TEMPORAL PROCESSING, AUDITORY WORKING MEMORY AND SPEECH PERCEPTION IN NOISE IN VOCALISTS, VIOLINISTS AND NON MUSICIANS

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ABSTRACT

Music is a highly complex sensory stimulus and is structured in several dimensions. This richness makes music an ideal tool to investigate the functioning of the human brain. Since there are many different training methods used to develop musical expertise (e.g. vocal or instrumental), these differences could lead to varying auditory processing abilities of acoustic signals. The current study aims to see if there are any differences in temporal processing abilities, speech perception in noise and auditory working memory between vocalists, violinists and non-musicians. 30 participants from each of the group were subjected to four temporal processing tests (gap detection threshold (GDT), duration discrimination test (DDT), duration pattern test (DPT), and the modulation detection threshold for sinusoidally amplitude-modulated noise, speech perception in noise test (QuickSIN) and four auditory memory tests (forward and backward digit span tests, Auditory verbal retention for meaningful and non meaningful pairs tests). This study also aimed to study the effect of years of musical experience on these above mentioned auditory processing skills by regrouping the same 30 participants in each group (i.e., the vocalists and the violinists) into 3 sub-groups consisting of 10 participants with different music expertise (10 participants in the junior level, 10 participants in the senior level and 10 participants in the vidwath level).

Overall results revealed that in all the auditory processing tests (temporal processing, speech perception in noise and auditory working memory) musicians (both vocalists and violinists) outperformed the non-musicians. However, no significant difference was noticed between violinists and vocalists. The results of the study are in congruence with other literature report indicating musical experience as an important factor inducing enhancements in the overall auditory perceptual abilities. Further, the study results lead to the possible speculations that type of music (vocal vs instrumental) does not influence music induced differences in the auditory processing skills. Similarly, there was no significant difference observed in the performance of the musicians with respect to the years of musical experience both in the violinists and vocalist groups (except in the Gap Detection Test and the Duration Discrimination Test in the violinists).

Keywords: Music, Temporal Processing, Auditory Working Memory, Speech perception in noise, Neuroplasticity.

CHAPTER 1

INTRODUCTION

The human ear is a very explicit organ than it appears. The sound passes through the outer ear through the pinna, middle ear and then the cochlea to ultimately be processed at a higher level in the brain. Thus the auditory information reaching the brain is appreciated for the final outcome- listening and comprehending the auditory signal. Auditory processing can be defined as "what we do with what we hear" (Katz, 1992). The 1996 ASHA Task Force defines Central Auditory processing as "the mechanisms and processes responsible for the following behavioral phenomena: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including temporal resolution, temporal masking, temporal integration, temporal ordering; auditory performance decrements with competing acoustic signals; and auditory performance decrements with degraded acoustic signals". A central auditory processing disorder is an observed deficiency in one or more of the above-listed behaviors (ASHA, 1996). Butler (1983) defined auditory processing as the abstraction of meaning from an acoustic signal and the retrieval of that meaning.

1.1 Temporal Processing, Auditory Working Memory and Speech Perception in Noise.

In our surroundings, we are seldom exposed to a solitary auditory signal; instead our auditory system must process instantaneously occurring complex auditory signals to extract relevant information. The perfect example of this is understanding speech in the presence of background noise which needs a set of cognitive and perceptual skills comprising detection of time varying perceptual cues, auditory working memory and stream segregation (Parbery-Clark, Skoe, Lam & Kraus, 2009).

The auditory system analyzes a sound signal in three basic domains: frequency, intensity and time. Time is an important domain in hearing since most of the sounds fluctuate over time. Temporal processing abilities are known to be of crucial importance in daily listening environment. Perception of temporal parameter of sound is important for a wide range of auditory behaviors including rhythm perception, phoneme discrimination, duration discrimination, periodicity and pitch discrimination, Furthermore, temporal processing plays a crucial role in language comprehension, perception of prosodic distinctions and speech perception in ambiguous conditions (Chermak & Musiek, 1997). Temporal processing ability is the ability of an individual to process and perceive the time-related cues within an acoustic signal (Shinn, 2003). These cues are important for the perception of speech (Minifie, 1973; Schneider & Pichora-Fuller, 2001) since speech is made up of a string of various sounds (consonants and vowels). Perception of these speech sounds depends upon recognizing characteristics such as place and manner of articulation. Production and perception of any speech sound involves a series of processes such as the movement of articulators and the encoding and decoding of the ensuing speech sounds. The processes involved provide cues which are necessary for decoding speech. The cues might relate to the intensity, frequency, or duration of an acoustic signal. Temporal processing ability relates mostly to the processing of duration-related cues. For example, the production and perception of a stop consonant includes a series of processes that involve time-related cues such as closure duration, burst duration, transition, and voice onset timing [(Lisker, 1957; Lisker & Abramson, 1964; Murthy, 1993). Any small difference or change in the timing or duration of such cues can help differentiate various speech sounds. For instance, the duration of a burst is more for velar and shorter for bilabial stop consonants (Fischer-Jorgensen, 1979), and closure duration is greater for a labial place of articulation than a velar [Zue, 1976].

