Release of Masking (Masking Level Difference), Quick-SIN and Contralateral Suppression of DPOAEs In Musicians and Non-Musicians

Swathi C S

13AUD027

This Dissertation is submitted as part fullfillment for the Degree of Master of Science in Audiology University of Mysore, Mysore

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CERTIFICATE

This is to certify that this dissertation entitled "**Release of Masking (Masking Level Difference), Quick-SIN and Contralateral Suppression of DPOAEs in Musicians and Non-Musicians**" is the bonafide work submitted in part fulfillment for the Degree of Master of Science (Audiology) of the student with Registration No: **13AUD027**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Dr. S. R. Savithri

Director

All India Institute of Speech and Hearing,
Manasagangothri, Mysore- 570 006.

Mysore,
May, 2015.

CERTIFICATE

This is to certify that this dissertation entitled "**Release of masking (Masking Level Difference), Quick-SIN and Contralateral Suppression of DPOAEs in Musicians and Non-Musicians**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Ms. N. Devi

Guide
Lecturer in Audiology,
Department of Audiology,
All India Institute of Speech and Hearing,
Manasagangothri, Mysore- 570 006.

Mysore,
May, 2015.

DECLARATION

This is to certify that this Master's dissertation entitled "**Release of Masking (Masking Level Difference), Quick-SIN and Contralateral Suppression of DPOAEs in Musicians and Non-Musicians**" is the result of my own study under the guidance of Ms. N. Devi, Lecturer 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.

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ABSTRACT

The behavioral and physiological tests involving the combination of contralateral suppression of otoacoustic emissions (OAEs), Quick Speech in noise (Quick-SIN) and masking level difference (MLD) tests provides an overall picture about the physiology of afferent and efferent pathway and about masking and release of masking. To investigate these differences in physiology between musicians and non-musicians, the study aimed at evaluating the effect of musical training on Quick SIN, contralateral suppression of OAE and MLD. 15 musicians and 15 non-musicians underwent Quick SIN test in Kannada, distortion product OAE (DPOAE) recording with and without noise, and MLD testing using pure tones. The results revealed significantly better performance in musicians on contralateral suppression of OAEs and Quick SIN test compared to non-musicians. Significant difference in suppression amplitude across the frequencies tested were observed for both musicians and non-musicians. However MLD did not reveal a significant difference between the two groups and across the MLD frequencies tested. For both the groups, significant level of correlation was present between few of the parameters tested. Hence it can be concluded that musical training strengthens the afferent and efferent pathway and thus aids in speech perception abilities in the presence of noise. Hence, musical training can be one of the choice of intervention for individuals with speech perception in noise difficulties. One should consider the musical experience of the individual for an appropriate test interpretation and diagnosis.

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Chapter 1

Introduction

Auditory system consists of ascending and descending pathway. One of the important functions of olivocochlear efferent pathway is processing of speech in noise (Giraud et al., 1997) and it provides an antimasking effect (Kawase, Delgutte, & Liberman, 1993). Olivocochlear bundle originates from superior olivary complex and innervates organ of Corti. The thick medial olivocochlear (MOC) fibers which are myelinated project majorly into contralateral outer hair cells, whereas thin lateral olivocochlear (LOC) fibers which are unmyelinated project majorly into ipsilateral inner hair cells (Guinan, 2006). Understanding speech in a difficult situation, like in the presence of background noise requires an intact auditory efferent system. This task is carried out as MOC fast effects by MOC efferents. In noisy background, without MOC activation, partial masking of the tone burst response in the noise takes place. When there is MOC stimulation, the dynamic range of fibers for tone burst response comes to normal levels along with the inhibition for noise response. This resulted in better perception of the signal in noisy condition and are called MOC unmasking (Guinan, 2006). This can be considered as one of the main effects of the MOC efferent system. Besides the function of speech perception in noise, efferent system has several other functions such as protection of cochlea from overstimulation, improving frequency selectivity, mediating selective attention, adaptation to the sound.

The MOC fast effects can be quantified using otoacoustic emissions (OAEs). Outer hair cells (OHCs) are cochlear amplifiers, responsible for the production of otoacoustic emissions, which is the energy send backwards to the middle ear, produced by the distortion and the reflection mechanism (Shera, 2004). OAEs are sounds generated within the ear, and was first described by Kemp (1978). Distortion product otoacoustic emissions (DPOAE) are produced by presenting two primary tones (f1, f2) which interact nonlinearly. They are usually generated in the region of maximum overlap between two primaries, which is near the characteristic frequency of f2 (Shera, 2004). DPOAEs can be measured at much higher frequency also, compared to transient evoked otoacoustic emissions (TEOAE).

MOC efferent functioning can be studied by measuring DPOAE in the presence and absence of noise. Thus, it has been reported that one way of increasing the MOC efferent neurons discharge and MOC activation was by the presentation of contralateral noise (Liberman, 1988). There are studies conducted to see the effect of medial olivocochlear bundle (MOCB) activation and found that changes in OAEs initiated with contralateral stimulation of noise at 10 dB SL (Collet et al., 1990). In the presence of a contralateral masker, there was a reduction in OAE amplitude reported (Puel & Rebillard, 1990). OHCs are innervated by MOC efferents, which in turn decreases the gain of the cochlear amplifier, resulting in amplitude reduction of OAEs. This provides a way to monitor the MOC effects (Guinan, 2006). Contralateral noise results in suppression of different types of OAE such as TEOAEs, DPOAEs. Suppression magnitudes of OAEs were reported to have inter subject variability, ranging from 0.5-2 dB for DPOAEs

(Moulin, Collet, & Duclaux, 1993). Type of masker, selective attention, test ear, aging are few among the other factors which may influence the contralateral suppression of OAE.

