To find out Correlation between FMDL, Short term auditory working memory and P300 in musicians and non-musicians

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

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May, 2015

Certificate

This is to certify that this dissertation entitled **"To find out Correlation between FMDL, Short term auditory working memory and P300 in musicians and non-musicians"** is a bonafide work in part fulfillment for the degree of Master of Science (Audiology) of the student with Registration No. 13AUD016. 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.

Mysore,

May 2015

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Mysore – 570006

Certificate

This is to certify that this dissertation entitled **"To find out Correlation between FMDL, Short term auditory working memory and P300 in musicians and non-musicians"** has been prepared under my supervision and guidance. It is also certified this has not been submitted earlier in other University for the award of any other Diploma or Degree.

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Declaration

This dissertation entitled **To find out Correlation between FMDL, Short term auditory working memory and P300 in musicians and non-musicians** is the result of my own study under the guidance of Dr. K Rajalakshmi, professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysore, **Register No**: 13AUD016

May, 2015

Dedicated to

Mom

Dad

Brother

Sister

My beloved Grand Mother

And My Guide

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Abstract

Musical training is a rigorous routine involving the segregation of vocal and instrumental sounds presented concurrently. To investigate the correlation of behavioral and electrophysiological tests on musicians and non-musicians, we compared frequency modulation detection level (FMDL), Short-term auditory working memory (Digit Forward and Digit Backward span test) and P300 in a group of trained musicians and non-musician controls. A total of 32 subjects comprised 16 musicians and 16 non musicians were taken, aged between 16-30 years. FMDL was done using MATLAB R2009b, Digit Forward and Digit Backward span tests was done using APEX software and P300 was done using Intelligent Hearing System. Digit forward scores and FMDL scores was found to be equivalent in both the groups. Musicians were found to have a more robust Digit backward scores and robust P300 amplitude compared to non-musicians. These findings suggest that musical experience helps to enhance neural coding to discriminate subtle differences and enhance auditory working memory.

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Chapter 1

Introduction

"Music can be defined as an art of sound in time that expresses ideas and emotions in significant forms through the elements of rhythm, melody, harmony, and color." (Wikipedia)

"Music is a succession of sounds and the composer the *organizer of sounds*." - John Cage

Studies have also demonstrated that musical training enhances pitch pattern recognition and increase the verbal memory and pre-school children's phoneme awareness skills and early reading skills are correlated with their musical training (Anvari et al, 2002).

There are many advantages of Music as a tool for auditory training. It is an enjoyable activity which emphasizes on timing skills & sound pattern of the speech. (Overy, 2003).

1. Frequency Modulation Detection Level (FMDL)

Frequency Modulation Detection Level (FMDL) is used as a psychophysical assessment to measure the fine structure processing of the auditory system. In this process, the person has to detect modulations in frequency at low modulation and carrier frequencies (Lacher Fougere & Demany, 1998; Moore & Sek, 1996). FMDL measures the ability to detect the instantaneous frequency of a tone which is slowly modulated, it depends more on the temporal patterning of neural response, in persons who have better abilities of phase locking.

In all earlier studies, monaural presentation was used to measure detection of FM. The processing of temporal fine structure has also been measured by binaural presentation. Most of these studies measured sensitivity to interaural time & phase differences as a function of frequency (Grose & Ma'amo, 2010; Hopkins & Moore, 2010; Lacher-Fougere & Demany, 2005; Moore et al., 2012a).

Studies show that, in younger subjects, detection of FM was better as compared to olders' and at 500Hz age-related differences were larger than at 4000 Hz. Mechanism behind this is neural phase locking is strong at low frequencies, which helps to code temporal information and this phase locking decreases with the increase in frequency.

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2. Working Memory

Also called as short term memory. It is thought to be the stage where the information is just processed. Its memory capacity is about 7 ± 2 items (Miller, 1956). This is true for digits, words, letters etc.

Digit span test includes Digits Backward & Digits Forward span tasks and are a prominent supporter in psychological assessment and are used to assess working memory.

Digit Span test has been a subtest of Wechsler's batteries for intellectual and memory assessment, since the origin of the Wechsler- Bellevue Intelligence Scales (Wechsler, 1939). While initially the scale was considered a measure of attention and concentration as well as verbal memory, now it considered as a test to measure working memory. Research shows the scores of Forward Digit Span were significantly higher than scores of backward recall.

3. P300

The P300 response is essentially a component within an extended ALR time frame that is recorded under special stimulus conditions, like using an oddball paradigm. Auditory late responses are generated from a frequent or predictable stimulus (the standard signal). The positive wave in the latency region of 300 ms are generated from the oddball or target signal produces which are infrequent (rare), unpredictable (presented randomly) or different (deviant) in some way from the first signal. The response is sometimes referred to as P300, because it is observed in the 300 ms region, and sometimes as the P3 wave, because it forms a third major positive voltage component after ALR waves PI and P2. In fact, however, the P300 may be recorded in normal subjects as early as 250 ms or as late as 400 ms, and may not necessarily be the third major component in the waveform. The P300 response is thought to reflect an updating of working memory; the response itself is a slow and broad positive peak that may occur between 250 and 800 ms and may exceed 10 µV (Polich, 1986).

Need of the study

Though literature has recorded some studies in the western literature and western music, the studies on Indian music are scarce. Hence, there is a need to study the relationship between psychophysical measures, working memory and electrophysiological correlates. Moreover, there are a very few studies to demonstrate the effect of music therapy on cognitively deficit individuals. So the present study is taken up to fill this gap in literature.

Aim of the study

1. To see FMDL abilities in non-musicians and trained-musicians.
2. Measure auditory working memory in non-musicians and trained-musicians.
3. Measure P300 in non-musicians and trained-musicians.
4. To see a correlations between above measures in non-musicians and trained-musicians.

Chapter 2

Literature Review

Neurophysiology in musicians and non-musicians

Pantev and his colleagues (1998) measured cortical representations in trained musicians by using fMRI. The Dipole moments for piano tones was found to be enlarge by about 25% in trained-musicians than non-musicians. This enlargement was well correlated with the age when musicians began to practice.

