Effect of Musical Training on Auditory Working Memory, Temporal Processing, Perception of Speech in Noise & Neural Plasticity in Children with Learning Disability

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This Dissertation is submitted as a part of fulfilment

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CERTIFICATE

This is to certify that this dissertation entitled **'Effect Of Musical Training On Auditory Working Memory, Temporal Resolution, Perception of speech In Noise & Neural Plasticity In Children With Learning Disability'** is the bonafide work submitted in part fulfilment for the Degree of Master of Science (Audiology) of the student with Registration No: **17AUD018**. 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.

Mysuru
May 2019

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CERTIFICATE

This is to certify that this dissertation entitled **'Effect Of Musical Training On Auditory Working Memory, Temporal Resolution, Perception of speech In Noise & Neural Plasticity In Children With Learning Disability'** 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.

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DECLARATION

This is to certify that this Master's dissertation entitled **'Effect Of Musical Training On Auditory Working Memory, Temporal Resolution, Perception of speech In Noise & Neural Plasticity In Children With Learning Disability'** is the result of my own study under the guidance of Dr. Rajalakshmi K, Professor of 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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I dedicate my first ever scientific work to Mumma (Kalpana Sharma), Papa (Rajendra Sharma), Big D (Babulal Sharma), Amu-Divu (Aman & Divyansh Sharma), to GURUDEV and to all my teachers for being who you are.

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Abstract

Introduction: There is a great association between music, auditory processing and neural plasticity. Children with Learning Disability face problems with auditory processing; and as musical training facilitates these skills and neural plasticity, an attempt is made to see the effect of musical training in children with learning disability.

Aim of the study: The aim of the study was to see the efficacy of musical training in children with Learning Disability.

Method: Two groups of Learning Disabled children (N=20, 10 in each group), were taken. One group received musical training and another did not. Two evaluations were done, one before training and another after training. Test of auditory working memory (Digit Span Test), Temporal processing (Gap detection test, duration pattern test, pitch pattern test), and Speech perception in noise along with LLR were done. Pre and post training scores of both groups were compared.

Results: All the behavioural tests showed improvement after training in the experimental group, whereas no differences were seen in control group. Individual differences were noted when improvement of all subjects was compared within each measure. Reduced latency of P2, increased N1-P2 amplitude was also noted.

Conclusion: Musical training is effective for enhancing auditory processing skills and neural plasticity. However, individual factors might affect its benefits.

Table of Contents

List of Tables

List of Figures

Chapter 1

INTRODUCTION

Learning disabled/disability is a general term that refers to a heterogeneous group of disorder manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning and/or mathematical abilities. These disorders are intrinsic to the individual presumed to be due to central nervous system dysfunction and may occur across a life span, but mostly it is found as a developmental disorder (National Joint Committee on Learning Disability (NJCLD), 1988).

Music is one of the socio-cognitive domains of the human species; in every human culture, people have played and enjoyed music (Huron, 2001). Music perception and even more, music creation or production are considered as one of the demanding tasks for the human brain engaging virtually all cognitive (sensory and motor) processes and precise monitoring of performance (Schlaug. et al, 2001.) Performing music at a professional level is undoubtedly a complex task. For example, a pianist has to bi-manually coordinate the production of up to 1,800 notes per minute. Music is a complex sensory stimulus and is structured in several dimensions (Schuppert et al, 2000). This richness makes music an ideal tool to investigate the functioning of the human brain (Munte, Altenmuller & Jancke, 2002). Neuroscience research has shown that music training leads to changes throughout the auditory system that prime musicians for listening challenges beyond music processing. This effect of music training suggests that, akin to physical exercise and its impact on body fitness, music is a resource that tones the brain for auditory fitness (Kraus & Chandrasekaran, 2010).

Studies have documented that musical training auditory processing abilities influences (Musacchia, Sams & Skoe, 2007) resulting in both altered behavioral and electro-physiological responses (Saha & Rajalakshmi, 2013). Parbery-Clark et al. (2009) found a distinct speech in noise advantage for musicians as measured by Quick Speech Perception in Noise (QuickSIN) test. Memory plays a central role in general cognition and hence it has become the focus of a rapidly growing literature that seeks to affect broad cognitive change through prolonged training on tasks. Evidence from literature has shown that music training is capable of improving memory (Jayakumar & Gore, 2014). Many researchers have tried to explore differences in visual and auditory (both verbal and non-verbal) memory between musicians and s. Children with language-based learning impairments (LLIs) have major deficits in their recognition of some rapidly successive phonetic elements and nonspeech sound stimuli (Merzenich et al., 1996).

Music reaches where words alone can't. Literature provides evidences for how music exposure makes cortical organization stronger (Musacchia, 2007), how it affects the cognitive abilities, temporal processing and ultimately speech perception. Children with Learning Disabilities have deficits in these domains, and evidences of music helping them provide us with an idea of using it as a treatment tool.

1.1 Justification for the study

Music perception appears to tap auditory mechanisms related to reading that only partially overlap with those related to phonological awareness, suggesting that both linguistic and nonlinguistic general auditory mechanisms are involved in reading (Anvari, Trainor, Woodside & Levy, 2002). Musical expertise, often linked to early and intensive learning, is associated with neuroanatomical distinctive features that have been demonstrated through modern neuroimaging techniques, especially magnetic resonance imaging (MRI) (Habib & Besson, 2009). Musical training provides a good and adequate neuro scientific model to study multimodal brain plasticity effects in humans, the musically trained subjects showed significant enlargement of MMN, reflecting greater enhancement of musical representations in auditory cortex (Lappe, Herholz, Trainor, & Pantev, 2008). Music and speech are very cognitively demanding auditory phenomena generally attributed to cortical rather than subcortical circuitry (Wong, Skoe, Russo & Kraus, 2007).

One of the evidence-based explanations for such a result of enhanced memory in musicians is given by Pallesen et al., (2010). Their study result showed that superior working memory skills in musicians rely on their enhanced cognitive control which is possibly a consequence of focused musical learning. In this study, they measured the blood oxygenation-level dependent (BOLD) activation signal in musicians and s during the working memory task. They observed differential brain activity wherein, musicians had larger BOLD responses than s in brain areas responsible for cognitive control, including regions of the lateral prefrontal cortex, lateral parietal cortex, insula and putamen in the right hemisphere, and bilaterally in the posterior dorsal prefrontal cortex and anterior cingulate gyrus. According to Kraus et al, 1996 children with Learning problems often cannot discriminate rapid acoustic changes that occur in speech, these temporal processing deficit can be overcome by training.

Musical training is thought to improve nervous system function by focusing attention on meaningful acoustic cues and these improvements in auditory processing cascade to language and cognitive skills (Kraus et al., 2014). The beneficial effects of musical training are not limited to enhancement of musical skills, but extend to language skills, (Tierney &

Kraus, 2013), thus we can assume musical training might improve speech perception and language learning as well.

Evans (1967) reported that the perceptual problems might occur due to-

i. Problems in temporal ordering of auditory impulses, incident at the temporal cortex.
ii. Problems in coding of auditory impulses at the terminal cortical areas of temporal cortex.
iii. Faulty transmission of impulses along the synaptic junction of the brainstem.

Adults who received formal music instruction as children had more robust brainstem responses to sound than peers who never participated in music lessons and that the magnitude of the response correlates with how recently training ceased. Study showed that neural changes accompanying musical training during childhood are retained in adulthood, (Skoe & Kraus, 2012), thus it is possible for effects of musical training to last longer than usual training.

Studies reveal that musicians' advantages for processing speech in noise are present during pivotal developmental years. Supported by correlations between auditory working memory and attention and auditory brainstem response properties, (Strait, Parbery-Clark, Hittner & Kraus, 2012), propose that musicians' perceptual and neural enhancements are driven in a top-down manner by strengthened cognitive abilities with training.

Specific learning disability (dyslexia, dysgraphia, and dyscalculia) afflicts 5-15% of school-going children (Karande, 2011). This study will help us in putting together all these magical effects of musical training for fulfilling the requirements of children with

Learning Disability. A structured musical training will not only bring the expected progress but would also lighten up the ways of treatment for these children. In this study an attempt will be made to correlate the effect of musical training on neural plasticity using behavioural and electrophysiological measures. All these measures will provide evidence based outcomes of musical training in children with Learning Disability.

1.2 Aim of the study

The aim of the study was to see the efficacy of musical training in children with Learning Disability.

1.3 Objectives of the study

1.3.1 To see the effect of musical training on auditory working memory

1.3.2 To see the effect of musical training in temporal processing

1.3.3 To see the effect of musical training in speech perception

1.3.4 To see the effect of musical training on neural plasticity

Chapter 2

REVIEW OF LITERATURE

About 5% of children in primary school exhibit severe and long-lasting problems in acquiring written language despite normal intelligence, adequate educational opportunities and in the absence of any obvious neurological or sensory deficiencies (Snowling, 2000). Learning Disability is a very general term. It comprises of many little problems within. Children with learning disability not only face difficulties in school, but also in day-to-day life. Every conversation that we have makes use of higher order functioning. Even though these children have no issue with their peripheral mechanisms, but they face a lot of problems when tasks involve central nervous system. Few of the many problems that they face are, difficulty to understand speech in noise, getting easily distracted, forgetfulness, or not being able to memorize at all. They may also have problem with reading and writing, which is also a form of communication. Because these problems somewhere cause issues with communication, auditory processing and academics the role of audiologist is crucial while dealing with it.

Zatorre (2002), examined the evidence that speech and musical sounds exploit different acoustic cues. Auditory processing of an individual can be measured through either behavioural tests or electrophysiological tests. Behavioural tests mainly aim at cutting down the external redundancy and assess for the processing of modified auditory stimuli. Each of these tests assess one or more of auditory processes and are sensitive to cortical and/or brainstem lesions of the auditory pathway. On the other hand electrophysiological tests assess for the underlying neurophysiology. Auditory evoked potentials (AEPs) provide powerful objective methods of assessing the neural integrity of pathway from auditory nerve to cortex (Hood, 1998). Using these techniques, it is possible to follow the course of brain's activity in time with the precision of tens of milliseconds and thus obtain knowledge not only of the end product of processing but also of the sequence, timing and stages of specific processes (Tapio, Leppanen & Lyytinen, 1997).

A majority of the electrophysiological studies carried out on learning disordered population have used cortical potentials to understand the auditory processing. Prolonged latencies (Byring & Jaryilehto, 1985; Jirsa & Clonts, 1990; Arehole, 1995; Radhika, 1997) and reduced absolute amplitudes (Pinkerton, Watson & McClelland, 1989; Jirsa & Clontz, 1990) for P1, N1, P2 and N2 waves have been reported in children with learning disability. Long latency responses give information regarding the basic representation of the sound signal.

2.1 Learning Disability and auditory processing

2.1.1 Learning Disability and Auditory working memory

Siegel & Ryan (1989) reported that children with Learning Difficulties were impaired if they have to retain temporary information concurrently with counting visual arrays, but not if the concurrent operations were not mathematical. This selective deficit was attributed to an impaired working memory system. Hitch & McAuley (1991) found that LD group tended to count more slowly than normal controls and had lower auditory digit spans. Swanson & Lee (1993) investigated the degree to which working memory differs between learning disabled and normal children. Their results suggest that learning-disabled children suffer generalized working memory deficits, possibly due to storage constraints in the executive system. In a study by Cohen-Mimran & Sapir (2007) performed a study on LD children to assess the two components of working memory by memory span and central executive system. They found that LD group performed significantly poorer that the normal control group.

