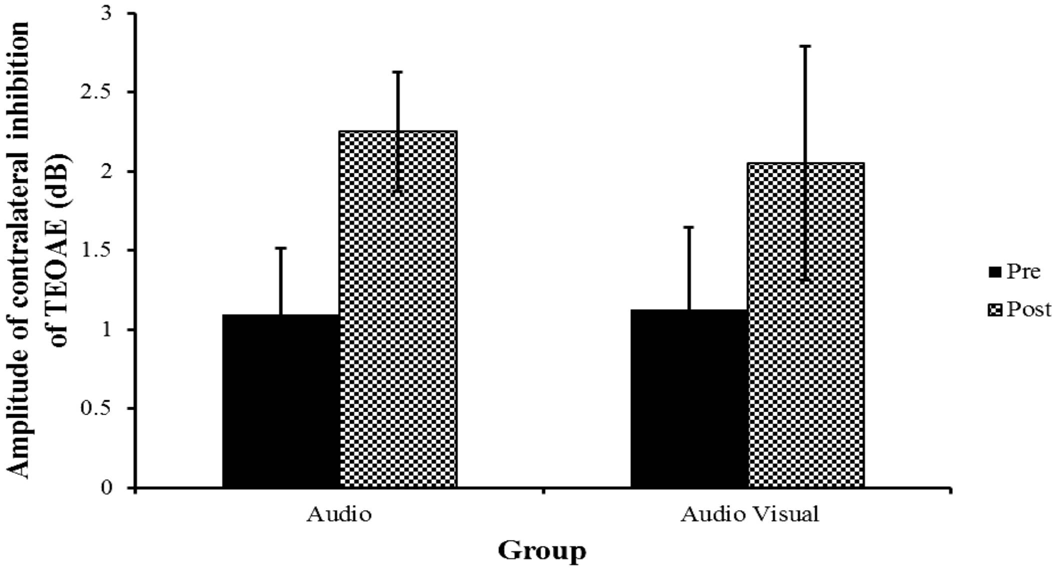

Figure 4.17. The pre and post-training contralateral inhibition of TEOAE amplitude for both audio and audio-visual group for left ear

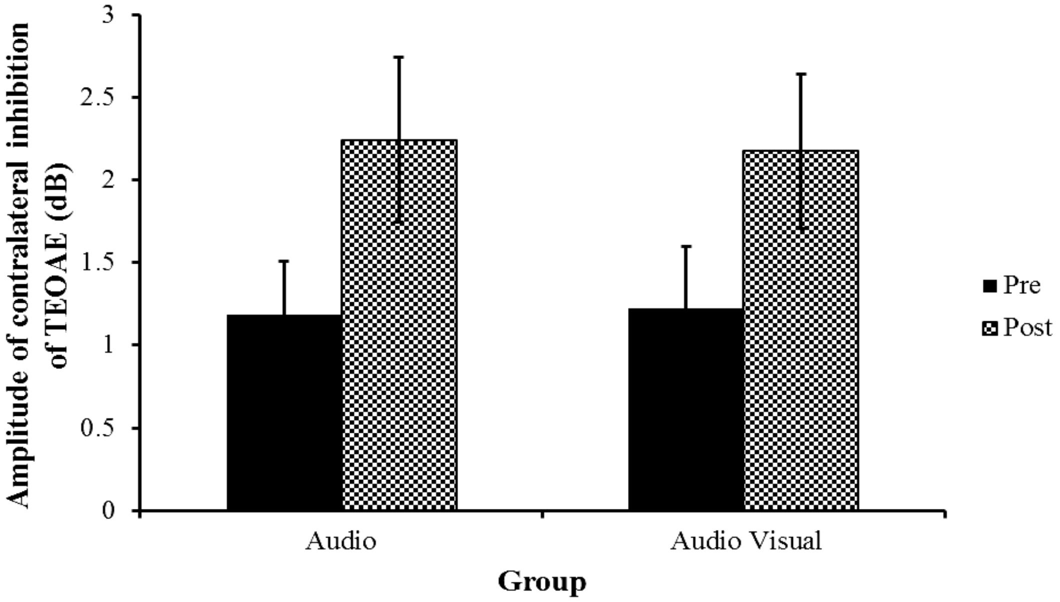

Figure 4.18. The pre and post-training contralateral inhibition of TEOAE amplitude for both audio and audio-visual group for right ear