Schneider and his colleagues (2002) compared morphology and neurophysiology in professional musicians with non-musicians, the activity evoked in primary auditory cortex was found to be 102% larger in musicians, and the volume of gray matter in the anteromedial portion of Heschl's gyrus was 130% larger in musicians.

Gaser and Schlaug (2003) found enhanced volume of gray matter in motor as well as auditory and visuospatial brain regions in professionally trained musicians by using voxel-by-voxel morphometric technique, when compared with matched amateur musicians and non-musicians.

Gaser, and Schlaug (2003) also measured brain structure differences in professional musicians, amateur musicians, and non-musicians by using High-resolution anatomical images of the whole brain by using acquisition gradient echo sequence. They found larger volume of gray matter in perirolandic regions which includes primary motor and somatosensory areas, premotor areas, anterior superior parietal areas, and in the inferior temporal gyrus bilaterally in professionally trained musicians, average values in amateur musicians, and least in non-musicians.

George and Coch (2010) Compared P300 in visual and auditory parameters in musicians and non-musicians, they found musicians having faster auditory and visual working memory updating. Musicians allocated more neural resources, reflecting greater sensitivity to the standard/deviant difference, only in the auditory condition, scored higher on standardized subtests of visual, phonological, and executive memory. This also suggests music training is associated with selective improvements in working memory, on both neural and behavioral levels.

Parbery-Clark and colleagues (2012) also found that music training can increase the ability to detect small differences between sounds. They measured the degree to which subcortical response timing differs to the speech syllables /ba/, /da/, and /ga/ in adult musicians and non-musicians. Enhanced subcortical discrimination of closely related speech sounds was found in musicians, and the extent of subcortical consonant discrimination was found to be well correlated with speech-in-noise perception scores. These entire findings showed musician have enhanced neural processing of speech and correlated with biological mechanism contributing to musicians' enhanced speech perception in noise.

Kraus and her colleagues (2014), administered neurophysiological test battery consisting of click and speech-evoked auditory brainstem responses using Intelligent Hearing System’s SmartEP platform on 44 children, having 1 and 2 years of musical training, they found a progressive enhancement of neurophysiological function on musical trained group, which showed a marked improvement in their neural differentiation of the syllables [ba] and [ga].

FMDL in musician vs. non-musician

Amir and his colleagues (2014) measured frequency discrimination, interval duration discrimination, threshold of intensity discrimination and threshold of spectrum discrimination, on fifteen non-musicians and twelve musicians (9 to 20 years musical experience). Frequency discrimination was found to be significantly better in musicians than non-musicians with a mean value of 3.82Hz in musicians and 7.79Hz in non-musicians.

Tervaniemi and his colleagues (2005) measured frequency difference threshold and auditory event-related potentials in twenty-six subjects (13 professional musicians and 13 non-musicians). For frequency difference threshold, they used 2AFC method, in which subject had to decide the higher pitch, out of two. For ERP they used the same frequencies, which they used for behavior test. Here the lowest frequency used as standard stimulus, and other higher frequencies used as deviant. Both behavioral and ERP tests revealed musicians detected the pitch changes faster and more accurately than non-musicians.

Kishon-Rabin and his colleagues (2001) measured DLF for pure-tones (250, 1000 & 1500Hz) in 16 professional musicians and 14 non-musicians by using 2IFC and 3IFC procedures. They found mean DLFs for musicians were approximately half the values of the non-musicians, which reveals musicians have better discrimination ability.

Short term working memory in musicians

Zuk and his colleagues (2014) performed two experiments to measure executive functions (cognitive capacities including planned & controlled behavior which deals with academic abilities). In first experiment, 30 adults were selected with and without musical training and in second experiment, 27 children (untrained & musically trained) were selected. They performed a standardized executive functions battery in both the experiments. They also used fMRI to check neural correlates of executive function skills in both the groups. Adult musicians showed enhanced performance on measures of cognitive flexibility, working memory, and verbal fluency as compared to non-musicians. Musically trained children also showed enhanced performance on measures of verbal fluency and processing speed, compared to non-musician children. Overall, musician group showed enhanced performance on several constructs of executive functions. These results reveal that musical training helps to enhance certain executive function skills, which in turn helps to enhance academic achievement.

Schulze and Koelsch (2012) reviewed behavioral and neuroimaging findings on similarities and differences between verbal and tonal working memory (WM), the influence of musical training, and the effect of strategy use on WM for tones. They concluded functional plasticity of different neural networks underlying verbal and tonal WM has been induced by musical training. Studies indicate both verbal and tonal auditory WM are based on the knowledge of how to produce the to-be-remembered sounds, this show a strong link between auditory working memory and recalling.

Benassi-Werke and colleagues (2012) measured digit forward and digit backward tests by using pseudoword, tone, and contour spans in amateur singers and professional singers. They found slight positive influence on the recall of tones by musical schooling, but recall of verbal material are not influenced by musical schooling. Furthermore, the ability to reproduce melodic contours (up and down patterns) is generally higher than the ability to reproduce exact tone sequences.

George and Coch (2011) used ERP and a standardized test of working memory to investigate both neural and behavioral aspects of working memory in adult non-professional musicians and non-musicians. In both, behavioral tests and ERPs, musicians performed better than non-musicians. Musicians demonstrated faster updating of working memory (shorter latency P300s) in both the auditory and visual fields and allocated more neural resources to auditory stimuli (larger amplitude P300), showing increased sensitivity to the auditory standard/deviant difference and less effortful updating of auditory working memory. Both behavioral and electrophysiological findings showed music training of long-term is related to improvements in working memory, in both modalities (auditory and visual).

Schulze and colleagues (2011) compared encoding and rehearsal of auditory working memory for structured and unstructured material in musicians and non-musicians. They found right pars orbitalis is functionally more activated in musicians compared to non-musicians by using fMRI. Musicians and non-musicians performed a working memory task on five-tone sequences that were either tonally structured or tonally unstructured sequences. In musicians, they found lateral (pre)frontal-parietal network (including the right premotor cortex, right inferior precentral sulcus and left intraparietal sulcus) was activated during working memory rehearsal of structured, as compared with unstructured, sequences. These findings indicate that this network plays important role in strategy-based working memory for non-verbal auditory information.