2.1.2 Learning Disability and Temporal processing

Learning disabled children make more errors than controls when the stimuli is presented rapidly (Tallal, 1980). Reading group differences for same-different judgments involving pairs of different frequency tones were also found by De Weirdt (1988). In addition to the findings with simple tone matching studies, dyslexics have also been found to be impaired when required to match more complex stimuli. Poor readers 7:9 to 10:4years of age were found to be worse than good readers on same-different judgments for pairs of synthesized consonant-vowel syllables (ba/da) from a phoneme continuum (Reed, 1989). She presented her subjects with pairs of vowel and pairs of consonant-vowel stimuli with a duration of 250 msec and with pairs of pure tones with a duration of 75 msec (as in the Tallal, 1980, study) and required them to perform a temporal order judgment with Interstimulus interval (ISIs) varying from 10 to 400 msec. Reed (1989) found that her reading disabled group was impaired relative to controls as ISIs decreased for pairs of tones and pairs of consonant-vowel syllables. Kinsbourne et al. (1991), May et al. (1988), Muller & Bakker (1968) all of them found a significant difference in performances of learning disabled and control group on task of temporal processing. The auditory temporal deficit hypothesis suggests that at least a subgroup of children with reading disorder have a deficit in low level auditory temporal processing that affects the perception of short transitional acoustic elements that provide important acoustic cues for phonemic contrasts (Miller & Fitch, 1993). The learning disabled group performed significantly more poorly on the temporal task such as Duration Pattern Test (DPT) and Pitch Pattern Test (PPT) in the study done by Watson (1992).

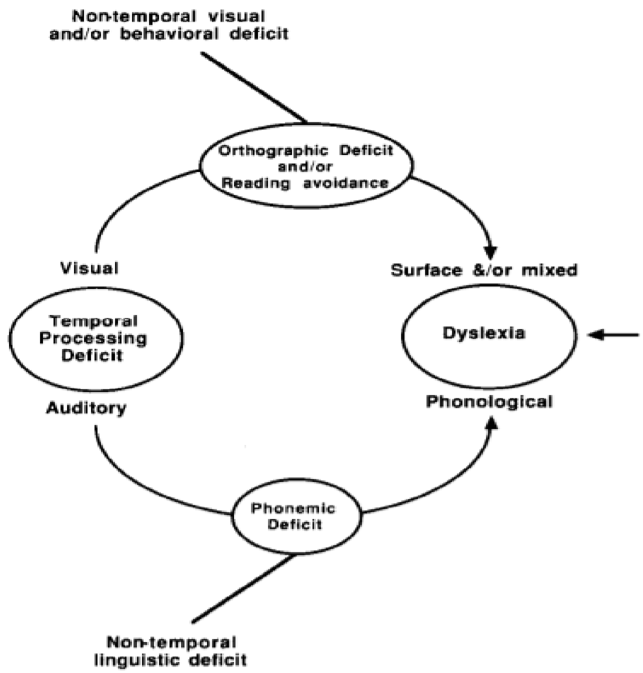

Figure A simplified view of the potential pathways to dyslexia from a temporal processing deficit in either the auditory or the visual modality.

Figure 2.1 Taken from The evidence for a temporal processing deficit linked to dyslexia: Mary E. Farmer and Raymond M. Klein (1995)

2.1.3 Learning Disability and speech perception in noise

In the study done by Ziegler et al (2009), learning disabled children exhibited clear speech perception deficits in noise but not in silence. They concluded that the core deficit of LD children was a lack of speech robustness in the presence of external or internal noise. LD children have a perceptual deficit that may interfere with processing of phonological information and speech perception difficulties may also be partially related to reading experience as reported by Manis et al (1997). The results of study by Hayes et al. (2003), suggest that the perception of simultaneous auditory and visual speech differs between normal listeners (NL) and LD children, perhaps reflecting variations in neural processing underlying multisensory integration.

2.1.4 Learning Disability and neural plasticity

Auditory evoked potentials such as auditory brainstem response, middle latency response and long latency responses can be used to study the basic representation of sound signals in the auditory nervous system. The hypothesis that children with learning disability have auditory processing disorder has been experimentally investigated by many studies. But, whether these auditory deficits are seen only in association with the language disorder or as causal factor is yet to be explored (Rosen, 2003). There are ample studies investigating speech evoked ALLR in children with learning disability. Cunningham, Nicol, Zecker and Kraus (2000) evaluated the maturational progression of speech-evoked P1/N1/N2 cortical responses over the life span. They reported that maturational patterns in the group of children with learning problems did not differ from the normal group. Learning and speech-in-noise perception, fundamental aspects of human communication, have been linked to neural indices of auditory brainstem function. When phonological processing and working memory measures were added to the models, brainstem measures still uniquely predicted variance in reading ability and speech-in-noise perception, highlighting the robustness of the relationship between sub cortical auditory function.

2.2 Effect of music on auditory processes

Coffey (2017), published a review article on Speech-in-noise perception in musicians. They have summarised 29 studies that discuss effect of music in perception of speech in noise. Musicians had several advantages over non-musicians. It directs us to ponder over effects of music. Ruggles et al. (2014), found no significant group differences in musicians while coding periodic voiced speech in continuous and fluctuating noise. Boebiner et al., (2015) reports musicians have no advantage on perceptual accuracy when degraded by spectrally rotated speech, speech spectrum steady state noise or speech amplitude modulated noise.

Whereas, Parbery-Clark et al., (2009) mentioned musicians outperformed non-musicians on both QuickSIN and HINT. He also reported they had better working memory and more fine grained frequency discrimination. Slater et al., (2015) concluded two years of music instruction in children showed clinically meaningful gain in SIN perception, and longer periods of training was related to greater SIN perception improvements. Baskent and Gaudrain, (2016) studied whether there is a musician advantage for speech on speech perception and if there is, how it varies with differences in two voices. They found, musicians performed better than non-musicians in all conditions. Clayton et al., (2016) also reported better performance of musicians in SIN perception along with better cognitive processing. Swaminathan et al., (2015) assessed perception of speech in musicians using varying informational and energetic maskers. He noted that musicians performed better than non-musicians in all conditions.

Parbery-Clark et al., (2011) tried to assess effect of music in SIN test, auditory working memory, auditory temporal acuity and visual working memory. They found musicians performed better in all the auditory tasks when compared to non-musicians. The same authors also noted that musicians have a stronger representation of the f0 in predictable condition whereas non-musicians did not.

Coffey et al., (2016) measured if the strength of periodicity encoding within different brain structure correlated with SIN scores and musicianship. They concluded, FFR-f0 representation localized to auditory cortex, thalamus, and brainstem (using MEG) correlated with SIN performance. And FFR-F0 in right auditory cortex was related to measures of musical experience. Musicians outperformed non-musicians at all SNRs and showed stronger recruitment of auditory ventral and dorsal regions. They also showed enhanced specificity of phoneme representations in bilateral auditory ventral regions according to study done by Du and Zatorre, (2016). Musacchia et al., (2008) performed a study to see if musical training shapes the auditory system in a coordinated manner or in disparate ways at cortical and subcortical levels. Parbery-Clark et al., (2012) reported that even aged musicians had better HINT scores, and had greater neural fidelity of the stimulus with faster neural response timing, better envelope encoding, greater neural representation of the stimulus harmonics.

The same author in 2009 reported, musicians demonstrate faster neural timing, enhanced representation of speech harmonics, and less degraded response morphology in noise. Bidelman and Weiss, (2014) in their study mentioned that musicians were faster at categorizing speech tokens and feature a more pronounced boundary between phonetic categories as compared with non-musicians.

Parbery-Clark et al., (2012) performed a study to see if musical training offset had any negative impact of aging on neural processing. And they found that musicians showed less age related effects. Strait and Kraus, (2011) questioned if musical training benefit cortical mechanisms that underlie selective attention to speech. Coffey et al., (2016) concluded that FFR-f0 amplitude from right but not left auditory cortex correlated with age of training onset. Varnet el al., (2015) also showed similar finding in his study. He reported that musicians performed better and demonstrated faster learning and relied more on acoustic cues.

Musacchia et al., (2007) performed a study to see if musicians had more robust EEG responses to speech and music. And he found that musicians had earlier and larger onset responses as compared with s. Fuller et al., (2014) mentioned that musicians were better able to identify words in speech-shaped noise. According to Strait et al., (2010) musicians have lower perceptual thresholds, specifically for auditory tasks that relate with cognitive abilities, such as backward masking and auditory attention.

2.3 Music training, Learning Disability & Auditory Processing

Compared to controls, the trained group (learning disability children group) improved on measures of auditory processing and exhibited changes in cortical responses in quiet and in noise. In quiet, cortical responses reflected an accelerated maturational pattern; in background noise, cortical responses became more resistant to degradation. Brainstem responses did not change with training (Hayes et al., 2003). There is growing evidence in literature that children with APD improve with auditory training programs. Both behavioural and electrophysiological tests have been used to document the improvement in auditory skill. Tremblay et al., (2001) studied the effect of auditory training on N1p2 complex on ten normal hearing children. They showed that perception improved, N1P2 amplitude increased. These findings suggest that the N1P2 complex may have clinical applications as an objective physiologic correlate of speech sound representation associated with speech sound training.

Register et al., (2007) studied the use of music to enhance reading skills of second grade students with learning disabilities. They found that children with learning disability made greater gains pre to post than the control group on all the subtests. Hooper (2002), studied the effect of music to develop peer interaction in children with learning disability. Numerous studies reveal how individuals exposed to music perform better in auditory tasks. Learning disabled children if trained using music might also get better in auditory performance. Besson and Mireille, (2007); Schon and Daniele, (2007); Moreno and Sylvian, (2007); Santos and Andreia, (2007); Magne and Cyrille (2007) studied influence of musical expertise and musical training on pitch processing in music and language. Results revealed that a set of common processes maybe responsible for pitch processing in music and in speech these processes these processes are shaped by musical practice. They also concluded that it provides evidence in favour of brain plasticity and open interesting perspectives for the remediation of learning disability using musical training. Overy (2006), studied effect of music lessons on children with learning disability and found that there is significant improvement post lessons in their timing skills and pitch skills. Overy (2000), in her study reported that temporal processing ability was improved through training, which may lead to improved language and literacy skills.

There is a lack of studies that talk about music training that can be given by an audiologist, therefore development of music training modules and evidences of their positive effects on auditory processes in learning disabled children should be provided using more studies.

Thus, it can be concluded that music training improves auditory abilities of children with learning disability. The above mentioned investigations have also revealed that the improvement with training can be monitored using Auditory Working memory test, temporal processing test, Speech in Noise Test (SPIN) and LLR. Also Music training might provide a valuable multisensory support tool for dyslexic children by encouraging the development of important auditory and motor timing skills and subsequently language skills.

Chapter 3

METHODS

The aim of the present study was to determine the effect of musical training on auditory working memory, temporal processing, speech perception in noise, and neural plasticity in children with learning disability.