Besides the objective tests like contralateral suppression of OAEs, another way to study the olivocochlear system functioning is by the use of different behavioral tests, which are used clinically to measure the performance of signal in the presence of the background noise. These include Speech in Noise test (SPIN), Hearing in Noise Test (HINT), Quick Speech in Noise test (Quick-SIN), Bamford Kowal Bench Speech in Noise test (BKB-SIN) and so on. Speech perception abilities in the presence of noise can be quantified in terms of signal to noise ratio (SNR), which is required to obtain a particular speech performance level in the presence of noise. Better speech perception can be exhibited as lesser SNR required to achieve particular speech identification scores depending on the criteria used. SNR-50 is the SNR required to obtain 50% of speech performance in the presence of noise. The comparison across HINT, Quick-SIN, BKB-SIN and Words in Noise (WIN) tests (Wilson, McArdle, & Smith, 2007) revealed that WIN and Quick-SIN materials were more sensitive indicators of speech perception ability in the presence of noise. Studies suggested that there was no statistically significant difference across the Quick SIN performance in normal hearing young adults and normative values unlike the HINT test (Duncan & Aarts, 2006).

Quick-SIN is a speech perception test using sentences in the presence of multi talker babble. This provides information about one’s ability to perceive speech in noise.

Administration time for this test is 1 minute. It measures the SNR required to obtain 50% word recognition scores in sentences with multi talker babble for a given individual.

Kumar and Vanaja (2004) studied the correlation between physiological and psychoacoustic measures of olivocochlear efferent system functioning using contralateral suppression of OAE and the speech identification scores in the presence of noise respectively. They found a positive correlation between the contralateral suppression of OAE and speech identification scores in the presence of noise with + 10 dB and +15 dB SNRs.

Another measure of studying the release of masking is Masking Level Difference (MLD). It is a binaural interaction task which requires the ability to attend to the target signal in the presence of background noise. MLD implies a psycho acoustical phenomenon with threshold differences occurring between signals in homophasic (S_0N_0) and antiphasic ($S_\pi N_0$) condition (Hirsh, 1948; Licklider, 1948). There are different factors which determine the ability to detect signal in the presence of noise, one of which includes interaural phase difference between two; that is, the different phase conditions of signal and noise. Thus, it is the release from masking effect or binaural unmasking effect. Initial threshold estimation can be either in diotic or monotic condition. The next set of threshold estimation can be in any of the dichotic conditions. Masking level difference was first described for pure tones by Hirsh (1948) and for speech by Licklider (1948).

Wong and Stapells (2004) suggested that binaural MLD processing occur either through different pathway or beyond the auditory processing at brainstem level underlying the 80 Hz auditory steadystate response (ASSR). A study done by Ferguson, Cook, Hall, Grose and Pillsbury (1998) suggested that MLD indicates brainstem level processing. There are different factors reported to affect MLD such as frequency of target, phase relationship between target and masker with larger MLDs in antiphasic condition (Hirsh, 1948), type of masking noise, type of target stimuli and duration of masker. As the noise level increased, there was an increase in MLD noted, that is, 10 dB increments in SoNo threshold with 10 dB increments in masker level, whereas there is less than 10 dB increments in SπNo threshold (McFadden, 1967). MLD is highest at low frequencies. This can be attributed to the activity of phase sensitive low frequency neurons, which are located in medial superior olive (MSO) and medial preolivary nucleus (MPO) (Goldberg & Brown, 1969). It was reported that as the frequency increases, MLD decreases (Hirsh, 1948). SoNo and SπNo thresholds increased with the increase in masker bandwidth up to a particular point (Wightman, 1971). Tonal MLD, when compared to speech MLD had greater sensitivity (79%) and specificity (88%) in separating normal hearing children and children suspected with auditory processing disorder (Sweetow & Reddell, 1978). Zwicker and Zwicker (1984) studied the effect of the masker and test tone duration on binaural masking level difference, and found that BMLD varies with the masker duration, but not with test tone duration.

Thus, using a combination of three tests, that is, contralateral suppression of OAEs, Quick-SIN and MLDs, provide information about masking and overall release of masking in an individual and provide an overall picture about the functioning of afferent pathway and efferent pathway. With MLDs, brainstem level processing could be assessed. With speech perception in noise tests and contralateral suppression of OAEs, the efferent pathway could be assessed.

Music is a fine art which requires ordering of the sounds in different sequences across the time, when heard evokes a pleasant and harmonious feeling in listeners. It is another form of expressing our ideas and emotions in addition to speech. Basic elements of music include pitch, form, timbre, dynamics and rhythm. Musical training has been reported to result in different anatomical and functional changes which includes faster synchronization of the nerves, changes in the efferent system (Perrot, Micheyl, Khalfa, & Collet, 1999), cortical system (Lappe, Herholz, Trainor, & Pantev, 2008) and enhanced brainstem encoding (Bidelman, Krishnan, & Gandour, 2011). This was reflected in the form of improvement in different domains, including fine motor skills as evidenced by timing accuracy (Kincaid, Duncan, & Scott, 2002), linguistic skills as evidenced by changes in neuro physiological mechanism underlying syntax processing (Jentschke & Koelsch, 2009) and enhanced auditory perceptual skills as evidenced by improvement in temporal resolution (Rammsayer & Altenmuller, 2006), pitch discrimination ability (Micheyl, Delhommeau, Perrot, & Oxenham, 2006), speech perception abilities in background noise (Parbery-Clark, Skoe, Lam, & Kraus, 2009b), duration discrimination ability in auditory modality (Guclu, Sevinc, & Canbeyli, 2011) and selective auditory attention (Strait & Kraus, 2011). Earlier studies suggested that musicians have better contralateral suppression of OAEs when compared to non-musicians (Micheyl, Khalfa, Perrot, & Collet, 1997). Since MLD is a binaural interaction task which requires accurate auditory processing, performance by musicians for MLD task is expected to be better.

1.1. Need for the study

Structural and functional changes in the auditory system with musical training, resulting in improved auditory skills in musicians have been reported. Masking paradigm uses different combination of tests. There is a dearth of the literature which focus on the response of musicians to the masking paradigm compared to the non-musicians. Hence, the present study will throw more light on the effect of musical training on masking and overall release of masking. Also, the correlations across Quick SIN, MLD and contralateral suppression of OAEs between the two groups were not extensively studied. As the study takes up a combination of different tests which assesses the afferent and efferent functioning, it will give more insight on the relative strength of these pathways between musicians and non-musicians.

1.2. Aim of the study

To evaluate the effect of musical training on speech perception abilities in the presence of background noise, contralateral suppression of OAE and masking level difference.