P300 in musician vs. non-musicians

Rabelo and colleagues (2015) measured P300's latency and amplitude using contralateral stimulation in 55 subjects (30 professional musicians and 25 non-musicians). In P300, without contralateral noise, they found musicians had lower latencies and higher amplitudes than the non-musicians. But in the presence of contralateral noise, latency values were significantly increased in the musicians. This shows musicians have more robust and efficient neural responses in the cortical and sub-cortical regions, demonstrating that musical experience benefits the processing of both non-linguistic and linguistic stimuli. So, they concluded central auditory nervous system of musicians presents peculiar characteristics of electrophysiological responses probably due to the plasticity imposed by musical practice.

Nikjeh and colleagues (2009) did MMN & P3a on trained musicians and non-musicians in three auditory stimulus conditions i.e., pure tones, harmonic tones & speech syllables. Musicians were found to have shorter MMN latencies for all deviances. For harmonic tones and speech, shorter P3a latencies was found, but not for pure tones. Based on these findings, they concluded, formally trained musicians showed more efficient neural detection of pure tones and harmonic tones, which demonstrates superior auditory sensory-memory traces for acoustic features of pure tones, harmonic tones, and speech; and revealed enhanced sensitivity to acoustic changes of harmonic tones and speech. All these findings help to conclude central auditory function is influenced by music training and facilitates auditory neural system enhancement.

George and his colleagues (2010) measured behavioral tests and P300 in 32 subjects, 16 musicians (9 to 16 years of musical training) & 16 non-musicians. They found mean P300 peak amplitude of 5.62 µV in musicians, which is significantly higher than 3.49 µV in non-musicians. This reflects musicians have greater sensitivity to discriminate standard and deviant stimulus.

George and Coch (2011) used ERP and working memory test on musicians and non-musicians, they found shorter P300 latency and larger P300 amplitude in musicians, compared to non-musicians, which shows enhanced sensitivity to discriminate standard and deviant stimuli in musicians.

Lopez and colleagues (2003) gave auditory stimulation (tone, chord, chord sequence, Mozart and Bach melodies) to 20 subjects (10 non-musicians and 10 musicians) and recorded both magnetic and electrical responses. Clear N1 was found for all paradigms, in all subjects. The amplitude and latencies of MMN and P300 were also significantly correlated with the musicality score and with the paradigm's difficulty.

Other benefits of musical training

1) Speech in noise

Strait and colleagues (2012) checked whether neural and perceptual enhancement in speech in noise is present in musically trained children, as in musically trained adults. They assessed the perception and subcortical processing of speech in noise and related cognitive abilities in musician and non-musician children. They found musicians have better processing of speech in noise during crucial developmental years which is supported by correlations between auditory working memory and attention and auditory brainstem response properties, they also proposed that musicians' perceptual and neural enhancements are driven in a top-down manner by strengthened cognitive abilities with training. Therefore, music training can be included in the treatment program of language-based learning deficits, which often have poor perception of speech in noise.

2) Higher order functioning

Oechslin and colleagues (2013) measured functional magnetic resonance imaging on non-musicians, amateurs, and expert musicians. Participants listened to a comprehensive set of specifically composed string quartets with hierarchically manipulated endings. They found, musical expertisation level helps in modulation of functioning of higher order brain. It suggests that cerebral plasticity depends on intensity of music training. fMRI data proved stepwise modulation of brain responses in a fronto-temporal network hosting universal functions of working memory and attention by both violation strength and expertise level. Additional independent testing proved an advantage in visual working memory for the professionals, which is also modulated by the intensity of musical training. These findings of brain plasticity helps to conclude that musical training have progressive impact on various cognitive brain functions.

Chapter 3

Method

1. Subjects

A total of 32 subjects were selected, with 16 Musicians (vocalists) with a minimum musical experience of 2 years and 16 non-musicians with an age range from 16 to 30 years.

1.1. Selection criteria

1.1.1. *Inclusion criteria*

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

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

1.2. Exclusion criteria

Subjects with any abnormality in auditory system, neurological problems were excluded.

2. Materials

2.1. Stimulus for FMDL

Sampling frequency = 44100Hz

Tones' duration = 0.5s

Carrier frequency = 1000Hz

Modulator frequency= 10Hz

2.2. Stimulus for P300

Frequent stimulus: /d/

Infrequent stimulus: /g/

2.3. Stimulus for Digit Span test

Monosyllabic English digits between 0 and 9, arranged according to the test requirement.

3. Equipments

i. A calibrated Piano Inventis dual channel clinical audiometer was used for pure tone and speech audiometry.

ii. A calibrated GSI Tympstar Immitance meter was used for evaluating middle ear status.

iii. Intelligent Hearing Systems (IHS version 4.3.02) AEP system with smart EP software was used for recording and analyzing P300.

iv. A computer with MATLAB R2009b and APEX was used for the generation of auditory stimulus.

v. HDA200 headphone with adjustable cushion

4. Testing environment

Recording of the stimulus and all audiological testing was conducted in sound treated rooms where the noise levels were within permissible limits (ANSI. S3.1, 1991). The rooms were also electrically insulated.

5. Procedure

The participants underwent preliminary hearing evaluation before the electrophysiological testing. The preliminary evaluation battery included brief interview, puretone audiometry, immittance evaluation and speech tests. An interview from all the participants was taken, to rule out any past or present otological and neurological complaints. Puretone audiometry using modified Hughson-Westlake procedure (Carhart & Jerger, 1959) was carried out to evaluate pure tone thresholds at octave frequencies from 250 Hz to 8 KHz for air conduction and from 250 Hz to 4 KHz for bone conduction modes.

Immittance evaluation involved tympanometry and acoustic reflex testing. Tympanometry was carried out using 226 Hz probe tone. The peak static admittance and peak pressure was estimated by sweeping the pressure from +200 to -400 dapa. In reflexometry, ipsilateral and contralateral reflex thresholds were measured at 500Hz, 1 kHz, 2 kHz and 4 kHz.