3.1 Research Design

It was hypothesized that, after the musical training learning disabled children will show significant improvement in Digit Span Test, Pitch Pattern Test, Duration Pattern Test, Speech in Noise Tests and in Late Latency Response. To test the hypothesis, Bivalent Between subject quasi experimental design was employed. All the mentioned tests were performed for all the subjects. All the subjects underwent pre training evaluation and thereafter, depending on their willingness and availability, they were assigned to experimental or control group. In order to equate the experimental and control group matching was done in such a way that all the extraneous variables such as age, severity of the problem etc. were similarly distributed.

3.2 Participants

A total of 20 participants in the age range of 8 to 12 years were selected for the study. The participants had normal hearing sensitivity (PTA within 15 dBHL for all audiometric frequencies, 250 Hz through 8000 Hz), had normal middle ear function (confirmed through Immittance evaluation). The participants of the study were not familiar with the tests and stimuli. A written consent was taken from all the participants for their willingness to participate in the study.

All 20 participants were diagnosed with Learning Disability, by a Speech Language Pathologist. All of them were given the chance to attend musical training, further depending on their willingness to attend training, they were either put in the experimental group that received musical training or they were made part of control group which did not receive the musical training. Ethical guidelines for Bio-behavioural research at All India Institute of Speech & Hearing, (Venkatesan, 2009) were followed during the study.

Table 3.1:

The mean and standard deviation of age in groups

GROUP	MEAN AGE (years)	SD
CONTROL	10.20	0.38
EXPERIMENTAL	10.52	0.42

3.3 Test Environment

All the experiments were carried out in a quiet room with good illumination, ventilation and minimum distraction. The rooms used for AEP recordings were also electrically shielded.

3.4 Instrumentation

1. Calibrated 2-channnel Piano Inventis diagnostic audiometer with TDH-39 and bone vibrator B-71 will be used for obtaining air conduction and bone conduction hearing thresholds, speech thresholds.

2. Calibrated GSI-Tympstar with probe frequency 226Hz will be used for Tympanometry and Reflexometry, to rule out middle ear pathologies.

3. A Laptop (Lenovo ideapad 320 model) installed with MATLAB version 7.10 (Mathworks Inc., 2010) for psychoacoustic tests.

4. Sennheiser HDA 200 circumaural headphones with MX 141 adapter for presentation of stimuli.

5. Calibrated 2-channnel Piano Inventis diagnostic audiometer with TDH-39 and bone vibrator B-71 will be used for obtaining SPIN scores as a Measure of speech perception

6. IHS (Intelligent Hearing System) Smart EP (3.94 USBez) system with ER-3A Insert ear phones will be used for recording Late Latency Response.

3.5 Materials

1. Psychophysical testing: The stimuli for all the psychophysical tests except for duration pattern test were generated through maximum likelihood procedure toolbox 9mlp toolbox, (Grassi & Soranzo, 2009) implemented in matlab. The details of the specific stimuli are provided under each test in the section 3.6. The stimulus for duration pattern test was generated using Audacity Software.

2. Working memory assessment: The measure of forward digit span test was done using Smriti Shravan Software developed by Kumar and Maruthy (2013).

3. Speech in Noise Test: It was done using standardized kannada word list (Manjula, Geetha, Sharath & Antony, 2012) at 0 dB SNR.

3.6 Stimulus and Procedure

3.6.1 Digit Span Test

Forward Digit Span (FDS) test: Participants were presented with a series of digits (e.g., '8, 1') and were instructed to immediately repeat them in the same given order. The inter-stimulus interval between two digits was 250ms. If they repeat it back successfully, they were given a longer list (e.g., '7, 2, 4'). This procedure continued until the participant failed to repeat the digits correctly. When the participant fails then another list with the same number of digits was presented. If the participant could repeat it correctly in the same order then he could go to the next series else the previous series (where he could repeat it successfully) was considered as his/her digit span memory.

3.6.2 Pitch pattern test

In this test, participant's ability to sequence the three tones varied in pitch was assessed. The test was performed in the similar way as given by Pinheiro (1977) and test stimulus was adapted from Kumar and Sangamanatha (2011). It consisted of 3 tones of 150 msec and 2 intertone intervals of 200 msec with 10 msec rise-fall time & 6 combinations-LLH, LHL, LHH, HLL, HLH, and HHL. The child was supposed to hum, write or verbally say the pattern of stimuli. Total of 30 series were used, and score was further converted in percentage.

3.6.3 Duration Pattern Test

In this test, participant's ability to sequence the three tones varied in duration was assessed. The duration pattern test (DPT) was performed in the similar way as given by Musiek (1994) and test stimuli were adapted from Kumar and Sangamanatha (2011). A 1000 Hz pure tone was generated using Audacity Software with two different durations (i.e. short 250 ms and long 500 ms). These two durations were combined in three tone pattern and thus six different patterns were generated. Test consisted of 30 test trials, every correctly repeated sequence was awarded a score of one and thus maximum score possible was 30. The score was converted to percentage at the end. So, possible score was 0% to 100%.

3.6.4 Gab Detection Test

The participant's ability to identify temporal gap in the centre of a 500 ms broadband noise was measured (Harris et al., 2010). The minimum and maximum duration of gap used was 0.1 ms and 64 ms. A three alternate forced choice method was used in which out of three blocks, two blocks consisted of a 500 ms broadband noise with no gap and the other block had a variable stimulus with the gap in it. The participants were asked to identify the block with the variable stimuli. The minimum gap duration corresponding to 79.4% confidence level in the psychometric function was calculated with MLP toolbox.

Figure 3.1 shows the graphical representation of waveforms of the stimuli used in gap detection test.

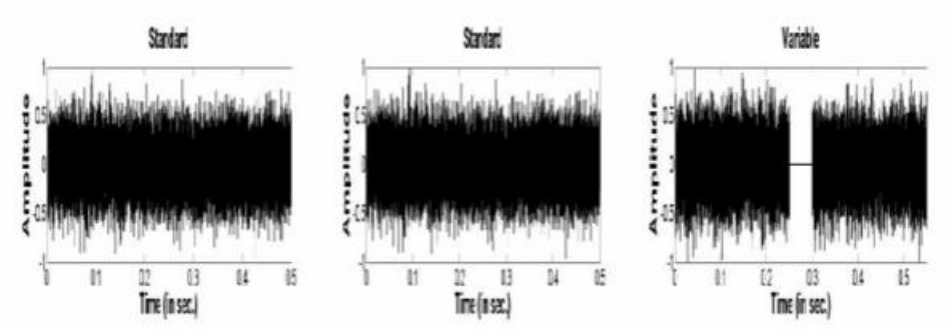

Figure 3.1 Shows the graphical representation of waveforms of the stimuli used in gap detection test.

3.6.5 Perception of Speech in noise

To test children's perception in noise word lists of Phonemically balanced words in Kannada by Manjula, Geetha, Kumar and Antony (2012). Each list had 25 words embedded in noise at -3dB SNR. The numbers of words repeated correctly were noted and were converted to percentage.

3.6.6 Late Latency Response

Subjects were seated in a comfortable position to ensure a relaxed posture and minimum muscular artifacts. They were instructed to relax and close their eyes or sleep. Two recordings were done to ensure replicability. The data was acquired after ensuring that the impedance at all electrode sites was within normal limits. The protocol used for recording is described in Table 2.

Table 3.2:

The parameters used while recording LLR

Stimulus Parameters	
Type	Speech (/da/- 40 msec)
Rate	1.1/sec
Polarity	Rarefaction
Intensity	70 dBHL
Number of sweeps	≤200
Presentation ear	Monoaural
Acquisition Parameters	
Amplification	50000 times
Sensitivity	25 or 50 μvolts
Analysis time	500 ms
Prestimulus time	100 ms
Data points	512
Filters: Band Pass	1 Hz – 30 Hz
Notch	
Electrode	
Type	Disc
Electro sites	Noninverting – Cz
	Inverting – A1

Ground – A2

Data analysis

The responses were analyzed for latency and amplitude of ALLR. In the ALLR P1, N1, P2 and N2 peaks were identified through visual inspection of the standard waveform. Peak latency, peak amplitude and relative amplitude of the waves were noted.

3.7 Experimental Procedure

3.7.1 Preliminary Audiological Evaluation

The Audiological evaluation was done only to rule out any peripheral hearing loss.

3.7.2 Experimental Procedure

Phase 1: All the subjects underwent pre-training evaluation in order to derive the baseline. Both behavioural and electrophysiological tests were included. Behavioural tests were Digit Span Test (DST), Gap Detection Test (GDT), Duration Pattern Test (DPT), Pitch Pattern Test (PPT) and Speech in Noise Test (SPIN); Late Latency Response (LLR) was the electrophysiological test.

Phase 2: Enrollment for therapy: 10 children were randomly given the allotment for therapy. Rest of the 10 children were taken for therapy later, but their scores were compared as a control reference.

Therapy was conducted successively, keeping in mind the reiteration effects and considering that learning requires repetitive & continuous stimulation.

Each session was of 45 minutes.

The therapy session involved musical training using recorded musical stimulus. This musical stimulus was recorded with the help of trained musician.

Music Modules

To begin with the study, two modules will be taken. These modules will involve, Basic Swara Patterns (Sarali Swaras) in the form of Chowkas, Janti patterns involving pairs, and combination of swaras that vary in pitch.

Chowka is a pattern of swaras in which each swara is prolonged and is followed by next one with spaces within it. It is hypothesized that variations in these patterns that take place in terms of duration will tap on temporal resolution and temporal patterning.

Janti pattern will be a pair of same swara like, (sasa..riri..gaga.. and so on). It is assumed that patterns like these will tap skills like rhythm.

The varying pitch of swaras might help children to make their pitch perception stronger.

Ultimately, children will be trained using all these recorded music modules and at the end their effect will be seen on the measures discussed earlier.

Training involved 3 activities.

Activity 1: Listening to a 15 minute long musical melody, which comprises musical instruments being played. In this activity child need not pay keen attention to the target, he/she might involve in other age appropriate activity such as playing with toys. This activity is a passive listening task just to stimulate the cortical areas responsible for music perception.

Activity 2: Identification of target Janti Pattern. In this activity series of Janti patterns were introduced to the child, and he/she was instructed to identify whether in the presented series target pattern was present or not.

Example:

Target: SaSa

Janti Pattern: NiNi…DhaDha, **Sasa**…ReRe (Child must identify SaSa) for increasing the difficulty level number of patterns were increased and number of targets too.

Activity 3: Discrimination between chowkas. In this activity, child chowkas will be presented to the child. These chowkas will differ in terms of number of swaras and duration between them. The child has to discriminate whether the 2 presentations were same or different. The difference between the number of swaras was reduced as the child could perform better.

Example:

I. Based on number of swaras

aa..aa..aa..aa..aa..aa..aa vs aa..aa (Easy)

aa..aa..aa..aa vs aa..aa..aa (Difficult)

II. Based on spaces between swaras

aa…..aa.….aa.….aa vs aa.aa.aa.aa (Easy)

aa…aa…aa…aa vs aa..aa..aa..aa (Difficult)

PHASE 3

1. After the therapy all subjects were again administered with all 5 measures.
2. First, comparisons were made between pre-training findings of the control and experimental group.
3. Second, comparisons were made for pre and post musical training findings within the experimental group and within the control group separately.
4. Second, comparisons were made across all subjects of the experimental control group, for each test separately.

4.8 Response Analysis

The data obtained from the study was subjected to statistical analyses using the Statistical Package for the Social Sciences (Version 17) and Amos (Analysis of Moment Structures, version 18, SPSS Inc, Chicago). Descriptive statistics was carried out to estimate the mean and standard deviation for all the parameters. Following this, normality and other assumptions of parametric tests were assessed.