1.3. Objectives

- To compare the speech perception abilities in the presence of background noise in musicians and non-musicians.
- To compare the contralateral suppression of OAE in musicians and non-musicians.

- To compare the scores of masking level difference in musicians and non-musicians.
- To compare the overall release of masking and masking effects in both the groups.

Chapter 2

Literature Review

Musical training has an influence on auditory system in terms of structural and functional domains, which in turn results in superior perceptual abilities in musicians. Several imaging studies have been carried out to point out structural differences between musicians and non-musicians.

2.1. Comparison between musicians and non-musicians by imaging techniques

Schlaug, Jancke, Huang, Staiger and Steinmetz (1995) carried out magnetic resonance morphometry in 30 musicians and age and gender matched 30 non-musicians. They found anterior half of the corpus callosum in musicians to be significantly larger, who started musical training at a very young age compared to untrained controls. Lee, Chen and Schlaug (2003) studied the interaction between musicianship and gender on the size of corpus callosum. 56 musicians and 56 age matched non-musicians underwent magnetic resonance imaging to obtain T1 weighted images. It was found that the anterior corpus callosum in male musicians were larger compared to non-musicians. However, such effects were absent in female musicians.

Gaser and Schlaug (2003) investigated upon the anatomical brain differences using magnetic resonance imaging across three groups of participants: 20 professional musicians, 20 amateur musicians and 40 non-musicians. The results revealed gray matter volume in different brain areas like premotor areas, primary motor areas, somatosensory areas, anterior superior parietal areas and inferior temporal gyrus in both the sides were greatest in professionally trained musicians, intermediate volume in amateur musicians and less in non-musicians. Hyde et al. (2009) studied musical training related structural brain changes in two groups of children: 15 children who were given musical training for 15 months, and 16 age and gender matched children who were not given any musical training. The participants underwent magnetic resonance imaging twice, one before and 15 months after the musical training. They found that with the instrumental musical training of just 15 months in the early childhood resulted in structural changes in the motor areas and the auditory areas in the brain.

Most of the imaging studies have reported larger structural and functional differences between musicians and non-musicians. However, there are few electrophysiological studies in the literature which studied about the differences present in musicians and non-musicians.

2.2. Comparison between musicians and non-musicians by electrophysiological/ physiological evidences

2.2.1. Comparison between musicians and non-musicians using auditory evoked potentials

Lee, Skoe, Kraus and Ashley (2009) investigated upon the auditory brainstem responses to the musical intervals across 10 musicians, 11 musicians and 5 amateur musicians. The responses were recorded binaurally for two musical intervals: consonant interval (major sixth), dissonant interval (minor seventh). Musicians exhibited enhancement in harmonic components of upper tone and more precise representation of periodicity of temporal envelope on comparison with non-musicians, and the advantages in musicians seen were correlated with duration of music training.

Rabelo, Neves-Lobo, Rocha-Muniz, Ubiali and Schochat (2014) compared P300 measures between 30 musicians and 25 non-musicians. P300 was recorded using tone burst stimuli of 1000 Hz as frequent, and 1500 Hz as infrequent with and without the white noise. In the absence of noise, higher amplitudes and shorter latencies were observed in musicians in comparison with non-musicians. Higher amplitudes in musicians compared to non-musicians were reported in the presence of noise. Prolonged latencies in P300 were noted with the addition of noise in musician group, unlike the non-musician group.

2.2.2. Comparison between musicians and non-musicians using OAE amplitude

Perrot et al. (1999) measured evoked OAE with clicks in 16 musicians and 16 age and gender matched non-musicians. Higher amplitude of evoked OAE in musicians in comparison with non-musicians in both ears were reported. Micheyl et al. (1997) also measured evoked OAE with clicks in 16 musicians and 16 age and gender matched non-musicians. However, they reported no statistically significant difference in EOAE amplitude growth function slope between the two groups. Brashears, Berlin and Hood (2003) measured TEOAE in 29 musicians and 28 age and gender matched non-musicians and they also found no significant difference in TEOAE level between musicians and non-musicians.

2.3. Need for contralateral suppression of OAE

Suppression of OAEs is mediated by the medial efferent system. Hence contralateral suppression of OAEs serves as a non-invasive, objective test, which assess the functioning of the auditory efferent system. Evidences suggested that musical training strengthens the efferent system and results in stronger activity of the MOC system (Micheyl, Carbonnel, & Collet, 1995; Micheyl et al., 1997; Perrot et al., 1999; Ameen & Maruthy, 2011). Hence contralateral suppression of OAEs provide more light on the physiological differences in efferent system between musicians and non-musicians.

2.4. Contralateral suppression of OAEs

Liberman (1988) studied the discharge properties of the efferent neurons in the anesthetized cats. It was found that in the presence of contralateral masker, there was an increase in discharge rates (140 spikes/s) and lowering of the thresholds for tones, which in turn implies an increment in signal to noise ratio.

Puel and Rebillard (1990) measured the changes in DPOAE in 20 guinea pigs with contralateral white noise presented at different intensity levels. The contralateral suppression of OAE was recorded before and after midsagittal sectioning of the brainstem. The results showed the suppression of DPOAE in the ipsilateral ear present earlier, did not occur after the sectioning of the brainstem. This suggested that the medial efferent system is responsible for these suppressive effects. The middle ear muscles such as tensor tympani and stapedial muscles of the animals in the study were transectioned to rule out the possibility of acoustic reflex influencing the results.

Collet et al. (1990) studied the effect of contralateral noise on cochlear micromechanics and thereby on the OAEs. TEOAEs were recorded in 21 normal hearing participants with and without the contralateral broad band noise at different levels (5-50 dB SPL in 5 dB steps). It was found that the suppressive effects on OAE were present, and this effect was seen to be starting at 10 dB SL of masker. Moulin et al. (1993) studied for the first time the changes in DPOAE with contralateral acoustic stimulation in humans. 36 healthy subjects underwent DPOAE recordings in the presence of contralateral broad band noise (BBN), which ranged from 0 dB SPL to 70 dB SPL. It was found that there was a reduction seen in the DPOAE amplitude across the distortion frequencies ranging from 0.5 KHz to 5 KHz with broadband noise above 55 dB SPL.