5.1.FMDL

FMDL was measured using MATLAB R2009b by using 3AFC procedure that incorporated a three-down, one-up stepping rule to converge on the 79.4% correct point. The stimulus was presented binaurally. In the two standard intervals, two of the stimulus was an un-modulated pure tone and one stimulus was a FM tone. The inter-stimulus interval was 500 ms. Listeners were instructed to find out the stimulus in which the frequency was modulated. The depth of FM was reduced after three consecutive correct responses; and the depth was increased after one incorrect response. The depth of frequency modulated tone was initially changed by a factor of $\sqrt{2}$ and, following two reversals in direction of depth change, the factor was further reduced by its square root. This track was continued for 10 reversals, and the mean of the last six reversal depths was taken as the threshold estimate for that track. Atleast three estimates of threshold were collected for each condition, and the final threshold value was taken as the mean of all estimates. A practice trial was given to all the subjects.

5.2. Digit span test

This test was done by using APEX with monosyllabic English digits, subjects were instructed to carefully listen to the numbers, and when the system finished the numbers, they were supposed to write the numbers according to the tests. The stimulus was presented binaurally. Initially two digits were presented and successively the numbers of digits increased up to eight digits.

5.2.1. *Digits Forward test:* The subjects were supposed to repeat the numbers in the same sequence as they heard them.

5.2.2. *Digits Backward test:* The subjects were supposed to repeat the numbers in the reversed sequence as they heard them.

Digits were given at the rate of one per second. All the digits were monotone without any variation in pitch of voice.

Correctly repeated forward and backward digits were taken as the total score of the individual.

5.3.P300

To record P300, the participants were made to sit in a comfortable reclining chair and were asked to relax. The Cz and Pz electrode sites were cleaned with skin preparation gel and the disc electrodes were placed using a conduction paste. Prior to recording P300, an absolute impedance of less than 5 k Ohms and relative impedance of less than 2 k Ohms was ensured.

The participants were asked to open their eyes and minimize eye blinks of the target EEG to reduce contamination from alpha activity. The stimulus was presented binaurally. The participants were instructed to pay attention to the blocks of stimuli which were presented and were asked to mentally count the infrequent stimulus (/t/) during the auditory presentation mode.

Table 3.1: Stimulus parameters used for P300

STIMULUS PARAMETERS	
Transducer	Insert ER- 3A
Stimulus paradigm	Oddball paradigm
Stimulus type	Standard: /da/ Deviant: /ga/
Intensity	70dB HL
Repetition rate	≤1.1/s
Stimulus probability	Standard: 80% Deviant: 20%
Polarity	Alternating
Presentation ear	Right

Table 3.2: Acquisition parameters used for P300

ACQUISITION PARAMETERS	
No. Of sweeps	120
Amplification	50,000
Analysis time	100ms prestimulus and 800ms post stimulus
Filter setting	1-30Hz
Notch filter	Yes
Electrode type	Disc electrode
Electrode montage	
Non-inverting	Fz, Cz and Pz
Inverting	Tip of nose
Ground	Ipsi mastoid
Other	Ocular

Chapter 4

Results and Discussion

The present study was designed to examine the effect of musical training on working memory, frequency modulation discrimination and higher order auditory processing. The P300 responses of both musicians and non-musicians were examined, and these findings were related to the performance of the subjects on the behavioral tasks like FMDL and Digit-forward & Digit-backward span tests.

Sixteen individuals who had undergone formal musical training and sixteen individuals who had no formal musical training constituted the experimental and control groups respectively. The amplitudes of P300, FMDL scores and Digit-forward & Digit-backward span scores were subjected to statistical analysis. In musicians, 2 subjects were outliers, and in non-musicians, 1 subject was outlier, so they were removed. So, finally 14 musicians and 15 non-musicians were selected for statistical analysis.

The following statistical analyses were done to compare the data from the control and experimental groups:

- Shapiro-Wilk test was done to test normality. $P<0.05$ was considered as normal. Amplitude values for both the groups were under normality, Digit span measures were not under normality for both the groups, FMDL measures were under normality in musicians and not under normality in non-musicians. So, for

Amplitude measures, parametric tests were applied and for Digit span & FMDL, non-parametric tests were applied.

- Mixed Analysis of Variance (ANOVA) was carried out to compare amplitude of Fz, Cz & Pz electrode placement between two groups and interaction effect between placement and group.
- Bonferroni – Multiple Comparison test was done to compare P300 amplitude of Fz, Cz & Pz placements.
- Repeated measure ANOVA was done to compare Fz, Cz & Pz amplitude in musicians and non-musicians separately.
- Mann-Whitney Test was done to compare, Digit forward and backward scores between musicians and non-musicians.
- Wilcoxon Signed Ranks Test was done to compare Digit-forward & Digit-backward scores, within musicians & non-musicians.
- Mann-Whitney Test was done for FMDL to compare between musicians & non-musicians.

After statistical analysis, following results were obtained:

1. P300

As per, data in table 4.1 & 4.2, significant difference is found between amplitude of musicians and non-musicians with F value of 7.677 & $P<0.05$.

Table 4.1: P300 amplitude (µV) in Non-musicians

Recording site	Mean	Std. Deviation	n
Fz_amp	3.8760	1.67562	15
Cz_amp	3.5073	1.44425	15
Pz_amp	3.5693	1.58096	15

Note. Fz, Cz & Pz are various recording site, according to international 10 – 20 system of electrode placement. n = no. of subjects.

Table 4.2: P300 amplitude (µV) in Musicians

Recording site	Mean	Std. Deviation	N
Fz_amp	5.6407	2.45198	14
Cz_amp	5.8093	2.09344	14
Pz_amp	4.9571	1.76237	14

Note. Fz, Cz & Pz are various recording site, according to international 10 – 20 system of electrode placement. n = no. of subjects.

Characteristics of P300 waveform obtained in musicians and non-musicians are displayed in figure 4:1 & 4:2 respectively. These figures show that amplitude of P3 is higher in musicians, as compared with non-musicians.