Auditory working memory refers to that information which has been perceived through the auditory mode. Auditory working memory is an important component of language comprehension, even when there is no background noise (Daneman & Merikle, 1996; Walters & Caplan, 2005). Auditory working memory capacity is further reduced when there is an addition of background noise resulting in the decreased ability to recall a target speaker's utterance, further deteriorating the perception of a speech signal already affected by noise (Parbery-Clark, Strait, Anderson, Hittner & Kraus, 2011). Broadway and Engle (2011) reported that individuals with low working memory capacity were less sensitive when compared to individuals with high working memory capacity in temporal discrimination tasks. Studies have shown that both temporal processing and working memory skills share a common anatomical site, i.e., the prefrontal cortex in the brain (Rajah, Ames & D’Esposito, 2008; Kane & Engle, 2002). Thus, it can be hypothesized that temporal processing abilities depend on cognitive functions such as working memory of the individual.

As evidenced by various studies on different population like normal adults, geriatrics etc, a link exists among temporal processing, auditory working memory and speech perception in noise. However, these domains have not been studied on musicians.

1.2 Music and Musicians.

Music is one of the oldest, most basic and ubiquitous socio-cognitive domains of the human species: in every human culture, people have played and enjoyed music (Huron, 2001). Out of all the species, humans are the only ones who can cooperatively play instruments or sing together in groups. Perceiving, composing and producing music is one of the utmost challenging tasks for the human brain involving nearly all cognitive (sensory and motor) processes and precise monitoring of performance (Schlaug, 2001; Zatorre, 2002; Gaser & Schlaug, 2003; Koelsch & Siebel, 2005; Munte, Nager, Beiss, Schroeder & Altenmuller, 2003). Performing music at a professional level is the most complex of human accomplishments. For example, a pianist has to bimanually coordinate the production of up to 1,800 notes per minute. Music is a highly complex sensory stimulus and is structured in several dimensions (Schuppert et al., 2000). So it extends beyond any of the stimuli that have been used in animal research. This richness makes music an ideal tool to investigate the functioning of the human brain (Munte, Altenmuller & Jancke, 2002).

Music is also a very personal experience, which is influenced by a combination of both genetic and environmental factors, such as training, personal and emotional involvement and previous exposure (Schlaug, 2001). Usually known as “the universal language," music involves the natural expression of human experiences, thought and emotions. Music is a form of art whose components include harmony, pitch, rhythm, melody, dynamics, tempo and texture.

a) Carnatic Music.

Carnatic music is a form of music most commonly practiced in the southern part of the India, and is roughly restricted to Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu. Hindustani music which is seen mostly in Northern India and Carnatic music and Hindustani are the two main sub- genre of Indian classical music that has evolved from ancient Hindu traditions. In contrast to Hindustani music which is melody based, the main emphasis in Carnatic music is on vocal music and is rhythm based; most compositions are meant to be sung, and even when it is played using instruments, they are meant to be presented in the gāyaki (singing) style**.**

Carnatic Music is of more recent origin. It is codified in many texts written by musicologists, the most influential ones among whom studied in North India and thereafter returned to South India to fashion Carnatic music out of the prevalent regional musical forms to be found in South India. In Carnatic music there is a fairly quick tempo from the start and thus, differs from Hindustani music. The notes are not held for long and are mostly quitted by a characteristic oscillation using indeterminate pitch. Although there are stylistic differences, the basic elements of Shruthi, Swara, Raga and Tala form the foundation of improvisation and composition in both Carnatic and Hindustani music.

Carnatic music is usually performed by a small ensemble of musicians, consisting of a principal performer (vocalist), a melodic accompaniment (probably a violin), a rhythm accompaniment (probably an mridangam), and a tambura, which acts as a drone throughout the performance. Other instruments which are typically used in performances may include the Morching, Veena, Ghatam, Kanjira and Flute.

b) Vocal music and Instrumental music.