Literature reported increased suppression of OAE with contralateral noise presentation in musicians compared to non-musicians. (Brashears et al., 2003; Ameen & Maruthy, 2011). Micheyl et al. (1995) studied loudness adaptation and efferent system in musicians and non-musicians using the tone decay test and TEOAE respectively. It was shown that there was less adaptation and increased OAE suppression with contralateral acoustic stimulation in musicians compared to non-musicians, indicating strengthened feedback of the medial efferent system in musicians. However, this suppression difference between musicians and non-musicians were statistically significant only at certain stimulus levels presented ipsilaterally. In this study, there were unequal number of participants in two groups and were not age and gender matched.

Micheyl et al. (1997) carried out a study to confirm the previous findings reported in a study (Micheyl et al., 1995) about the difference in efferent system functioning between musicians and non-musicians. Contralateral suppression of evoked OAEs were recorded in right ear with minimum of five stimulus intensities on 16 musicians who had played instrumental music for at least 10 years and on 16 non-musicians. Evoked OAEs were recorded using clicks with and without 30 dB SL contralateral broadband noise. It was found that with contralateral noise stimulation, musicians exhibited an overall enhanced amplitude reduction over different ipsilateral stimulus intensities than non-musicians for evoked OAEs, which indicated enhanced MOCB activity in this group compared to the control group. The study included equal number of age and gender matched participants in both the group, thereby ruling out the age and gender based factors influencing the results of the study. The authors suggested that the enhanced activity at the level of higher centers was exhibited as enhanced MOC activity in musicians. However, this study did not address the issue of asymmetry between two ears for evoked OAE suppression between the two groups, as only right ear was considered for the study.

Perrot et al. (1999) also carried out similar studies wherein contralateral suppression of evoked OAEs were investigated on 16 musicians and 16 non-musicians, who were age and gender matched. EOAEs were measured with and without contralateral broadband noise in both the ears. Their results were in agreement with previous studies, that is, bilaterally greater contralateral suppression of evoked OAE in musicians, which suggest greater efferent influences in musicians in both the ears. The study also assessed the asymmetry between two ears for evoked OAE suppression between musicians and non-musicians, which was previously reported in the literature. It was found that there was greater EOAE suppression for right ear in both the groups. The results obtained helped to overcome the notion that these suppression effects in musicians were specific to one side as only right ear was tested in few of the previous studies. (Micheyl et al., 1995; Micheyl et al., 1997)

Ameen and Maruthy (2011) compared the contralateral suppression of OAE in 20 non-music listeners, 20 music listeners, and 20 vocal musicians. TEOAEs were recorded with and without contralateral BBN at 50 dB SL. The suppression was more in musicians compared to the other two groups. However, no statistically significant difference was seen between the music listeners and the control group, except at high frequencies. The influence of musical training in terms of greater EOAE attenuation was not only seen with contralateral suppressor, but also with binaural suppressor.

Brashears et al. (2003) studied the binaural suppression of TEOAE in 2 groups: 29 musicians and 28 age and gender matched non-musicians using binaural bursts of noise. The study also compared pure tone thresholds, OAE levels, and MEMR thresholds between the two groups. Pure tone audiometry, tympanometry and reflexometry for 500 Hz, 1 kHz, 2 kHz, 4 kHz and BBN were carried out ipsilaterally and contralaterally in both the groups. TEOAEs were recorded in the presence and absence of binaural BBN bursts at 70 dBpeSPL. The results showed increased suppression in musicians compared to control group for both ears with a right ear advantage. The authors explained this in terms of strengthening of the central auditory pathway due to musical training which in turn affects the reflex arc. Also, it was reported that within the musician group alone, participants with younger age and women exhibited a greater suppression. The authors attributed this to the higher degree of variability within the non-musician group. Increased acoustic reflex thresholds for musicians was also found as a result of sound conditioning. However, no significant difference in pure tone thresholds or OAE level were found between the two groups. Also, there was no correlation found between OAE suppression and acoustic reflex threshold.

The evidences for better performance by musicians relative to non-musicians are just not limited to the imaging and electrophysiological tests, differences are being reported even for the behavioral tests.

2.5. Comparison of speech in noise between musicians and non-musicians

Individuals with musical experience demonstrate advantages in terms of better understanding of speech in difficult listening conditions. Janet and Yathiraj (2003) studied the effect of musical training on frequency discrimination, word sequencing and speech in noise performance tasks. The experimental group consisted of 15 children (6-12 years) with training in instrumental and vocal music and control group included 15 age and gender matched children without any training. Speech in noise was assessed in right ear for both the groups using speech material from Kannada Speech identification test with speech noise presented ipsilaterally at 0 dB SNR. The children with musical training showed better performance than those without musical training in speech in noise tasks which could be attributed to the training to attend to melodies, in the presence of constant rhythm in the background.

Oxenham, Fligor, Mason and Kidd (2003) studied the effect of musical training on informational masking in 12 musicians and 12 non-musicians. The masked threshold for 1 kHz tone burst was found with notched noise masking and multitoned masking procedures, that is, in the presence of notched noise masker and multitone maskers. The results showed reduced susceptibility for musicians to informational masking compared to non-musicians. This implies greater analytic abilities in the former group.

Parbery-Clark, Skoe and Kraus (2009a) studied the subcortical representation of the speech in presence of noise in two groups of participants: one group trained in instrumental music with 16 participants and other group who are non-musicians with 15 participants. Speech evoked ABR recordings for /da/ stimuli were done binaurally in two conditions: in quiet and in noise (multitalker babble) at +10 dB SNR. Results were correlated with speech perception tests like Quick-SIN and HINT. Musical training limits the degrading effects of background signal as evidenced by improved performance in HINT test and robust speech ABR with earlier onset timing of response, better phase locking to temporal waveform in musicians compared to non-musicians. This helps the musicians take advantage of better speech understandability in the presence of background noise. However, this study did not rule out the variables like group genetic differences which could have influenced the results.