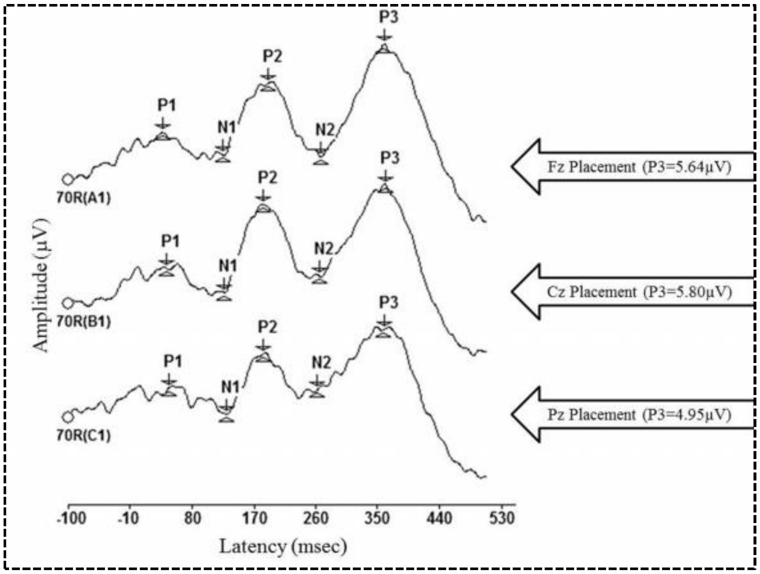

Figure 4:1: Characteristics of P300 waveform in musicians. The X-axis represents latency of waveform; the Y-axis represents amplitude of waveform.

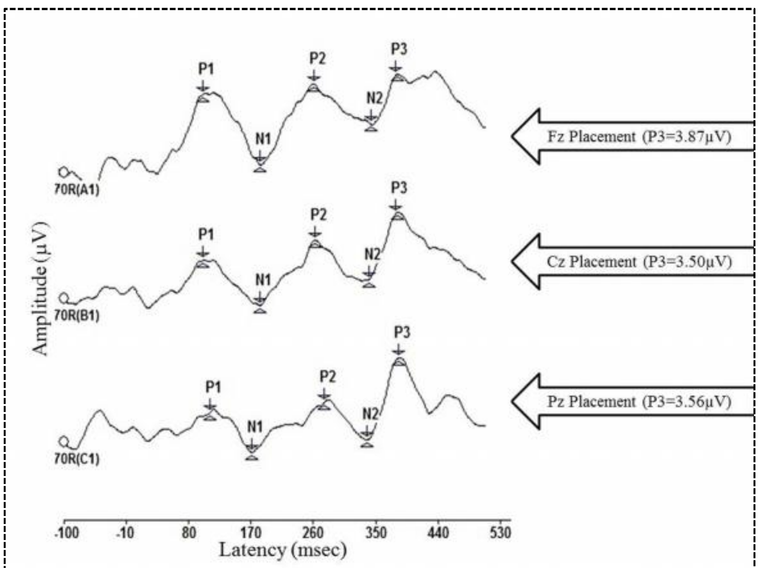

Figure 4:2: Characteristics of P300 waveform in non-musicians. The X-axis represents latency of waveform; the Y-axis represents amplitude of waveform.

Significant difference is found between P300 amplitude (figure 4:3) of musicians and non-musicians with F value of 7.677 & $P<0.05$. These shows mean value of P300 amplitude in musicians are higher than non-musicians.

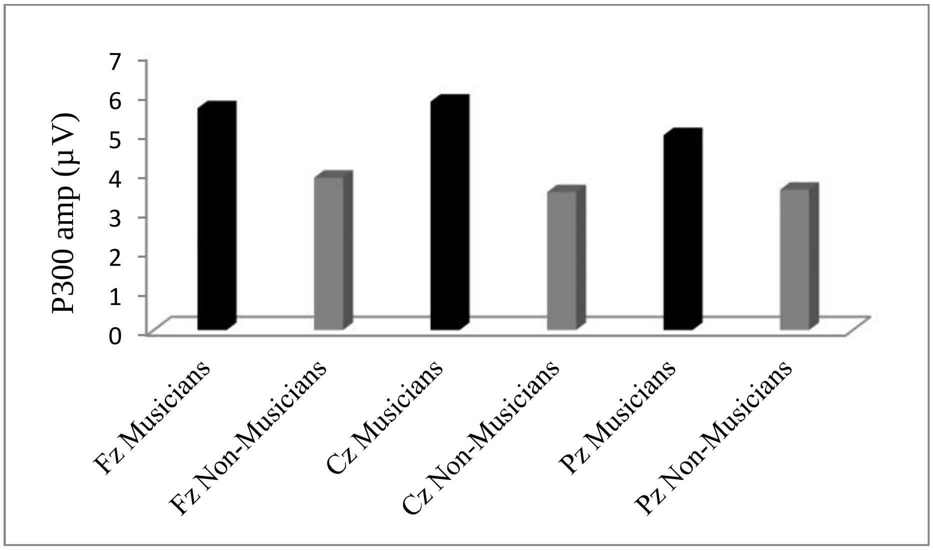

Figure 4:3: P300 amplitude (µV) in musicians and non-musicians. The X-axis represents various placements of recordings in musicians and non-musicians; the Y-axis represents amplitude of waveform.

A significant difference between amplitude was found for Cz & Pz and Fz & Pz in musicians (figure 4:4) with the F value of 3.987 & P<0.05. Fz & Cz was found to have more amplitude than Pz site.

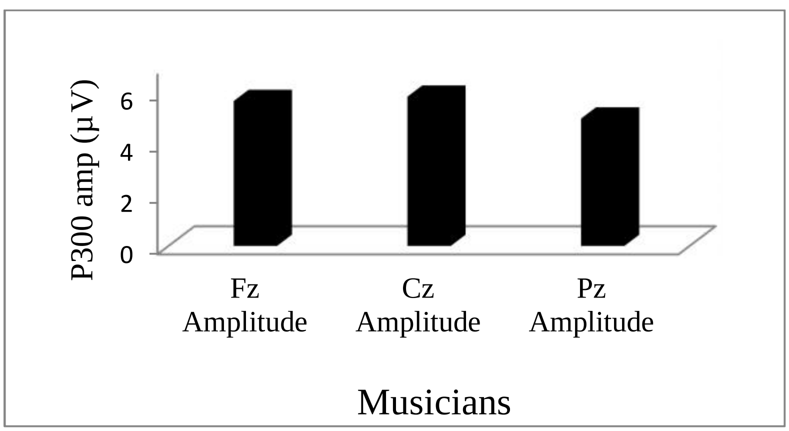

Figure 4:4: P300 amplitude (µV) in musicians. The X-axis represents various placements of recordings in musicians and non-musicians; the Y-axis represents amplitude of waveform.