Depending on the descriptive analysis, further inferential statistics was done.

Chapter 4

RESULTS

The study was done to find the effectiveness of Musical Training in children with learning disability. Its effect on auditory working memory, temporal processing, speech perception and neural plasticity was observed. The data of 20 children who were diagnosed with learning disability were analyzed. While 10 of these children received music training, 10 did not. Before going ahead with the statistical analysis, data was screened to look for outliers, as no participants had exceptionally low or high scores all of them were considered for further analysis. Descriptive statistics was done and normality of the data was checked using Shapiro-Wilk test. After descriptive statistics, it was noted that most of the tests did not fulfil the assumptions of normality ($p<0.05$), non-parametric tests were used for inferential statistics. The following statistical evaluations were done to analyze the data collected.

1. Comparison of Pre-Training evaluations across groups
2. Comparison of the Pre-Training and Post-Training evaluations for the
    a. Experimental group
    b. Control group
3. Comparison of each test score in experimental group

1. Comparison of pre-training evaluations between groups

In order to do group comparisons, it was very essential to make sure that the two groups were matching before the training. To rule out differences at the group assignment level, comparison between pre-training test scores was done between control and experimental group. There wasn't huge dissimilarity between the participants of the two groups. To confirm this Mann-Whitney U Test was carried out. The U values and P values obtained after comparing mean scores of the pre-training evaluation between two groups are mentioned in table 4.1.

Table 4.1:

Comparison of pre-training scores between control and experimental group

Test	**Mean score pre-training (control group)**	**Mean score pre-training (experimental group)**	**U value**	**P value**
Digit span test	3.60 (.516)	3.50 (.527)	45.00	.661
Gap Detection Test (msec)	10.78 (3.99)	11.66 (4.70)	45.00	.705
Duration pattern Test (%)	46.98 (6.37)	49.63 (8.06)	40.00	.441
Pitch pattern test (%)	49.63 (7.77)	47.97 (6.88)	46.00	.759
Speech in Noise test (%)	40.80 (12.33)	46.80 (11.47)	39.50	.424
N1 Latency (ms)	106.2 (5.83)	104.55 (5.03)	36.00	.290
P2 Latency (ms)	155.77 (6.98)	169.12 (6.14)	6.00	.001
N1-P2 Amplitude	1.70 (.394)	1.43 (.416)	25.00	.058

Significance level <0.05

The table shows that p value was >0.05 in all tests except for latency of P2. This denotes that two groups were quite similar in terms of their performances and are comparable in this study.

2. Comparison of the Pre-Training and Post-Training evaluations for the:

a) Experimental group

All the tests that were performed showed a difference across pre and post evaluations. These differences varied for different parameters. For example tests like Digit Span Test showed increase in the scores whereas tests like Gap Detection Test showed a decrement. The trend, either positive or negative showed a positive effect of training.

The scores obtained by the experimental group during pre-training evaluation and post training evaluation on all the tests were compared (Table 4.2). The comparison was done using the Wilcoxon Signed Ranks test for all the behavioural tests: Digit Span Test (DST), Gap Detection Test (GDT), Duration Pattern Test (DPT), Pitch Pattern Test (PPT), Speech in Noise Test (SPIN) and electrophysiological test; Late Latency Response (LLR).

Table 4.2:

The mean scores, z value and p value for pre- & post-training Behavioral Tests (Experimental group)

Test	**Mean pre training score**	**Mean post training score**	**Z value**	**P value**
Digit span test	3.50 (.527)	4.40 (5.16)	-2.460	.014*
Gap Detection	11.66 (4.70)	7.04 (2.26)	-2.402	.016*

Test (msec)				
Duration pattern Test (%)	49.63 (8.06)	57.96 (5.92)	-2.680	.007*
Pitch pattern test (%)	47.97 (6.88)	57.65 (6.28)	-2.831	.005*
Speech in Noise test (%)	46.80 (11.47)	54.60 (9.43)	-2.692	.007*

*Significant at 0.05 level

The table contains mean scores for each test performed for two conditions i.e Pre & Post training. There is a significant difference between pre and post training scores for all the behavioural tests. The scores demonstrate group findings where N=10 for experimental group. This group underwent the musical training for 8 sessions.

Table 4.3:

The mean scores, z value and p value for pre- & post-training Electrophysiological Test (Experimental group)

Test	**Mean pre training score**	**Mean post training score**	**Z value**	**P VALUE**
N1 Latency (ms)	104.55 (5.03)	104.32 (5.08)	-1.687	.092
P2 Latency (ms)	169.12 (6.14)	159.24 (5.89)	-2.803	.005*
N1-P2 Amplitude	1.43 (.416)	1.960 (.196)	-2.677	.007*

*Significant at 0.05 level

Table 4.3 contains mean scores of pre- & post-training responses obtained using electrophysiological measure (LLR). The latency of N1, P2; and amplitude of N1P2 complex is shown. All parameters except N1 show significant differences, demonstrating effect of training.

The results for comparison between pre & post training scores of experimental group reveal there is a significant change in the scores of pre- & post-training evaluations.

b) Control group

Similar measures were performed for the control group (N=10) except that no training was given to this group. Table 4.4 shows mean scores of the group in all the behavioral tests. The p value >0.05 signifies there was no significant difference between pre and post scores for any test. Hence, it can be inferred that there is no change in scores of control group when no training is given.

Table 4.4:

The mean scores, z value and p value for pre- & post-training Electrophysiological Test (Control group)

Test	**Mean pre training score**	**Mean post training score**	**Z value**	**P value**
Digit span test	3.60 (.516)	3.80 (.632)	-1.414	.157
Gap Detection Test (msec)	10.78 (3.99)	9.56 (2.96)	-.837	.403
Duration pattern Test (%)	46.98 (6.37)	47.96 (5.90)	-.707	.480

Pitch pattern test (%)	49.63 (7.77)	91.91 (131.60)	-1.186	.236
Speech in Noise test (%)	40.80 (12.33)	41.20 (12.22)	-.577	.564

Significance level 0.05

Results reveal there was no significant difference seen in the pre- & post-training scores in the control group for all the behavioral tests.

Similar measures were performed for the control group (N=10) except that no training was given to this group. Table 4.5 shows mean scores of the group in all the parameters (N1, P2 latency; & N1P2 amplitude) of LLR. The p value >0.05 signifies there was no significant difference between pre and post scores for any test. Hence, it can be inferred that there is no change in scores of control group when no training is given.

Table 4.5:

The mean scores, z value and p value for pre- & post-training Electrophysiological Test (Control group)

Test	**Mean pre training score**	**Mean post training score**	**Z value**	**P value**
N1 Latency (ms)	106.2 (5.83)	105.6 (5.87)	-1.687	.092
P2 Latency (ms)	155.77 (6.98)	155.62 (7.35)	-.561	.575
N1-P2 Amplitude	1.70 (.394)	1.67 (.359)	-.409	.682

Significance level 0.05

The difference in scores across individual tests

Digit Span Test:

The figure 4.1 shows mean scores of both control and experimental groups for the Digit Span Test for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training scores, whereas it was quite significant for post scores. These findings show after training, scores only differed in experimental group and remained unchanged in control group.

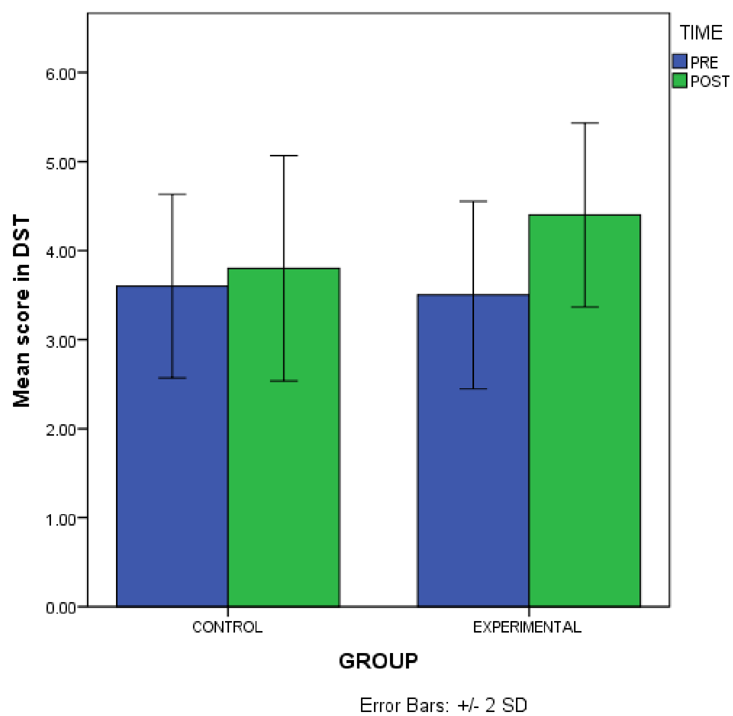

Figure 4.1: Comparison of pre and post training scores in control and experimental group for Digit Span Test (DST). Error bars indicate two standard deviations from the mean.

Gap Detection Test (GDT)

The figure 4.2 shows mean scores of both control and experimental groups for the gap detection test for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training scores, whereas it was quite significant for post scores. These findings show that after training, scores only differed in experimental group and remained unchanged in control group.

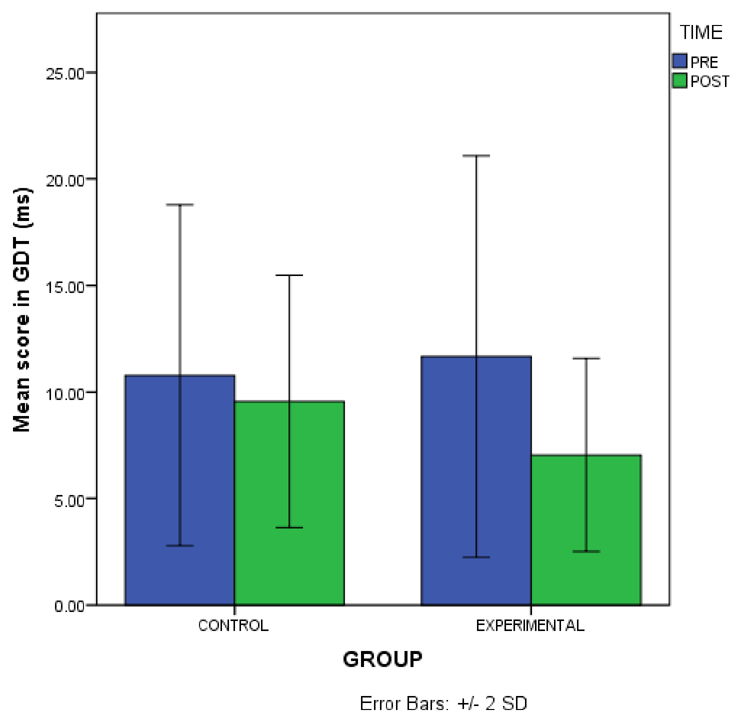

Figure 4.2: Comparison of pre and post training scores in control and experimental group for Gap Detection Test. Error bars indicate two standard deviations from the mean.