C. The Relationship between the Behavioural and the Physiological Test Results

To find out the relationship between behavioural measures and physiological measures, Karl Pearson’s Product Moment correlation analysis were carried out between following variables

a. Slope of learning and changes in the contralateral inhibition of TEOAE amplitude following training
b. Minimum number of notes required to identify the Raga with the accuracy of 50% and changes in the contralateral inhibition of TEOAE amplitude following training
c. Raga identification scores on music test and the contralateral inhibition of TEOAE amplitude following training

The results revealed that there was no significant correlation between physiological measures and any of the behavioural measures. Table 1 shows correlation coefficients and significance values.

Table 4.1.

Correlation coefficients and significance values between physiological and behavioural measures.

	Audio only				Audio-visual			
	Correlation coefficient		Significance		Correlation coefficient		Significance	
	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear	Right ear	Left ear
a	0.372	0.158	0.233	0.624	0.203	0.397	0.526	0.201
b	-0.036	0.193	0.911	0.548	0.158	-0.155	0.623	0.63
c	0.193	0.108	0.548	0.738	-0.462	0.184	0.131	0.568

Chapter- 5

Discussion

Perceptual learning can be defined as practice induced improvement in the ability to perform specific perceptual tasks. Ragas in Carnatic music have specific note sequences and only trained musician can identify the Ragas. Results of the present study showed that even non-musicians can learn to identify Ragas with short-term perceptual training. This perceptual learning was not restricted to compositions that were used in the training sessions but generalized to new songs also as evidenced by improvement in the scores on Music test. The short-term auditory training can result in auditory system plasticity due to which there can be enhancement in the behavioural as well as physiological responses. Improvement due to auditory perceptual learning is reported by many other investigators too (Bosnyak, Eaton, & Roberts, 2004; Kraus, 2011; Kraus et al., 1995; Lappe et al, 2008; Lappe, Trainor, Herholz, & Pantev, 2011; Tremblay et al., 2001; Tremblay & Kraus, 2002).

Furthermore, results also indicated that short term perceptual training of music resulted in improved speech perception in noise and increased activity of medial olivocochlear reflex. Previous studies have shown that long-term musical training can result in enhanced performance in perceptual identification of music and listening in background noise (Kraus & Chandrashekharan, 2010; Parbery-Clark, Skoe, Lam et al., 2009; Parbery-Clark, Skoe, & Kraus, 2011; Strait & Kraus, 2011; Strait et al., 2012; Zendel & Alain, 2012). Parbery-Clark, Skoe, Lam et al. (2009) reported that musical training enhances speech in noise performance. They investigated speech perception in noise using Hearing In Noise Test (HINT) and QuickSIN in 16 musicians and 15 non-musicians. Working memory and frequency discrimination was also measured. The results revealed that musicians outperformed non-musicians on all the tasks. The authors conclude that long-term musical experience can enhance speech in noise performance and working memory and frequency discrimination. There was also a positive correlation between the speech perception in noise and working memory performance which suggest that there lies a shared mechanism for processing of the two. Parbery-Clark, Skoe, and Kraus (2009) studied the behavioural speech perception in noise and correlated that with the subcortical neural response to speech in presence of background noise. They investigated speech perception in noise using HINT and QuickSIN in 16 musicians and 15 non-musicians and correlated that with the subcortical neural response obtained for /da/ stimulus. The results showed that the degradation in the neural response due to the presence of noise was reduced in musicians when compared to non-musicians.