In non-musicians, there is no significant difference between amplitudes (figure 4:5) of Fz, Cz & Pz sites with a F value of 2.082 & P>0.05. i.e., amplitude of all sites is almost equal.

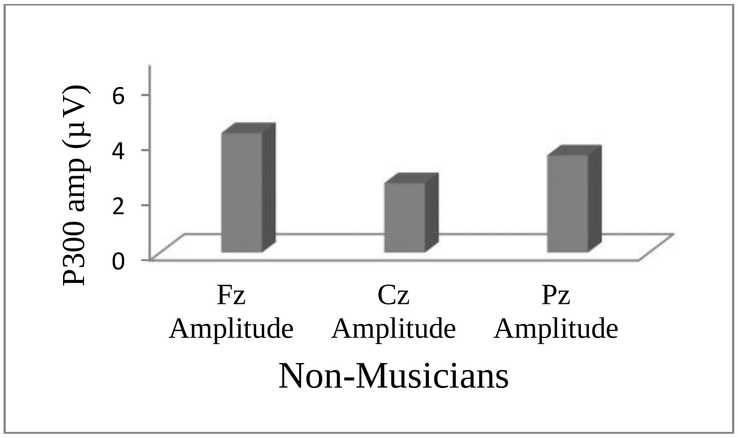

Figure 4:5: P300 amplitude (µV) in non-musicians. The X-axis represents various placements of recordings in musicians and non-musicians; the Y-axis represents amplitude of waveform.

2. FMDL

As per data in table 4.3, there is no significant difference found in FMDL scores between musicians and non-musicians (|z| = 1.641, P>0.05).

Table 4.3: FMDL (Hz) in musicians and non-musicians

	Non-musicians	Musicians
n	15	14
Mean	5.8551	4.9161
Std. Deviation	1.31039	1.39545
Median	5.3350	4.9155

Note. n = no. of subjects.

Musicians have lesser FMDL scores than non-musicians (figure 4:6). But the difference is not significant.

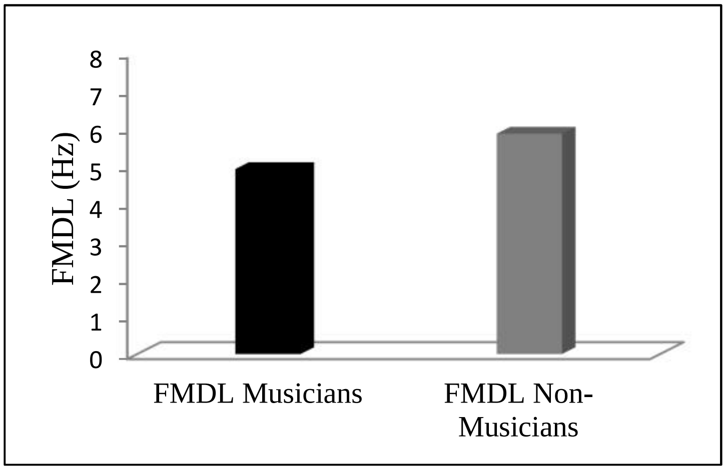

Figure 4:6: FMDL (Hz) scores in musicians and non-musicians. The X-axis represents subjects; The Y-axis represents FMDL scores.

3. Digit Span Tests

In Digit forward test, there is no significant difference between musicians and non-musicians. ($|z| = 1.523$, $P>0.05$). In Digit backward test, there is significant difference between musicians and non-musicians. ($|z| = 3.135$, $P<0.05$). Scores of digit span test in musicians and non-musicians are shown in table 4.4 & 4.5 respectively.

Table 4.4: Digit Span Scores in Musicians

	Digit_forward	Digit_backward
n	14	14
Mean	7.3571	6.7143
Std. Deviation	.63332	.91387
Median	7.0000	7.0000

Note. n = no. of subjects.

Table 4.5: Digit Span Scores in Non-musicians

	Digit_forward	Digit_backward
n	15	15
Mean	6.8000	5.5333
Std. Deviation	1.01419	.74322
Median	7.0000	5.0000

Note. n = no. of subjects.

Digit span scores of musicians and non-musicians are shown in figure 4:7, which shows musicians have higher digit forward and backward scores as compared to non-musicians.

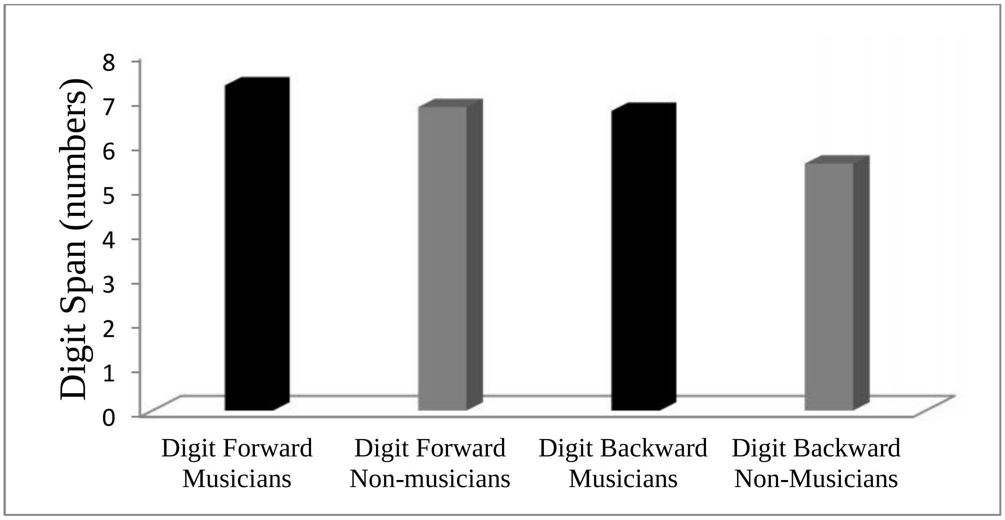

Figure 4:7: Digit span scores in musicians and non-musicians. The X-axis represents subjects; The Y-axis represents digit span scores in numbers.