Duration Pattern Test (DPT)

The figure 4.3 shows mean scores of both control and experimental groups for the Duration Pattern Test for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training scores, whereas it was quite significant for post scores. These findings show after training, scores only differed in experimental group and remained unchanged in control group.

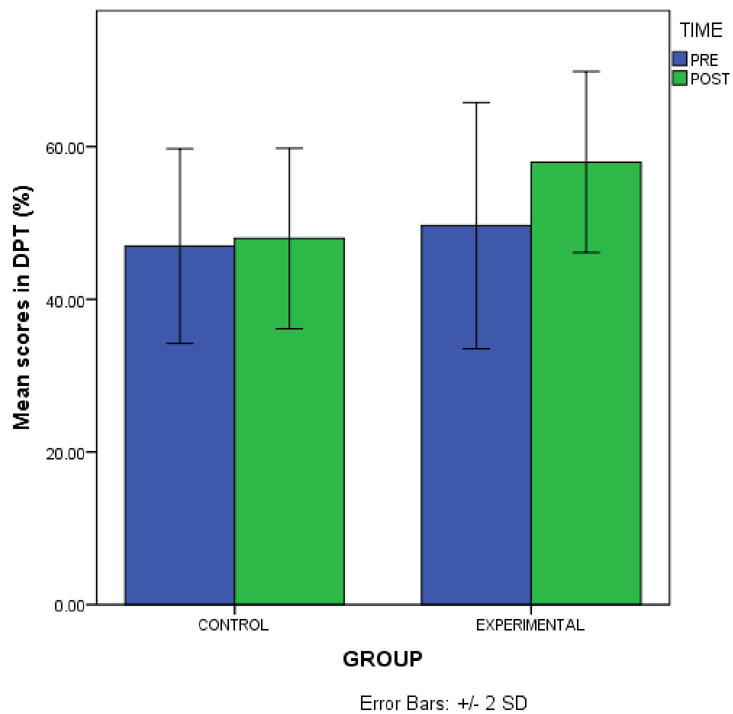

Figure 4.3: Comparison of pre and post training scores in control and experimental group for Duration Pattern Test (DPT). Error bars indicate two standard deviations from the mean.

Pitch Pattern Test

The figure 4.4 shows mean scores of both control and experimental groups for the Pitch Pattern Test for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training scores, whereas it was quite significant for post scores. These findings show after training, scores only differed in experimental group and remained unchanged in control group.

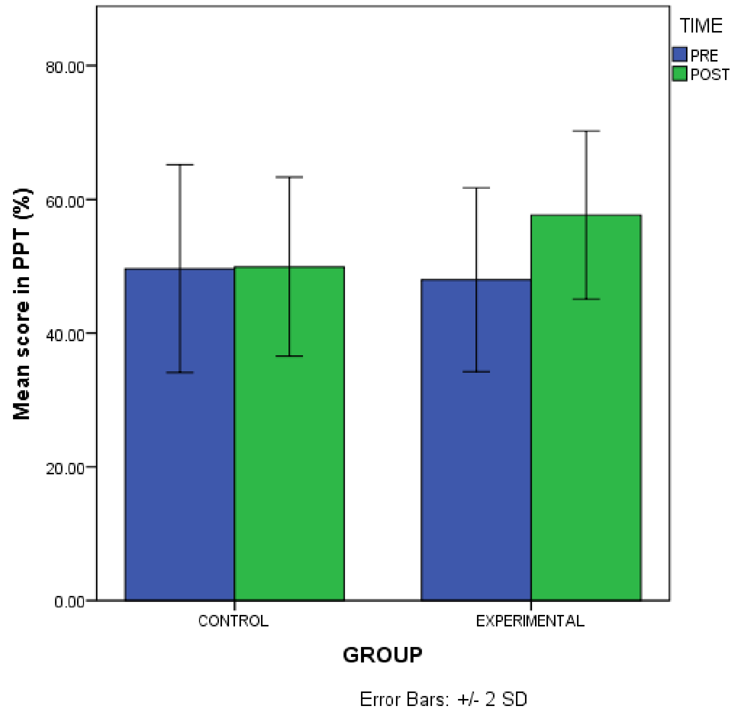

Figure 4.4 Comparison of pre and post training scores in control and experimental group for Pitch Pattern test (PPT). Error bars indicate two standard deviations from the mean.

Speech in Noise Test

The figure 4.5 shows mean scores of both control and experimental groups for the Speech in Noise Test for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training scores, whereas it was quite significant for post scores. These findings show after training, scores only differed in experimental group and remained unchanged in control group.

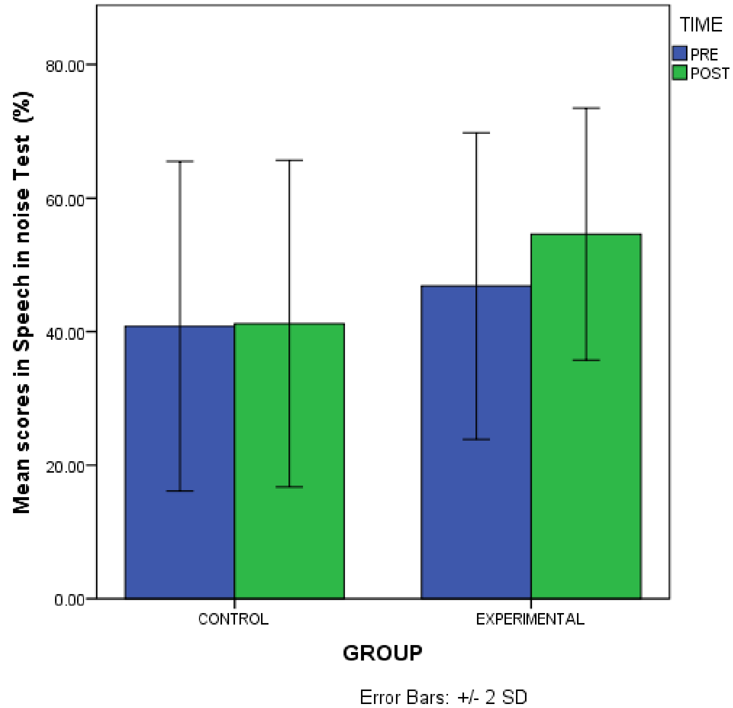

Figure 4.5 Comparison of pre and post training scores in control and experimental group for Speech in Noise Test (SPIN). Error bars indicate two standard deviations from the mean.

LLR: N1 Latency

The figure 4.6 shows mean latencies of both control and experimental groups for the latency of N1 peak in LLR recordings for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre- & post-training evaluation. These findings show after training, scores did not change in both control group & experimental group.

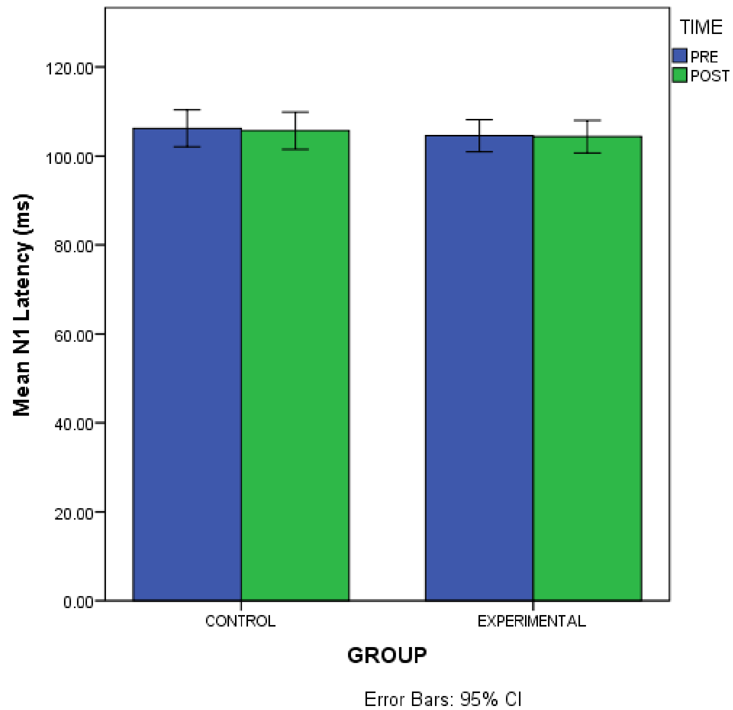

Figure 4.6 Comparison of pre and post training change in control and experimental group for N1 Latency of LLR., Error bars indicate two standard deviations from the mean.

LLR- P2 Latency

The figure 4.7 shows mean latencies of both control and experimental groups for the latency of P2 peak in LLR recordings for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training evaluation, whereas it was quite significant for post training evaluation. The mean latency for P2 decreased significantly in experimental group whereas it remained unchanged in control group.

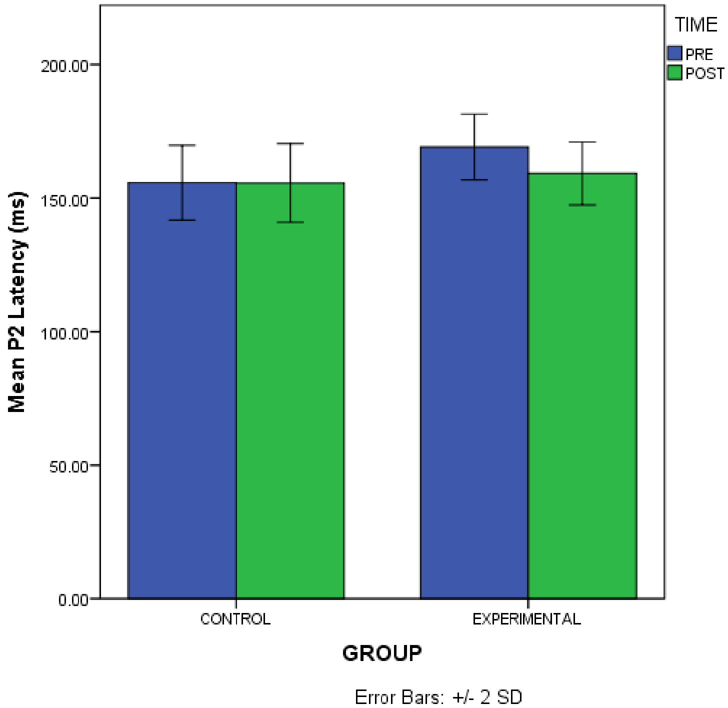

Figure 4.7 Comparison of pre and post training change in control and experimental group for P2 Latency of LLR., Error bars indicate two standard deviations from the mean.

LLR- Amplitude of N1-P2 complex

The figure 4.8 shows mean amplitude of both control and experimental groups for the amplitude of n1-P2 complex in LLR recordings for 2 conditions (pre- & post-training). The graph demonstrates that the difference between control and experimental group was not significant for pre-training evaluation, whereas it was quite significant for post training evaluation. The mean amplitude of N1P2 complex increased significantly in experimental group whereas it remained unchanged in control group.