Parbery-Clark et al. (2009b) compared the performance between 16 musicians trained in instrumental music and 15 non-musicians on speech perception ability in noise. Quick SIN and HINT tests were administered in both the groups. In addition to these tests, tests for assessing working memory and frequency discrimination tests were also done. It was found that musicians showed better performance than non-musicians on Quick SIN and HINT. Duration of musical experience had positive correlation with Quick SIN, frequency discrimination and working memory, but not with the HINT scores. Better performance in Quick SIN can be attributed in part to the enhanced frequency discrimination and working memory seen in trained musicians. HINT performance was moderately linked with the working memory, but not with the frequency discrimination, and this was found to be better in musicians compared to non-musicians. Hence, they suggested that musical training helps in better understanding of speech in the presence of competing signals.

Thomas and Rajalakshmi (2011) studied the effect of musical training in trained Carnatic musicians on temporal resolution abilities and speech perception in noise at different SNRs. The subjects were divided into four groups, five participants in each group depending on their years of musical training. SPIN test was done using phonetically balanced wordlist in the presence of speech noise at three different SNRs (-5 dB, 0 dB, -10 dB) to assess the speech perception ability in noise. Tests like TMTF, GDT were also administered to assess the temporal resolution abilities. Speech perception ability in noise was better for musicians in comparison to non-musicians. However, in the study, as the musical training experience increased, the SPIN scores improved. But the results were not statistically significant at all three SNRs across the groups with different duration of training experience. This was not in agreement with the studies by Parbery-Clark et al. (2009b). This difference in result was explained based on the difference in the type of masker and in subject selection criteria taken in the earlier studies. However a reduction in speech identification scores at lower SNR was consistently seen in all the groups taken for the study.

A study by Vinod and Rajalakshmi (2012) aimed at finding whether the Carnatic musicians who are trained, exhibited enhanced speech perception in the presence of background noise and subcortical encoding of speech stimuli. Two group of participants, including 15 musicians and 15 non-musicians underwent speech evoked ABR testing with /da/ stimuli in quiet and in the presence of white noise ipsilaterally at 0 dB SNR. Musicians exhibited shorter latencies, and greater amplitudes with better wave morphology even in the presence of noise compared to non-musicians, indicating that noise affects musicians minimally compared to non-musicians. The results were in agreement with a number of studies in literature. However, this study did not rule out the variables like group genetic differences which could have influenced the results.

Rajalakshmi (2011) studied speech perception abilities in the presence of background noise in children by dividing them into different groups depending on their musical background and musical training. Experimental group consisted of children with musical background which included 10 musicians and 10 non-musicians. The control group consisted of children without musical background which included 10 musicians and 10 non-musicians. Quick SIN in Kannada was administered in all the groups to study the speech perception in noise ability. It was found that musical training resulted in enhanced speech perception abilities in children irrespective of their musical background. This study adds on information to the existing knowledge on speech perception abilities of children who are from a family with a musical background. This study explored the possibilities of genetic factors involved in achieving musical skill.

2.6. Comparison of masking level difference between musicians and non-musicians

Binaural Masking Level Difference (BMLD) has been extensively studied in different clinical population such as meniere’s disease, conductive hearing loss sensorineural hearing loss, noise induced hearing loss, cortical lesion, presbycusis, multiple sclerosis, eight nerve tumour, severe dysfunction of brainstem and so on. Also, studies were done in elderly individuals with normal hearing and children as well.

Hall and Grose (1990) investigated on the developmental changes in MLD by including two group of participants: 26 children from 3.9- 9.5 years and 10 adults as control group. MLDs were measured using 500 Hz pure tone with the masking noise of 300 Hz and 40 Hz wide, both centered at 500 Hz. It was found that with a 300 Hz wide band masker, MLDs increased up to the age of 5-6 years and with a 40 Hz wide band masker, MLDs did not reach up to the adult values even at 5-6 years of age. Such differences between two groups observed were attributed to the peripheral/ brainstem auditory system development.

Grose, Poth and Peters (1994) compared MLD for pure tones and speech in 9 normal hearing elderly individuals and 10 young normal hearing individuals. MLD was measured for 500 Hz pure tone with NBN centered at 500 Hz and for spondee words with speech noise. It was found that the performance was poorer in elderly individuals than in younger individuals for both tones and speech stimuli, this in turn would have contributed to difficulties in perceiving speech in the presence of noise in elderly.

Earlier researchers suggested that musicians have better auditory processing abilities than non-musicians. However, the performance with MLD, which assesses the binaural processing has not been extensively investigated in musicians.

Chapter 3

Method

The present study was aimed to see the effect of musical training on speech perception abilities in the presence of background noise, contralateral suppression of OAE and masking level difference. In order to accomplish these aims, the following method was adopted.

3.1. Participants

A total number of 30 healthy individuals with normal auditory system were included in the study. They were classified into two groups with each group consisting of 15 participants, based on their musical training experience.

Group 1: Individuals aged between 18-35 years (Mean= 20.67, SD= 1.63) who had undergone at least 5 years of formal Indian Classical music training.

Group 2: Individuals aged between 18-35 years (Mean= 20.67, SD= 2.58), who had not undergone any formal training for music.

3.2. Participants Selection criteria

- All participants with normal air conduction thresholds (≤15 dB HL) at all the octave frequencies from 250 Hz to 8000 Hz and normal bone conduction thresholds (≤15 dB HL) at all octave frequencies from 250 Hz to 4000 Hz.
- Normal middle ear function (A type tympanogram for 226 Hz probe and normal reflexes for both the ears)
- Speech recognition threshold within ±12 dB with respect to pure tone average

- Speech identification scores not less than 80%
- No neurological problems as reported
- No difficulty in understanding speech in the presence of noise
- No illness as reported on the day of testing
- No other otological problems such as tinnitus, ear pain or ear discharge.
- Absence of any long term noise exposure or ototoxic drug usage.

3.3. Test Environment

All tests were carried out in an acoustically treated room where noise levels were within the permissible limits. (ANSI S3.1; 1999).

3.4. Instrumentation

Pure tone audiometer: A calibrated two channel Inventis Piano Plus audiometer coupled to impedance matched TDH 39 earphones housed with MX-41/ AR cushions and a bone vibrator (Radio ear B-71) were used to carry out pure tone audiometry, speech audiometry and MLD testing. A calibrated two channel GSI Audio Star Pro audiometer was used to carry out Quick –SIN testing.