In Musicians, there is significant difference between Digit-forward & Digit-backward scores. ($|z| = 2.008$, $P<0.05$). In Non-Musicians also, there is significant difference between Digit-forward & Digit-backward scores. ($|z| = 2.809$, $P<0.05$). Data of both the groups are shown in figure 4:8 and 4:9 respectively.

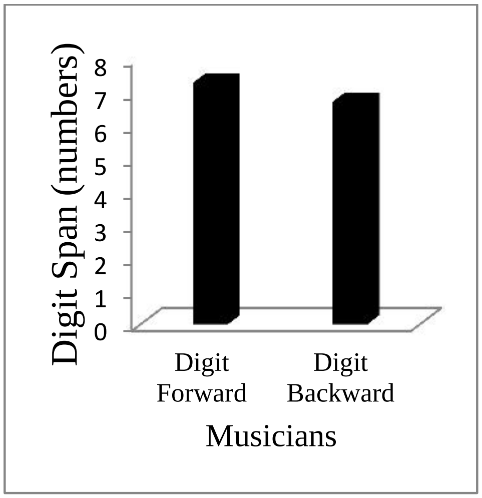

Figure 4:8: Digit span scores in musicians. The X-axis represents subjects; The Y-axis represents FMDL scores.

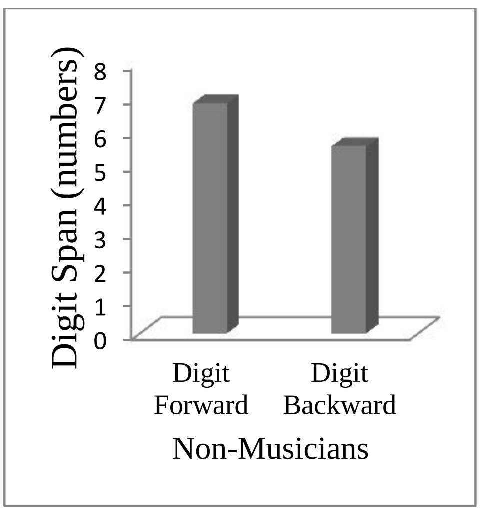

Figure 4:9: Digit span scores in non-musicians. The X-axis represents subjects; The Y-axis represents FMDL scores.

In the present study, higher mean P300 amplitude in musicians is obtained than non-musicians, which indicates that musicians have a superior ability to detect subtle differences in signals. The P300 response is thought to reflect an updating of working memory, and this is correlating with working memory test (Digit Span test) i.e., enhanced

P300 in musicians indicates better updating of working memory. The P300 response is likely to have multiple generators, mostly in and around the hippocampus. And hippocampus lobe is near to Fz & Cz electrodes, therefore amplitude of Fz & Cz, was found better than Pz amplitude in musicians, because studies have proved that musicians have better hippocampus lobe than non-musicians. This is consistent with the implication of the hippocampus in short-term memory formation. Activity evoked in primary auditory cortex is 102% larger in musicians, and the volume of gray matter in the anteromedial portion of Heschl's gyrus is 130% larger in musicians (Schneider P. et al., 2002). Volume of Gray matter is enhanced in motor as well as auditory and visuospatial brain regions in professional musicians (Gaser &Schlaug, 2003). Larger volume of gray matter is found in perirolandic regions including primary motor and somatosensory areas, premotor areas, anterior superior parietal areas, and in the inferior temporal gyrus bilaterally in professional musicians (Gaser & Schlaug, 2003). Musicians allocated more neural resources, reflecting greater sensitivity to the standard/deviant difference in auditory condition (George & Coch, 2010; Parbery-Clark et al., 2012). Music training is associated with selective improvements in working memory, on both neural and behavioral levels (George & Coch, 2010). Marked improvement was seen on neural differentiation of the syllables in musicians (Kraus et al., 2014). All these anatomical & neurophysiological factors are well correlated with the present study, in which it is found that enhanced P300 amplitude in musicians. Musicians had lower latencies and higher amplitudes than the non-musicians (Rabelo et al., 2015; George et al., 2011). Formally trained musicians showed more efficient neural detection of pure tones and harmonic tones; demonstrated superior auditory sensory-memory traces for acoustic features of pure tones, harmonic tones, and speech; and revealed enhanced sensitivity to acoustic changes of spectrally rich stimuli (Nikjeh et al., 2009). Mean P300 peak amplitude of 5.62 µV in musicians, which is significantly higher than 3.49 µV in non-musicians (George et al., 2010).

In this study it is observed that, musicians have better FMDL scores as compared to non-musicians, but the difference is not significant. Better FMDL scores in musicians indicate better discrimination ability in musicians. Frequency discrimination was found to be significantly better in musicians than non-musicians (Amir et al., 2014). Both behavioral and ERP tests reveal, Musicians detected the pitch changes faster and more accurately than non-musicians (Tervaniemi et al., 2005). Mean DLFs for musicians were approximately half the values of the non-musicians, which reveals musicians have better discrimination ability (Kishon-Rabin et al., 2001).

In Digit Span test, Digit backward scores are significantly better than non-musicians, which indicate better short term working in musicians. No significant difference was found in Digit forward scores, because it is equally easy for both musicians and non-musicians, so both groups scored almost equally. Musicians showed enhanced performance on measures of cognitive flexibility, working memory, and verbal fluency (Zuk et al., 2014). Different neural networks underlying verbal and tonal working memory in musicians, suggesting that functional plasticity has been induced by musical training (Schulze & Koelsch, 2012). Musical schooling has a positive influence on the recall of tones (Benassi-Werke et al., 2012). In standardized behavioral tests of working memory, musicians performed better than non-musicians (George and Coch, 2011).