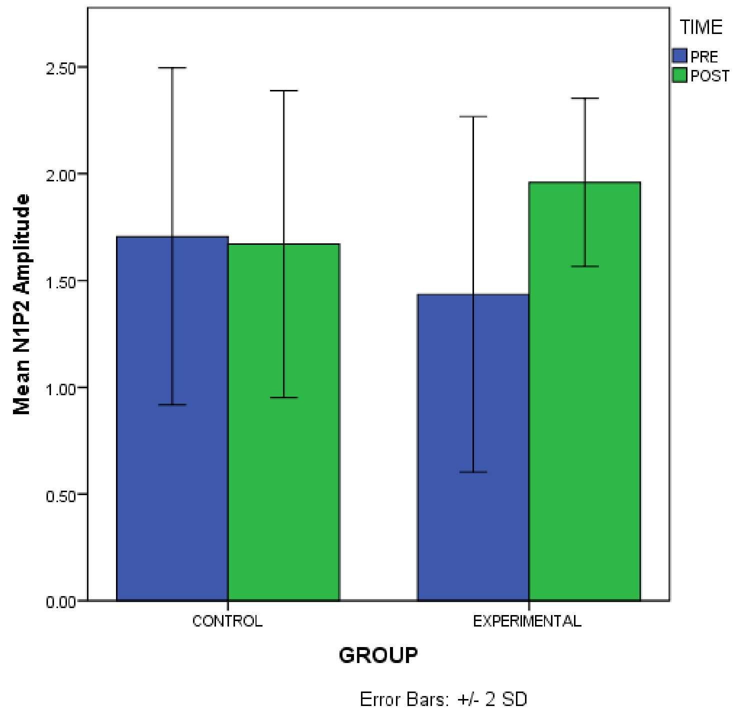

Figure 4.8 Comparison of pre and post training change in control and experimental group for N1P2 amplitude of LLR. Error bars indicate two standard deviations from the mean.

3. Pre-Post training score difference across subjects

In the above mentioned tables & graphs representation of group means was provided. However, performance of each subject is essential to make a comment on effects of training. The scores obtained from post-training evaluations were subtracted from the scores obtained in pre-training evaluations in order to get the effect of training on each subject. In the graphs provided below, x-axis shows individual subjects in the experimental group while y-axis shows the difference between pre- & post- training scores in specified test.

<u>*Digit Span Test*</u>

In figure 4.9 pre-post differences between scores obtained in Digit span test are shown. The graph shows marked improvement in subject 3 & 4, similar and moderate improvement in subjects 1, 7, 8, 9 and 10. The training showed no effect on subjects 2, 5 and

6 for the task of auditory working memory. This shows that the musical training was not effective in a similar fashion for all the subjects.

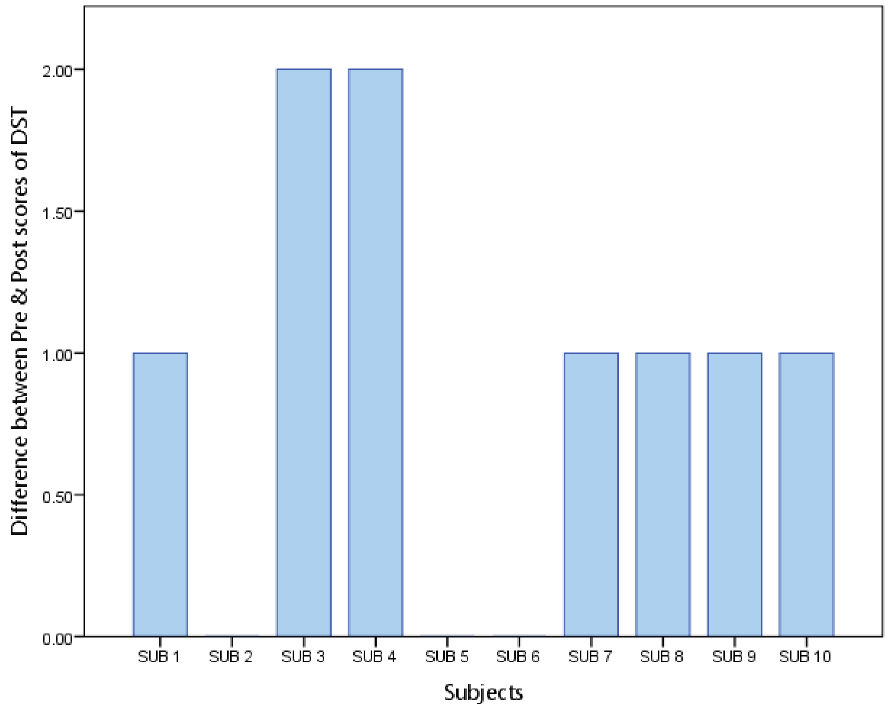

Figure 4.9 Difference between Pre & Post training scores of DST across all subjects of experimental group

<u>Gap Detection Test</u>

In figure 4.10 pre-post differences between scores obtained in Gap detection test are shown. In the graph lower the bar goes, better is the improvement. Bar denote that after training GDT was reduced. However, the difference in scores for all subjects varied. Subject 5 showed least improvement, whereas subject 10 had increase in GDT. This shows that the musical training was not effective in a similar fashion for all the subjects.

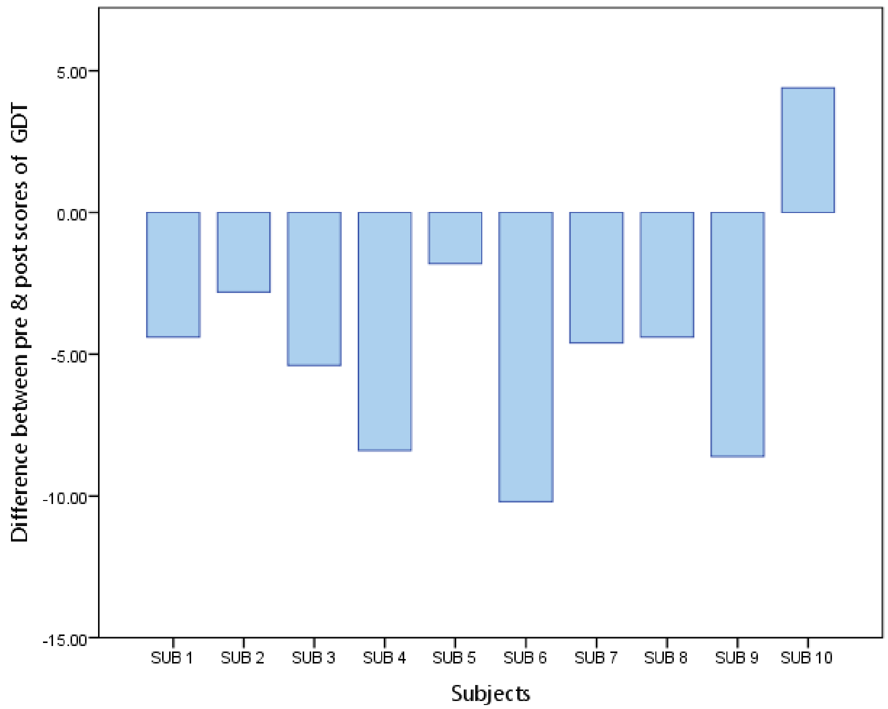

Figure 4.10 Difference between Pre & Post training scores of GDT across all subjects of experimental group

Duration Pattern Test

In figure 4.11 pre-post differences between scores obtained in Duration pattern test are shown. The graph shows marked improvement in all the subjects except subject 10. This shows that the musical training was not effective in a similar fashion for all the subjects.

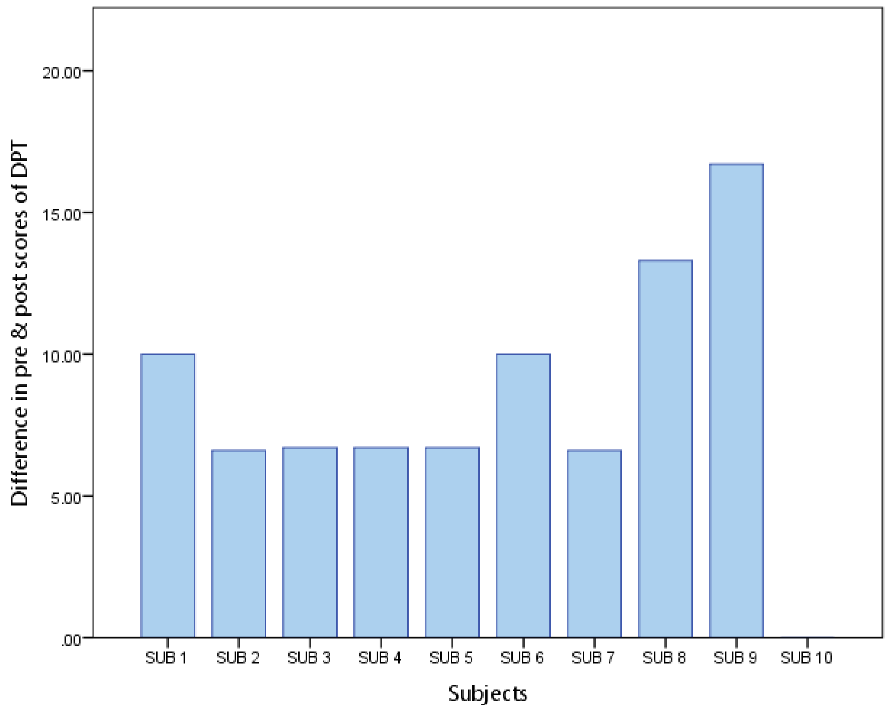

Figure 4.11 Difference between Pre & Post training scores of DPT across all subjects of experimental group

Pitch Pattern Perception Test

In figure 4.12 pre-post differences between scores obtained in Pitch Pattern Test are shown. The graph shows marked improvement in all the subjects. Findings for this test shows that pitch pattern perception became better after training in all the subjects. There were still variations across subjects.

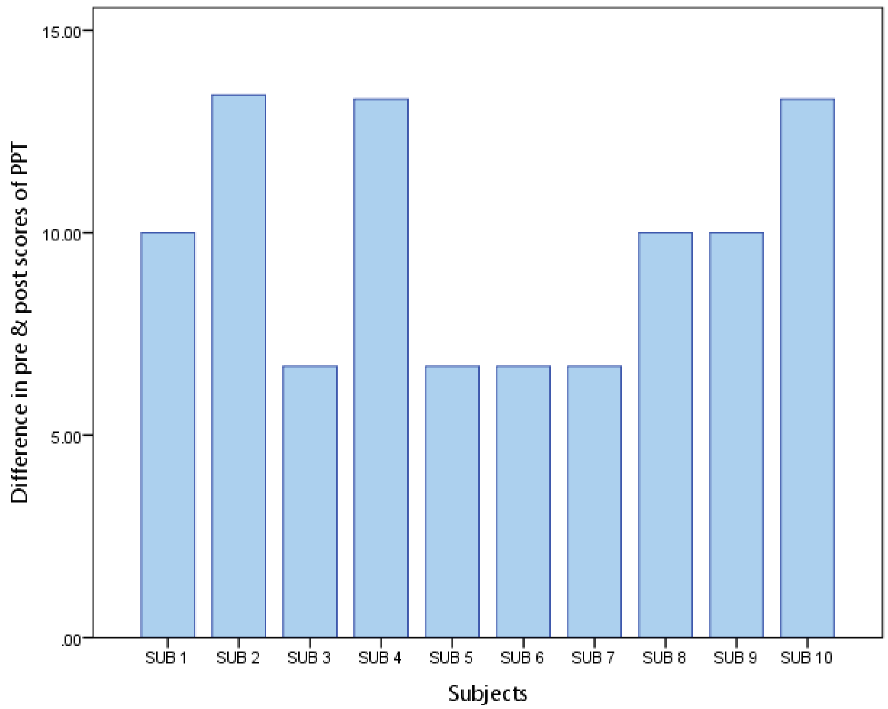

Figure 4.12 Difference between Pre & Post training scores of PPT across all subjects of experimental group

<u>*Speech in noise Test*</u>

In figure 4.13 pre-post differences between scores obtained in Speech in noise test are shown. The graph shows marked improvement in all the subjects except subject 7. This shows that the musical training was not effective in a similar fashion for all the subjects.