Immitance meter: A calibrated GSI Tympstar (Grason Stadler Inc.) middle ear analyzer was used for tympanometry and reflexometry

Otoacoustic Emission Analyser: Otodynamics Ltd, ILO v6 was used for measuring DPOAEs. Contralateral noise was presented using calibrated two channel Inventis Piano Plus audiometer through insert receiver.

3.5. Procedure

Before the actual procedure, a written consent was taken from the participants for their willingness to participate in the study.

Pure tone and speech audiometry: Pure tone audiometry was carried out using modified Hughson and Westlake method (Carhart & Jerger, 1959) for obtaining air conduction thresholds at octave frequencies from 250 Hz- 8000 Hz using TDH 39 earphones and bone conduction thresholds for octave frequencies from 250 Hz- 4000 Hz using Radio ear B-71. Speech identification scores were obtained using phonemically balanced word list developed by Yathiraj and Vijayalakshmi (2005).

Immittance audiometry: Tympanometry was administered using 226 Hz probe tone and ipsilateral and contralateral reflexes were obtained at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz to rule out the middle ear pathology.

Quick-SIN: Speech perception ability in noise was measured using SNR-50, which is the signal to noise ratio (SNR) required to understand 50% of the presented speech in the presence of competing signal. The test stimuli developed by Avinash, Methi and Kumar (2010) was used with 3 dB steps (Hijas & Kumar, 2013). SNR 50 was measured in the presence of four talker babble presented binaurally, routed through the headphones via the audiometer connected to the computer. Each list contains seven sentences in Kannada with five key words each. The signal to noise ratio was decreased in 3 dB steps from +8 dB SNR to -10 dB SNR for every succeeding sentence from 1 to 7 in each list. These sentences were presented at 70dB HL through the audiometer. The participants were asked to listen to the sentences and repeat back the target sentences heard in the presence of multi-talker babble at different SNRs. At each SNR, the number of correct key words identified were counted and scores were calculated using the Spearman-Karber equation (Finney, 1952) as:

SNR-50= I + ½ (d) – (d) (# correct) / (w)

Where,

I= initial presentation level (dB S/B)

d= attenuation step size (decrement)

w= number of key words per decrement

correct= total number of correct key words

Masking level difference: Participants were made to sit comfortably and was made to wear TDH 39 earphones housed with MX-41/ AR cushions. Thresholds for NBN noise were found initially. Later, the participants were instructed to respond only to tone in the presence of noise. The MLD testing was carried out using pulsating tone at 1500 Hz and 2000 Hz binaurally in two conditions. That is, homophasic condition (S_0N_0- Signal and noise in phase in both ears) and antiphasic condition ($S_\pi N_0$ -Polarity of signal 180^0 out of phase in one of the ears, with noise in phase in both ears).

- Homophasic condition:

  The level of noise was kept constant at 40 dB SL and the threshold of the tone was found ($T_{homophasic}$) in 2 dB steps.

- Antiphasic condition:

  The level of noise was kept constant at 40 dB SL and the threshold of the tone was found ($T_{antiphasic}$) in 2dB steps.

Once both the thresholds were obtained, MLD was calculated by substracting $T_{antiphasic}$ from $T_{homophasic}$.

$$MLD = T_{homophasic} - T_{antiphasic}$$

Contralateral suppression of OAE: DPOAE recording was done using Otodynamics Ltd, ILO v6 in an acoustically treated room. The participants were made to sit comfortably in an armchair and was asked to remain steady throughout the testing procedure. The probe tip was placed in the ear canal to get a good seal. The total testing included two baseline recordings in the absence of noise and two recordings in the presence of contralateral noise. Right ear was used for testing as contralateral acoustic suppression was reported to be more for right ear (Perrot et al., 1999).

The probe was positioned in the test ear canal and was adjusted to maintain a flat stimulus frequency spectrum. DPOAEs were obtained using two pure tones of frequencies f1 and f2 and intensities at L1 and L2 respectively. f2/ f1 ratio was maintained constant at 1.22. The intensity of two stimuli, L1 and L2 were kept constant at 65 and 55 dB SPL respectively. OAEs were considered present only if it was at least 6 dB above the noise floor (Wagner, Heppelmann, Vonthein, & Zenner, 2008)

Noise thresholds were obtained using ER-3A insert earphones of Inventis Piano Plus audiometer. BBN was presented to contralateral ear at 50dB SL (relative to noise threshold) via same ER3A insert earphones used for estimating the noise thresholds. Noise was presented 15 seconds before the presentation of primaries while recording in contralateral noise condition. The position of the probe was maintained throughout the testing. Contralateral suppression of OAE was calculated from the difference between OAE amplitudes with noise and without the noise condition.

Chapter 4

Results

The data obtained for Quick SIN scores, contralateral suppression of DPOAE and MLD from both the group of participants were tabulated and then analyzed using Statistical Package for Social Sciences (SPSS, version 21.0) software.

Descriptive statistics was applied on the obtained data for all the parameters. The mean, median and standard deviation are shown in the Table 4.1.

Table 4.1: *Mean, median and standard deviation for CAS, MLD and Quick SIN scores for both the groups*

	Groups					
Measures	**Musicians**			**Non-musicians**		
	Mean(dB)	Median(dB)	SD	Mean(dB)	Median(dB)	SD
1 kHz	2.14	2.10	0.28	1.09	1.10	0.54
1.5 kHz	2.19	2.20	0.54	1.17	1.00	0.49
CAS: 2 kHz	2.24	2.30	0.85	1.15	1.25	0.48
3 kHz	1.64	1.70	0.50	0.88	1.00	0.39
4 kHz	1.64	1.70	0.59	0.84	0.70	0.42
6 kHz	1.48	1.50	0.56	0.44	0.40	0.15
MLD: 1.5 kHz	1.73	2.00	0.46	1.73	2.00	0.46
2 kHz	1.67	2.00	0.82	1.73	2.00	0.59
Quick SIN	-6.62	-6.10	1.18	-5.38	-5.50	1.49

Note: SD- Standard deviation, CAS- contralateral suppression of DPOAE, MLD- masking level difference.