Thus from the above results, it can be inferred that musical training improves performance on discrimination abilities, working memory and higher order processing, which can be evidenced through better FMDL, better Digit backward score and higher P300 amplitude respectively. This shows a better correlation of electrophysiological and behavioral tests on musicians.

Chapter 5

Summary & Conclusions

In the present study, electrophysiological test (P300) and behavioral tests (FMDL & Digit span tests) was done on musicians (vocalist) and non-musicians. After statistical analysis of data of all the tests, following results were obtained:

1. Higher P300 amplitude in musicians, compared to non-musicians.
2. Less FMDL in musicians, compared to non-musicians.
3. More scores on Digit Span test, in musicians, compared to non-musicians.

With all these findings, we can conclude that, musicians have enhanced higher order processing, which includes their capability to discriminate subtle difference in stimuli, both electrophysiologically and behaviorally. That is, P300 values are well correlated with FMDL values. Higher P300 values in musicians, compared to non-musicians reveals, enhanced working memory in musicians, compared to non-musicians. This is also well correlated with the higher scores of Digit Span tests in musicians, compared to non-musicians. So better correlation was obtained between psychophysical measures, working memory and electrophysiological measures in musicians, compared to non-musicians.

IMPLICATION OF THE STUDY

1. Present study has found the effect of music training on cognitive processes like working memory and neural discrimination of subtle difference in stimulus.

2. Music therapy can be included in the remediation of cognitively deficit individuals having learning disability, attention deficit hyperactive disorder, central auditory processing disorder, dementia etc.

References

Amir, N., et al. (2014). Pitch, Intensity, Duration and Spectrum – Psychoacoustic Thresholds of musicians compared to non-musicians. *ISMA.*

Anvari, S. H., et al. (2002). Relations among musical skills, phonological processing, and early reading ability in preschool children. *J Exp Child Psychol* 83(2): 111-130.

Benassi-Werke, M. E., et al. (2012). Musicians' working memory for tones, words, and pseudowords. *Q J Exp Psychol (Hove)* 65(6): 1161-1171.

Gaser, C. and G. Schlaug (2003). Brain structures differ between musicians and non-musicians. *J Neurosci* 23(27): 9240-9245.

Gaser, C. and G. Schlaug (2003). Gray matter differences between musicians and nonmusicians. *Ann N Y Acad Sci* 999: 514-517.

George, E. M. and D. Coch (2011). Music training and working memory: an ERP study. *Neuropsychologia* 49(5): 1083-1094.

George, E., & Coch, D. (2010). Neural and behavioral evidence of working memory differences in musicians and non-musicians. Poster presented at the *17th Annual Meeting of the Cognitive Neuroscience Society, Montreal, Quebec, Canada.*

Grose, J. H., & Ma'amo, S. K. (2012). Frequency modulation detection as a measure of temporal processing: age-related monaural and binaural effects. *Hear Res, 294*(1-2), 49-54.

He, N. J., Mills, J. H., & Dubno, J. R. (2007). Frequency modulation detection: effects of age, psychophysical method, and modulation waveform. *J Acoust Soc Am, 122*(1), 467-477.

James W. Hall. (2007). *New Handbook for Auditory Evoked Responses*. Pearson Allyn and Bacon Publishers.

Kishon-Rabin, L., et al. (2001). Pitch discrimination: are professional musicians better than non-musicians? *J Basic Clin Physiol Pharmacol* 12(2 Suppl): 125-143.

Kraus, N., et al. (2014). Music enrichment programs improve the neural encoding of speech in at-risk children. *J Neurosci* 34(36): 11913-11918.

Laures-Gore, J., Marshall, R. S., & Verner, E. (2011). Performance of Individuals with Left-Hemisphere Stroke and Aphasia and Individuals with Right Brain Damage on Forward and Backward Digit Span Tasks. *Aphasiology, 25*(1), 43-56.

Lopez, L., et al. (2003). Musicians versus nonmusicians. A neurophysiological approach. *Ann N Y Acad Sci* 999: 124-130.

Nikjeh, D. A., et al. (2009). Preattentive cortical-evoked responses to pure tones, harmonic tones, and speech: influence of music training. *Ear Hear* 30(4): 432-446.

Oechslin, M. S., et al. (2013). Degree of musical expertise modulates higher order brain functioning. *Cereb Cortex* 23(9): 2213-2224.

Overy, K., et al. (2003). Dyslexia and music: measuring musical timing skills. *Dyslexia* 9(1): 18-36.

Pantev, C., et al. (1998). Increased auditory cortical representation in musicians. *Nature* 392(6678): 811-814.

Parbery-Clark, A., et al. (2012). Musicians have fine-tuned neural distinction of speech syllables. *Neuroscience* 219: 111-119.

Patricia Espe-Pfeifer, Jana Wachsler-Felder. (1949). Neuropsychological Interpretation of Objective Psychological Tests *(Critical Issues in Neuropsychology)*. Kluwer Academic/ Plenum Publishers.

Rabelo, C. M., et al. (2015). Cortical inhibition effect in musicians and non-musicians using P300 with and without contralateral stimulation. *Braz J Otorhinolaryngol* 81(1): 63-70.

Schneider, P., et al. (2002). Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nat Neurosci* 5(7): 688-694.

Schulze, K. and S. Koelsch (2012). Working memory for speech and music. *Ann N Y Acad Sci* 1252: 229-236.

Schulze, K., et al. (2011). Neural correlates of strategy use during auditory working memory in musicians and non-musicians. *Eur J Neurosci* 33(1): 189-196.

Strait, D. L., et al. (2012). Musical training during early childhood enhances the neural encoding of speech in noise. *Brain Lang* 123(3): 191-201.

Tervaniemi, M., et al. (2005). Pitch discrimination accuracy in musicians vs nonmusicians: an event-related potential and behavioral study. *Exp Brain Res* 161(1): 1-10.

Wilde, N., & Strauss, E. (2002). Functional equivalence of WAIS-III/WMS-III digit and spatial span under forward and backward recall conditions. *Clin Neuropsychol, 16*(3), 322-330.

Zuk, J., et al. (2014). Behavioral and neural correlates of executive functioning in musicians and non-musicians. *PLoS One* 9(6): e99868.