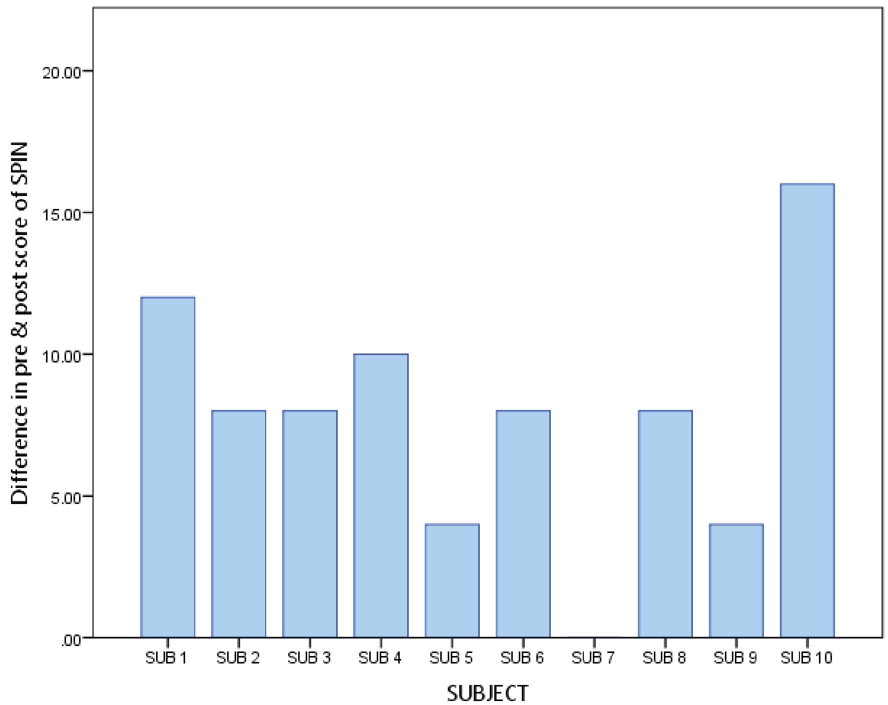

Figure 4.13 Difference between Pre & Post training scores of SPIN test across all subjects of experimental group

LLR- N1, P2 Latency

In figure 4.14 pre-post differences between scores obtained in N1, P2 latencies of LLR are shown. The graph shows marked difference in P2 latency. Change in N1 latency is not much. This pattern is consistent across all the subjects. Thus, one can note that the effect of training was mostly seen on P2 latency.

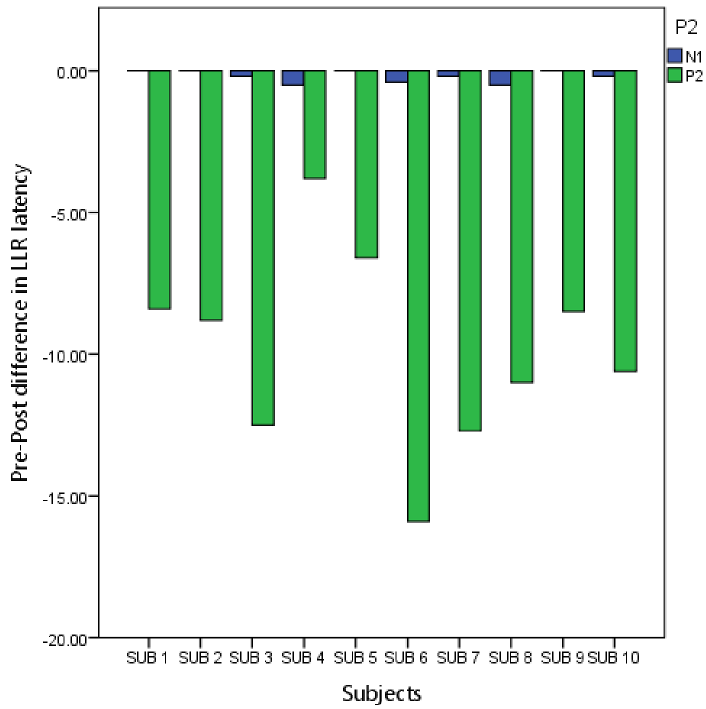

Figure 4.14 Difference between Pre & Post training change in N1 & P2 latencies across all subjects of experimental group

<u>*LLR: Amplitude of N1-P2 complex*</u>

In figure 4.15 pre-post differences between results obtained in LLR for amplitude of N1-P2 complex are shown. The graph shows marked improvement in all the subjects except subject 7. This shows that the musical training was not effective in a similar fashion for all the subjects.

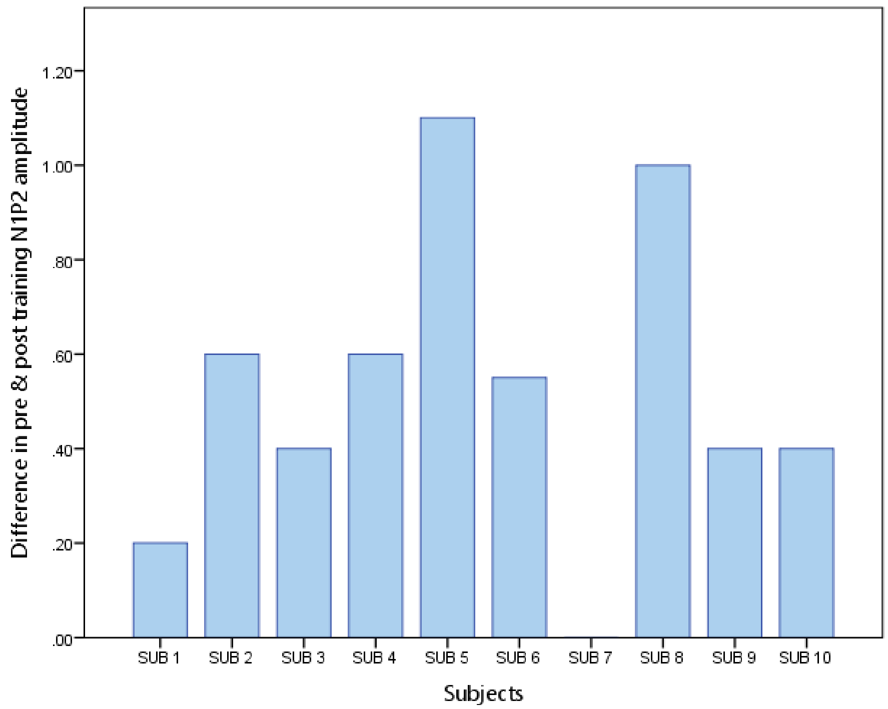

Figure 4.15 Difference between Pre & Post training change in N1P2 amplitude across all subjects of experimental group

Results indicate that in general, musical training results in betterment of scores in the behavioral and electrophysiological parameters considered. However, the magnitude of improvement can vary widely depending on the subject.

Only for pitch pattern perception test, all subjects followed a similar trend.

Chapter 5

DISCUSSION

In this research an attempt was made to see the effect of musical training on several auditory processes and neural plasticity. The main objectives were to see effect of auditory working memory, temporal processing, speech perception and LLR. Varying results were found for all the subjects; however the group scores signify significant improvement in most of the parameters that were measured. Individual therapy was given to the experimental group for 8 sessions and a post training evaluation was conducted to jot down the effect of training. The results were congruent with several other studies wherein authors found that as less as 8 sessions are good enough to see the significant changes in the auditory processing and neural plasticity. Also significant differences were seen for all the parameters except N1. Not only do musically trained individuals demonstrate better verbal memory than s, but this advantage can be seen with as little as one year of musical training (Ho, Cheung & Chan, 2003). Similar observations have been made in poor readers, in addition to children with poor perception of speech presented in background noise (Chandrasekaran et al., 2009); these findings are extended to the domain of music. This relationship is not surprising given the importance of sound repetition and sequencing for music perception.

I. Comparison of Pre-Training evaluation between the groups

The comparison between the control and experimental group before the training showed no significant differences in any test except in the latency of P2 in LLR. However, the mean latencies of N1 & P2 and amplitude of N1-P2 complex is similar to the findings of Arehole (1995). In the current research mean (SD) of N1, P1 latencies and N1-P2 amplitude were 106.2 (5.83), 155.77 (6.98), 1.70 (.394) respectively. In a study by Arehole (1995) values found were 101.0 (12.3), 160.4 (18.6), 1.9 (1.3) for N1, P2 and N1-P2 complex. The mean scores of both the groups for DST, GDT, DPT, PPT and SPIN were also falling in the range of values obtained for Learning Disability (LD) population (Musiek, 1987; Pinheiro, 1990; Torgesen & Houck, 1980; McLean & Hitch, 1999; Dawes et al., 2008; Iliadou, Baniou & Kaprinis, 2008; Watson, 1992; Ziegler et al., 2009).

Studies have noted reduced N1 and N1-P2 complex amplitude and increase in P2 latency (Arehole, 1995; Satterfield et al., 1984; Pinkerton et al., 1989; Lubar et al., 1992). They attribute these trends to aberrant processing. To put it in few words, there was no significant difference in the two groups, and the findings of all the studies are supported by above mentioned studies.

II. Comparison of Pre Vs Post Training evaluation within the group

After the training, second evaluation was done. Comparison of pre- & post-training evaluations was done, to comment on effect of musical training. Comparison of each test was done separately as it taps on different auditory processes.

Auditory Working Memory

Digit Span test was done to tap on auditory working memory. Auditory working memory is thought to be benefitted by musical training (Ho, Cheung & Chan, 2007). There was a significant increase in the score after training. Moreno, Bialystok and Barac (2011) found similar findings after a short term music training, which resulted in enhanced verbal intelligence, executive function and auditory working memory. Roden, Grube, Bongard and Kreutz (2013) also concluded that music training enhanced working memory performance. These results confirm previously reported associations between musical practice and cognitive ability (Hurwitz et al., 1975; Schellenberg, 2006; Forgeard et al., 2008; Ruthsatz et al., 2008). The dose-response relation also supports the previously reported causal relation between the two (Schellenberg, 2004; Bugos et al., 2007). Over the past decade, research has shown that Working Memory (WM) capacity is subject to training-induced improvements (Klingberg et al., 2002, 2005; Holmes et al., 2009; Thorell et al., 2009; Brehmer et al., 2012; Green et al., 2012) and that the size of the transfer effects are linearly related to practice time (Jaeggi et al., 2008; Nutley et al., 2011). In the results obtained for Digit Span Test (DST), Speech in Noise perception (SPIN) and LLR; one can note that a positive improvement was seen. These findings can be supported using studies by Strait et al. (2010) & Chan et al. (1998) who have shown the relationships between auditory working memory and attention and musical skill. Not only do musicians demonstrate better verbal memory than s, but this advantage can be seen with as little as one year of musical training (Ho, Cheung & Chan, 2003).