It was observed that overall CAS values were greater and Quick SIN values were lesser in musicians compared to non-musicians. CAS was higher at 1 kHz, 1.5 kHz and 2 kHz compared to 3 kHz, 4 kHz and 6 kHz for both musicians and non-musicians. MLD was equal in both the groups at 1.5 kHz and greater in non-musicians at 2 kHz. For musicians, MLD was greater at 1.5 kHz compared to 2 kHz. For non- musicians, MLD was equal at 1.5 kHz and 2 kHz.

Shapiro Wilk's test was carried out to check the normality of the data obtained. CAS data followed the normal distribution and hence parametric test was carried out. MLD and Quick SIN data did not follow the normal distribution and hence non-parametric tests were done.

4.1. Comparison of contralateral acoustic suppression of DPOAEs between and within the two groups

Mixed ANOVA (Repeated measures ANOVA for comparison of frequency with participant group as between factor) was carried out. Mixed ANOVA revealed significant main effect of CAS frequency [F (5, 140)= 11.751, p< 0.01] and significant main effect of groups [F (1, 28)= 96.477, p< 0.01]. However, there was no interaction between the frequency and groups [F (5, 140)= 0.664, p> 0.01]. Hence pairwise comparison of mean suppression amplitudes across CAS frequencies were carried out. Results of the pairwise comparison are shown in the Table 4.2.

Table 4. 2: *Pairwise comparison for CAS frequencies*

(I) frequency	(J) frequency 1 kHz	1.5 kHz	2 kHz	3 kHz	4 kHz	6 kHz
1 kHz		-.065	-.078	.357*	.370*	.654**
1.5 kHz			-.013	.422**	.435	.719**
2 kHz				.435*	.448*	.732**
3 kHz					.013	.297
4 kHz						.284
6 kHz						

Note: *p<0.05, **p<0.01

The results of pairwise comparison from Table 4.2 revealed that there was significant difference (p< 0.05) in the data obtained between frequencies: 1 kHz and 3 kHz, 1 kHz and 4 kHz, 1 kHz and 6 kHz, 1.5 kHz and 3 kHz, 1.5 kHz and 6 kHz, 2 kHz and 3 kHz, 2 kHz and 4 kHz, 2 kHz and 6 kHz.

4.1.1. Comparison of groups within each frequency of CAS

Multivariate Analysis of Variance (MANOVA) was carried out to compare between musicians and non-musicians in each of the CAS frequency conditions. The results revealed significant main effect of groups for frequencies at 1 kHz [F (1, 28)= 44.129, p< 0.01], 1.5 kHz [F (1, 28)= 28.499, p< 0.01], 2 kHz [F (1, 28)= 18.788, p< 0.01], 3 kHz [F (1, 28)= 21.162, p< 0.01], 4 kHz [F (1, 28)= 18.031, p< 0.01], 6 kHz [F (1, 28)= 49.068, p< 0.01], with greater suppression observed for musicians compared to non-musicians.

4.1.2. Comparison of frequency of CAS within each group

Repeated measures ANOVA was carried out to compare the difference in mean suppression amplitude across the frequencies within each of the two groups: musicians and non-musicians. CAS frequencies were taken as within subject variable. Results of repeated measures ANOVA showed a significant difference across frequencies in musicians [$F (5, 70) = 6.055$, $p < 0.01$] and non-musicians [$F (5, 70) = 6.443$, $p < 0.01$], and this trend followed the results of mixed ANOVA.

4.2. Comparison of masking level difference between and within the two groups

4.2.1. Comparison of groups within each frequency

Differences between the groups in terms of mean was observed at 2 kHz and not at 1.5 kHz. Hence, Mann Whitney test was carried out to check for significance at 2 kHz. The test revealed no significant difference between the two groups at 2 kHz ($|z| = .207$, $p > 0.05$)

4.2.2. Comparison of frequency within each group

Differences between the frequencies in terms of the mean was observed for musicians and not for non-musicians. Hence Wilcoxon Signed rank test was carried out to check for significance in musicians. There was no significant difference across frequencies in musicians ($|z| = .302$, $p > 0.05$).

4.3. Comparison of Quick SIN between the two groups

Mann Whitney test was carried out to compare the two groups for Quick SIN. The test revealed a significant difference between the two groups ($|z| = 2.266$, $p < 0.05$). The scores obtained were significantly better for musicians than when compared to non-musicians.

4.4. Correlation across contralateral suppression of DPOAE, masking level difference and Quick SIN for musicians and non-musicians

Spearman's correlation was done to investigate the correlation across contralateral suppression of DPOAE, MLD and Quick SIN in musicians and non-musicians. Results revealed significant positive correlation between CAS at 1.5 kHz and MLD at 2 kHz in musicians ($\rho = .569$, $p < 0.05$). This indicates that as the suppression at 1.5 kHz increases, MLD at 2 kHz also increases. That is, better the suppression of OAEs at 1.5 kHz, better is the MLD performance at 2 kHz. However, there was no significant correlation ($p > 0.05$) between other parameters, that is, between CAS and MLD at different frequencies and Quick SIN in musicians.

In non-musicians, significant negative correlation was observed between CAS at 4 kHz and Quick SIN ($\rho = -.622$, $p < 0.05$). This indicates that as suppression at 4 kHz increases, Quick SIN scores decreases. In Quick SIN, lesser SNR obtained indicates better performance. Hence, it was observed that better the suppression at 4 kHz, better is the Quick SIN performance. However, there was no significant correlation ($p > 0.05$)

between other parameters, that is, between CAS and MLD at different frequencies and Quick SIN in non-musicians.

Chapter 5

Discussion

Results showed that musicians outperformed non-musicians in Quick-SIN and contralateral suppression of DPOAEs. However, there was no significant difference in terms of MLD between the two groups.

5.1. Contralateral acoustic suppression of DPOAEs

Contralateral suppression of DPOAEs were obtained across the frequencies. Results revealed significant difference across the frequencies. Contralateral suppression of DPOAEs were found to be significantly greater at mid frequencies compared to high frequencies. The reduced suppression at high frequencies were in agreement with studies reported in the literature (Veuillet, Collet, & Morgon, 1992; Kim, Frisina, & Frisina, 2002; Sun, 2008). Moulin et al. (1993) found lesser slope in the decrement of DPOAE amplitude with the increment in contralateral noise, when frequency was increased. They attributed this frequency difference in suppression to unequal firings by BBN in efferent fibers across the frequencies. Studies have reported maximum suppressive effects at mid frequencies (1 kHz and 2 kHz), as uncrossed MOC efferent fibers innervate mostly to the centre region of the cochlea (Kumar & Barman, 2000).