It is also been suggested that long term musical training improves auditory attention (Kraus & Chandrasekaran, 2010; Strait & Kraus, 2011; Strait et al., 2010), and working memory (Gaab & Schlaug, 2003a; Pallesen et al., 2010; Parbery-Clark, Skoe, Lam et al., 2009; Parbery-Clark, Strait, Anderson et al., 2011; Strait et al., 2012). Strait and Kraus (2011) studied speech perception in noise and auditory attention in 11 musicians and 12 non-musicians. The speech in noise performance was measured using HINT and the auditory attention was assessed using Multicentre Battery of Auditory Processing’s Auditory Attention subtest. The result revealed that the speech perception in noise and auditory attention was superior in musicians when compared to non-musicians. There was a positive correlation between the perception of speech in noise and auditory attention. Strait et al. (2010) studies the effect of long-term musical training on auditory attention tasks. Participants were 18 musicians and 15 non-musicians. The auditory attention was assessed using Multicenter Battery for

Auditory Processing. The results indicated an enhanced auditory attention performance in musicians when compared to non-musicians.

The results of the previous studies revealed that there lies an interconnection between the areas of brain that are responsible for auditory attention and working memory and speech in noise. The musical training requires more careful manipulation of the musical instrument and memorizing musical sequence of chords during musical practice which results in an enhanced auditory attention and working memory in musicians. Auditory attention and working memory plays an important role in the extraction of speech from difficult to listen situation such as in the presence of background noise. The musical training enhances auditory attention which in turn may result in improved perception of speech in noise.

Results of the present study showed that short term music training enhanced the medial olivocochlear reflex. Previous studies have shown that fine tuning the lower level centres to the appropriate auditory information is one of the major functions of the efferent auditory pathway (Bajo et al., 2010; Suga, 2008). It is demonstrated that individuals having stronger efferent control over auditory processing will have greater improvement for brief duration auditory task (de Boer & Thornton, 2008). Musicians have demonstrated enhanced top down control over auditory processing (Kraus & Chandrasekaran, 2010; Strait et al., 2010). Music training may shape functions of the peripheral auditory structures such as cochlea. It has been demonstrated that efferent neural pathway in musicians control outer hair cell activity to a greater extend when compared to non-musicians (Brashears., et al., 2003; Perrot et al., 1999). Results of the present study extends these findings and shows that even short-term musical training can enhance the activity of efferent auditory pathway.

Chapter 6

Summary and Conclusion

The aim of the present study was to find out the effect of short-term bi-sensory (auditory and visual) and uni-sensory (auditory only) musical exposure on speech perception in noise and contralateral inhibition of otoacoustic emissions.

For the purpose of the study 24 participants (14 males and 10 females), between ages 18 to 25 years, who did not have any formal training in music, were taken. Stimuli were two Carnatic Ragas selected from a violin instrument, which would sound similar to amateur listener. Participant’s ability to identify this Raga was assessed by determining (i) minimum number of notes required to identify a Raga and (ii) identification of Raga by listening to small excerpts of music. Signal to noise ratio required to identify 50% of the speech (SNR-50) and contralateral inhibition magnitudes of transient evoked otoacoustic emissions were also measured. Following this, the participants were randomly divided into two training regimes - audio only and audio-visual group. Audio only group was presented with audio stimuli of the music composition and the audio-visual group was presented with audio and video sample of the music composition. Listeners were trained for 8 days. Following training, minimum number of notes required to identify a Raga, identification of Raga by listening to small excerpts of music, SNR 50 and contralateral inhibition magnitudes of transient evoked otoacoustic emissions were measured again.

Results showed that, there was improvement in identification of two Carnatic Ragas following training. This indicates that, perceptual training improves identification of Ragas. Furthermore, short-term musical training improved SNR-50 and magnitude of contralateral inhibition magnitudes of transient evoked otoacoustic emissions. This suggests that, perceptual training of music not only improves perception of music but also speech in noise and fine-tunes efferent auditory pathway which plays an important role in speech understanding in noise. Improvement observed in speech identification was not significantly different for two training regimes.

From the present study it can be concluded that short-term musical training has significant beneficial effects on speech perception in noise. Neurophysiologically it increases the strength of corticofugal tuning mechanism. However, generalization and long-term maintenance of these benefits are yet to be evaluated.

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