The underlying reason behind these improvements can be the descending auditory system. Strait, Hornickel and Kraus, (2011) mentioned that the brain shapes perception according to predictions that are made based on regularities; this shaping can be accomplished by comparing higher-level predictions with lower-level sensory encoding of an incoming stimulus via the corticofugal (i.e., top down) system.

<u>Temporal Processing</u>

Gap Detection Test (GDT) taps temporal resolution. In this test too, there was a marked improvement in the experimental group post-training. These effects of musical training on Gap Detection Test are supported by many studies (Mishra, Panda & Herbert, 2014; Mishra & Panda, 2014; Sangamantha et al., 2012). It might be because at cognitive level, music and speech share the same memory and attention skills which are important to track down the acoustic event which helps in auditory scene analysis (Patel, 2003). Musical training improves auditory temporal resolution which in turn enhances the auditory perceptual skills. (Sangamantha et al., 2012).

Duration Pattern Test (DPT) revealed significant differences between pre & post training findings. Ability to detect duration pattern is also a temporal ordering process. As quoted by several authors, musical training influences neural plasticity (Cristaudio, Perez-Gozalez & Covey, 2009; Dean, Robinson, Harper & McAlpine, 2008) this might explain why the children are able to identify these patterns better after musical training.

*Pitch Pattern Test (*PPT) showed the maximum benefit across all the tests. It might be attributed to the task involved in the training, which was related to identification of patterns in the music material. Besson et al. (2007), in their study on influence of musical training on pitch pattern perception concluded that, pitch pattern perception in individuals having musical training is better. They attribute this effect to be because of brain plasticity. Music training facilitates pitch pattern perception (Schon, Magne & Besson, 2004). They claim that musical training refines the frequency-processing network which facilitates detection of pitch patterns. Specifically, repetition and regularity lends to the perception of tonality (Krumhansi, 1980), rhythm and meter (Hannon, Snyder, Eerola & Krumhansi, 2004; Large & Jones, 1999) and the structural use of musical themes.

Speech in Noise Test (SPIN) showed significant increase in post-training evaluation when compared to the pre-training scores. Many studies in literature talk about relationship between speech and music skills. Besson et al. (2007) found that a set of common processes may be responsible for pitch pattern perception in music and in speech and these two are shaped by musical training. Music training facilitates pitch pattern perception and language

(Schon, Magne & Besson, 2004). The same authors discussed that processing of F0 is similar in language and music, which is why while training with music one also gets better at language and speech. Slater et al., (2015) provided evidence of better speech perception in noise in the group who received music training. It is clear from the literature that the brain's ability to use sensory regularities is a fundamental feature of auditory processing, promoting even the most basic of auditory experiences such as language processing during infancy (Pelucchi, Hay & Saffran, 2009; Saffran & Aslin, 1996) and speech comprehension amidst a competing conversational background (Chandrasekaran et al., 2009). The extent of this sub cortical enhancement of regularly-occurring speech relates to better performance on language-related tasks, such as reading and hearing speech in noise. This fine-tuning is thought to be driven by top-down cortical modulation of sub cortical response properties (Suga, 2008) and its absence in poor readers is consistent with proposals that child reading impairment stems from the brain's inability to benefit from repetition in the sensory stream.

Specifically, children with dyslexia fail to form perceptual anchors–a type of perceptual memory– based on repeating sounds (Suga, 2008; Evans, Saffran & Robe-Torres, 2009). In a study by Sho et al., (2004) results provide evidence for positive transfer effects between music and speech perception.

Late Latency Response (LLR)

Latencies of N1, P2 and amplitude of N1-P2 complex was considered for analysis; wherein, P2 latency and N1-P2 amplitude showed significant change in post-training evaluation while N1 remained unchanged.

Our findings are in accordance with the growing body of literature in support of short term music training inducing neuro-plastic changes in auditory processing (Bosnyak et al., 2004; Fujioka et al., 2006; Magne et al., 2006; Moreno et al., 2008; Reinke et al., 2003; Tremblay et al., 2001; Tremblay & Kraus, 2002). The impact of stimulus regularity on auditory processing has been well established in the auditory cortex (Winkler, Denham & Nelken, 2009); Baldeweg, 2006) and was recently documented at and below the level of the brainstem (Malmerica, Cristaudio, Perez-Gozalez & Covey, 2009; Dean, Robinson, Harper & McAlpine, 2008; Pressnitzer, Sayles, Micheyl & Winter, 2008; Wen, Wang, Dean & Delgutte, 2009). Due to its multisensory nature, attentional demands and reliance on rapid audio-motor feedback, music is a powerful tool for engendering neural plasticity, particularly for auditory processing (Kraus & Chandrasekaran, 2010; Norton et al., 2005; Schlaug, 2001; Schlaug et al., 2009; Schlaug, Norton, Overy & Winner, 2005). This plasticity is not constrained to the brain's music networks but applies more generally to auditory functions (Tervaniemi et al., 2009; Strait, Kraus, Skoe & Ashley, 2009; Strait, Kraus, Musacchia & Sams, 2007; Skoe & Kraus, 2007; Parbery-Clark, Skoe, & Kraus, 2009; Schon, Magne & Besson, 2004).

Reporting the preliminary results of on-going studies, Schlaug et al. (2005) found that children with 4 years of musical training had significantly more gray matter volume in several brain regions including the sensorimotor cortex and larger activation in the superior temporal gyrus than control children. Using the event-related potentials (ERPs) method, results have shown that the amplitude of early (P1, N1, and P2; Shahin et al. 2004) and late P3 (Trainor et al. 1999) auditory evoked potentials is influenced by musical expertise. The amplitude of the auditory evoked potentials N1c and P2 was enhanced after such a short training and the N1c enhancement was larger over the right than left hemisphere. Although it remains difficult to establish a direct correspondence between ERP components in children and adults, the most important point may be that, in both adults and children, short-term musical training seems to produce effects that are similar to those observed with long-term musical training (Menning et al. 2000; Bangert et al. 2001, 2006; Haueisen and Knosche 2001; Pascual-Leone 2001; Tremblay et al. 2001; Atienza et al. 2002; Bosnyak et al. 2004; Fujioka et al. 2006; Magne et al. 2006; Shahin et al. 2003, 2004).

In one study authors found that 8 weeks of musical training had no effects except to reduce the amplitude of the positivity to strong incongruities in speech (Moreno and Besson 2006).

III. Comparison of each test score within experimental group

A comparison among difference between pre & post training scores was done across all the subjects in experimental group. This was done to see individual benefits from the musical training. All the subjects got better scores in post evaluation in 1 or more tests. However, there were few subjects who showed no improvement in some tests, and also showed poorer performance that pre-training scores.

These individual differences can be attributed to some external variable which could not be controlled. The increased threshold for GDT might be the result of poor attention in post-training test or a random guess in the pre-training test. Many studies have documented that factors like attention, motivation, IQ, parental involvement, personality etc. affect the outcomes of musical training (Moreno et al., 2008).

In PPT, all the subjects showed significant improvement. This might be the direct effect of task, as the one of the activities in training involved materials that varied in pitch and child had to identify it. Subject 10 showed no improvement in DPT, and had increased GDT post training. For this subject, the temporal processing seems to be untapped. But for the same subject SPIN and PPT scores showed maximum improvement.

Chapter 6

SUMMARY & CONCLUSION

Music has shown to have magical effects on human brain. Studies have proven that musical training improves auditory processing; also there is dearth of evidence on how musicians perform better in auditory task in comparison to s. Children with learning disability on the other hand face various difficulties with auditory processing. Review of literature indicates, better processing in musicians and poor processing in learning disability children, then why not provide learning disability children with what musicians receive i.e. musical training. Therefore, a study was conducted to look for effects of musical training on various auditory processes, namely auditory working memory, temporal processing, speech in noise perception and neural plasticity.

The aim of the study was to see effect of musical training in children with disability. The main objectives were to see these effects on auditory working memory, temporal processing, speech perception and neural plasticity. In order to accomplish these objectives, 2 groups (N=20) of learning disabled children were taken. Both groups underwent a series of test including- Digit Span Test (DST), Gap detection test (GDT), Duration pattern test (DPT), Pitch pattern test (PPT), speech in noise test (SPIN) and LLR. After the testing 10 subjects were given the musical training (experimental group), and 10 subjects were considered a control group who did not receive any training. The training was given for 8 sessions of 45 minutes each. Experimental group was tested with same tests after training and control group was tested with similar tests after 8-10 days without any training.

Afterwards, statistical analysis was performed. Shapiro-Wilk test was used to check for normality, which indicated a non-normal distribution of data for most of the parameters.

Therefore Non parametric tests were chosen. Mann-Whitney U Test was done to compare pre-training scores between control and experimental group, and Wilcoxon Signed rank test was done to compare pre & and post training scores within control and experimental group.

Statistical analysis showed no significant differences in pre-training scores of two groups, which assured that both groups were similar. Analysis for within group comparison i.e pre vs post test scores revealed no significant difference in control group, meaning there was no effect seen in the group who did not receive any training. Whereas, the pre-post comparison in experimental group showed significant improvement in all the behavioural test i.e DST, GDT, DPT, PPT and SPIN. Significant differences were seen for electrophysiological test (LLR), wherein P2 latency and N1-P2 amplitude. No effect was seen for latency of N1.

When individual scores of every subject was compared for each test, it was found that there was no uniformity across subjects. A few subjects gained benefit in one parameter while others performed better in another parameter despite of getting the same training. There might be other intrinsic or extrinsic factors responsible for this which could not be identified.

We draw from prior work linking enhanced auditory brainstem encoding with heightened auditory perception, executive function, and auditory-based communication skills (Parbery-Clark et al., 2009; Ruggles et al.,2011; Kraus et al., 2012; Krizman et al., 2012; Song et al., 2012) to suggest that musical training during development may produce long-lasting positive effects on the adult brain.

Also short-term musical training produces effects similar to those found with long-term musical training (Bangert et al. 2001, 2006; Pascual-Leone, 2001; Haueisen and

Knosche, 2001; Tremblay et al., 2001; Tremblay and Kraus, 2002; Shahin et al. 2003, 2004; Bosnyak et al., 2004). From these evidences one can assume that effects of these 8 sessions training might last long, even though permanence of treatment benefits was not monitored.

1. Musical training has shown its effect on auditory processing and neural plasticity.
2. Improved auditory working memory, temporal processing and speech perception in noise.
3. Reduced P2 latency and increased N1P2 amplitude are the electrophysiological evidences to show that musical training has positive effects. However, these effects are not uniform for every subject.
4. Future Research:
    i. More work needs to be done in order to study factors influencing or affecting the effect of musical training on a larger population.
    ii. Professionals must develop more training programmes and consider musical training as one of the treatment options for children with learning disability and/or central auditory processing disorder.
    iii. Further studies can be done by grouping different types of LD children to see which kind of children benefit more, and also long lasting effects of training can be ensured by looking for permanence. One can look for how long these effects last and also how different types of musical training affect the outcomes.

Implications of the study:

- The study adds on to the literature on musical training and its effect on auditory processing and neural plasticity.
- The current study is an evidence for positive effects of musical training.
- Musical training may help in the management of children with learning disability.
- This training might be extended to other disorders that have impaired auditory processing.

Limitations of the study:

- Participants in the two groups were not assigned randomly, but on the basis of their willingness.
- The permanence of post-training effects of musical training was not looked for.

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