Music is a universal language and has many types. There is much diversity across the world in terms of music genres and types of musicians. Basically, musicians can be classified either as vocal musicians (vocalists) or instrumental musicians (e.g. Violinists, Veena players, Guitarists, etc.). Vocal musicians, also known as singers, are trained to produce and perceive detailed structures (e.g. variations in pitch, loudness, rhythm, melody, etc.) of chain of speech sounds with or without using an instrument. The vocal musicians use their larynx, the organ within the human body responsible for voice production. On the other hand, instrumental musicians are trained mainly with the production and perception of non-verbal sounds using an instrument such as Violin, Guitar, Veena, etc. Although the term musician includes instrumentalists and vocalists, previous neurophysiological research has focused largely on instrumentalists than vocalists.

There are changes in the human brain as a result of practice and experience which can be termed as neuroplasticity (Teter & Ashford, 2002). Studies comparing the brains of musicians and nonmusicians have reported both anatomical and physiological differences in the cortex and cerebellum (Schlaug, 2001). Although 'musician' includes instrumentalists and vocalists, there is a scarcity of comparative research including formally trained vocal musicians and instrumental musicians. Earlier neurophysiological research has concentrated either on instrumental musicians (e.g., violinists, keyboard players) or on vocal musicians (Münte, Nager, & Beiss, 2003; Schlaug, 2001; Zatorre, 2003). Vocal musicians adhere to the same rigorous training as other musicians; however, the auditory system of vocal musicians has been studied to a much lesser extent. The overall objective of this study is to take an initial step to contribute to the body of basic research regarding the temporal processing speech perception in noise and auditory working memory among the vocal and instrumental musicians.

1.3 Studies comparing vocal and instrumental musicians:

Nikjeh, Lister and Frisch (2008) used Mismatch negativity (MMN) to study pitch deviances and difference limen for frequency (DLF) among 61 young adult women, consisting of 20 vocal musicians, 21 instrumental musicians, and 20 nonmusicians. The stimuli used were harmonic tone complexes from the mid-female vocal range (C4-G4). MMN was elicited by the multideviant paradigm. Difference Limen for Frequency was obtained by using an adaptive psychophysical paradigm. They reported that the musicians identified pitch changes earlier and DLFs were 50% smaller than the nonmusician control group. Both vocal musicians and instrumental musicians had superior sensory-memory representations for the acoustic parameters. Vocal musicians along with instrumental training seemed to have an auditory neural advantage over instrumental or vocal only musicians.

Nikjeh, Lister and Frisch (2009) used psychoacoustic measures to examine pitch production accuracy and active pitch discrimination between nonmusicians and two classes of musicians. Subjects included 40 formally trained musicians (20 vocalists/21 instrumentalists) and 21 nonmusician controls. All of them were right-handed young adult females with normal hearing. Stimuli were harmonic tone complexes simulating piano tones and represented the mid-frequency of the untrained female vocal range, $F0$ = 261.63–392 Hz (C4–G4). DLFs were obtained by an adaptive psychophysical paradigm. Vocal pitch recordings were spectrally analyzed to determine pitch production accuracy. Musicians demonstrated superior pitch discrimination and production accuracy as compared to nonmusician control group. These abilities did not distinguish in instrumental musicians and vocal musicians. DLF and pitch production accuracy were significantly correlated with each other only for musicians with instrumental training; however, Pitch production accuracy was most consistent with minimal variance for vocalists. They concluded that a relationship between difference limen for frequency and pitch production accuracy develops with musical training, and these abilities can be differentially affected by the type of music training.

In a different category of musicians, Kishon-Rabin, Amir, Vexler & Zaltz (2001) reported a significant difference in frequency discrimination thresholds (using DLFs) between classical musicians and contemporary musicians. Seppanen, Brattico & Teravaniemi (2007) also reported a significant difference in mismatch negativity (MMN), which assesses pre-attentive acoustic discrimination, between musicians who prefer aural strategies to practice and those who use other strategies. Halwani, Loui, Ruber & Schlaug (2011) have reported that singers have a larger tract volume in the left dorsal and ventral arcuate fasciculus compared to instrumentalists, although there is no significant difference between the two. They further concluded that musicians, especially singers, can be used as a model to demonstrate structural as well as functional adaptations of the auditory – motor system by showing structural differences between the brains of those engaged in specific types of music training (vocal versus instrumental).

1.4 Need for the study

A convergence of evidence acknowledges that instrumental musicians experience changes in the auditory system following music skill acquisition and sensory stimulation and have superior auditory pitch discrimination compared to non-musicians (Fujioka, Trainer, Ross, Kakigi & Pantev, 2004; Koelsch, Schroger, & Tervaniemi, 1999; Tervaniemi, Just, Koelsch, Widmann & Schroger, 2005). Previous psychoacoustic and electro physiologic research suggests that auditory skills may differ between musicians of distinct musical genres (Kishon-Rabin, Amir, Vexler & Zaltz, 2001; Nager, Kohlmetz, Altenmuller, Rodriguez-Fornells & Munte, 2003; Seppanen, Brattico & Tervaniemi, 2007; Spiegel & Watson, 1984; Tervaniemi, Castaneda, Knoll, & Uther, 2006). Research reported on the vocal musicians is scarce and more so on comparisons between vocal and instrumental musicians have not been investigated much. There are a few differences which exist between vocal and instrumental music.