Contralateral suppression of DPOAEs were compared between musicians and non-musicians. The study revealed significantly greater suppression of DPOAEs in musicians compared to non-musicians across all the frequencies. The results of the present study were in agreement with earlier studies reported in the literature. (Micheyl et al., 1995; Micheyl et al., 1997; Perrot et al., 1999; Brashears et al., 2003; Ameen & Maruthy, 2011). Micheyl et al. (1997) suggested enhanced activity at the level of higher centers which would enhance the MOC activity in musicians compared to non-musicians, which in turn would have resulted in overall enhanced amplitude reduction over different ipsilateral stimulus intensities in musicians. Brashears et al. (2003) found greater DPOAE suppression with binaural suppressor in musicians compared to non-musicians and attributed this to the strengthening of central auditory pathway as a result of musical training.

5.2. Masking Level Difference

The masking level difference was compared between musicians and non-musicians and across two frequencies: 1.5 kHz and 2 kHz. The study revealed no significant difference between musicians and non-musicians for both the frequencies. Also, there was no significant difference across the frequencies for both the groups. The magnitude of masking level difference itself is less at 1.5 kHz and 2 kHz compared to low frequencies (Hirsh, 1948). Hence the difference in MLD between musicians and non-musicians and across 1.5 kHz and 2 kHz may not be so evident due to its reduced magnitude.

5.3. Quick SIN

Quick SIN scores were compared between musicians and non-musicians. The study revealed significantly greater speech in noise abilities in musicians compared to non-musicians. The results were in agreement with earlier studies reported in the literature (Parbery-Clark et al., 2009b; Parbery-Clark, Strait, Anderson, Hittner, & Kraus, 2011; Rajalakshmi, 2011; Parbery-Clark, Tierney, Strait, & Kraus, 2012). Earlier studies reported better performance in Quick SIN and working memory in younger musicians (Parbery-Clark et al., 2009b) and older musicians (Parbery-Clark et al., 2011) compared to non-musicians. Quick SIN includes semantically less predictable and longer sentences and hence it has been reported to require good working memory. These authors attributed the better performance in Quick SIN test to the superior abilities in the working memory among the musicians (Parbery-Clark et al., 2009b; Parbery-Clark et al., 2011).

One of the main function of efferent system is speech perception in the presence of noise (Kumar & Vanaja, 2004). Hence it could be probable that the stronger efferent system in musicians resulted in better perception of speech in the presence of noise in them.

5.4. Correlation across contralateral suppression of DPOAE, masking level difference and Quick SIN in musicians and non-musicians

Correlation across contralateral suppression of DPOAE, MLD and Quick SIN were studied in musicians and non-musicians. Within musicians there was correlation between CAS at 1.5 kHz and MLD at 2 kHz, however there was no correlation found between other parameters. Within non-musicians there was correlation between CAS at 4 kHz and Quick SIN, however there was no correlation found between other parameters. These variations could be attributed to the heterogeneity within the musicians and non-musicians. Within the musicians, there could be variability in terms of the type of musical training (vocal or instrumental musical training), age at which the musical training started, duration of musical training. Within the non-musician group, there could be variability in terms of innateness of musicality. Since correlation was observed only at few frequencies across the three tests in both the groups, it is not possible to draw conclusions about correlation across contralateral suppression of DPOAE, MLD and Quick SIN. By the addition of more number of participants in the study, probably may help in commenting on the correlation between the tests.

Chapter 6

Summary and Conclusion

Perception of speech in the presence of noise is one of the major functions of olivocochlear efferent pathway. Contralateral suppression of otoacoustic emissions (OAEs) provides information about the efferent system functioning. Quick SIN provides a measure of performance of signal in the presence of background noise. Masking level difference (MLD) also provides a measure of release of masking. Thus, the combination of contralateral suppression of OAEs, Quick-SIN and MLDs provides a measure of masking and overall release of masking and also provides information about the afferent and efferent system functioning. The performance of musicians can be expected to be better in these tests relative to non-musicians.

The aim of the current study was to evaluate the effect of music training on speech perception abilities in the presence of background noise, contralateral suppression of OAE and masking level difference. Hence Quick SIN, contralateral suppression of OAE and MLD tests were administered on musicians and non-musicians. Appropriate statistical analysis was carried out and the study revealed the following:

1. Contralateral suppression of OAEs were significantly greater in musicians compared to non-musicians
2. In musicians and non-musicians, a significant difference across CAS frequencies were observed for contralateral suppression of OAEs.
3. MLD was not significantly different between musicians and non-musicians.

4. In musicians and non-musicians, there was no significant difference across MLD frequencies at 1.5 kHz and 2 kHz.
5. Quick SIN scores were significantly better in musicians compared to non-musicians.
6. Significant positive correlation was found between CAS at 1.5 kHz and MLD at 2 kHz in musicians.
7. Significant negative correlation was observed between CAS at 4 kHz and Quick SIN in non-musicians.

The results obtained indicates that the effect of musical training can be quantified using contralateral suppression of OAEs and Quick SIN. Hence, while assessing the effectiveness of musical training, contralateral suppression of OAEs and Quick SIN tests can be considered. From the results of the study, we can infer that musical training strengthens the afferent and efferent pathway and facilitates speech perception abilities in the presence of noise. And hence it can be concluded that musicians have superior afferent and efferent functioning compared to non-musicians.

Implications:

- Individuals with difficulty in understanding speech in noisy situation could be recommended for music training which would help them in better perception.
- Individuals with hearing impairment could be recommended for music therapy by audiologists, which could improve their speech perception in noisy situations.
- The musical experience of the client could be included as a factor to be considered for an appropriate test interpretation and diagnosis.

- This study gives additional information to the existing knowledge on the effect of release of masking and masking effects with musical training.

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