Almost all acoustic musical instruments have highly linear resonators that determine the playing frequency whereas the voice does not. In plucked strings (and in many percussion instruments), the playing frequency is determined by the linear resonator alone. In contrast, the instruments that can produce sustained notes have a nonlinear mechanism. However, in instruments but not in vocal music, the pitch is determined by a resonator. For example, the bow-string contact produces nonlinear oscillation, but over a limited range of parameters (Schelleng, 1973). The pitch is governed by the resonances of the string. The nonlinear vibrations of flute air jets, reeds in woodwinds and lips of brass players are controlled by the resonances of the air column. Further, in most of these instruments, the parameters that determine the frequency are easily held constant. These allow the production of a sustained note with a frequency largely independent of loudness, without compensating adjustment of those parameters. The vocal tract is a highly linear, waveguide resonator, but it does not control the pitch of the voice. To hold a constant pitch in a strong crescendo and decrescendo requires considerable adjustment of the parameters of the vocal folds.

Most tuned instruments have a series of resonances that fall in harmonic or nearly harmonic ratios which indicates that even linear instruments, such as plucked strings, bells and some drums, can produce complex sounds with nearly harmonic frequency components. For nonlinear instruments, automatic coincidence of higher harmonics and higher resonances means more stability of the pitch and higher power in the high harmonics. But, there is no such phenomenon in the voice. Another very important difference between vocal and instrumental music is that, in music, broadband sources having no pitch, play a secondary role (examples include components of the starting transients of many instruments, part of the sound of untuned percussion and the breath sound in wind instruments; (Wolfe et al., 2002). Where the envelope of the broadband spectrum is variable, it is usually not independent of the harmonic components. These features and the difficulty in controlling them make instruments poor at speech.

Instrumental music sounds unnatural without broad band components, but they make little difference to recognition of melody or harmony. In speech, in contrast, broadband sources are important in most phonemes and vital to comprehensibility. Further, whispering shows that speech (even in tonal languages) can be understood with only broadband signals. The most important difference, however, is pitch control by the resonator. The pitch change produced in the absence of regulation of the parameters of the nonlinear components is rather smaller than it would be for the voice. However, playing a sequence of notes with pitches almost independent of loudness requires relatively simple and almost independent adjustment of parameters. Many instruments have keys, valves, frets or tone holes, that give nearly digital control of pitch. An instrument with continuous pitch, such as violin is often judged as difficult to learn. To be able to sing in tune and to control pitch and loudness independently, one has to learn to control parameters of the vocal folds and the subglottal average pressure in subtle combination: changing pitch at the same loudness (or vice versa) requires modification of several parameters. Further, one requires precise 'muscle memory' of the parameter values required for entries and for changes. Fortunately, because of plenty of practice, vocalists will be able to do it with precision. Compared with singing, playing in tune and controlling pitch and loudness independently would seem to require less complicated control on nonlinear instruments with resonator control (e.g. Violin, Trumpet), where relatively fine adjustments are required to counter the dependence of pitch on loudness. It is much easier on the linear, digital instruments (e.g. Guitar), even though these instruments have other difficulties.

Kahari, Axelsson, Hellström and Zachau (2001) reported that percussion and woodwind players displayed slightly worse hearing thresholds than the other musicians and players of large string instrument had the best hearing threshold values. Since, hearing thresholds do have an effect on tasks involving temporal processing, string instruments were selected for the present study. Also, psychoacoustic studies suggest that musicians who tune their own instrument have better frequency discrimination than those who do not (Spiegel & Watson, 1984). This particular finding was not replicated by Kishon-Rabin, Amir, Vexler and Zaltz (2001); however, their findings suggest that classically trained instrumental musicians have significantly better frequency discrimination than those with contemporary background.

Halwani, Loui, Ruber & Schlaug, 2011; have reported that singers have a larger tract volume in the left dorsal and ventral arcuate fasciculus compared to instrumentalists, although there is no significant difference between the two. They further conclude that musicians, especially singers, can be used as a model to demonstrate structural as well as functional adaptations of the auditory – motor system by showing structural differences between the brains of those engaged in specific types of music training (vocal versus instrumental). Jayakumar and Gore (2010) compared temporal resolution (using Random Gap Detection Test) among guitarists, vocalists and percussionists and concluded that guitarists (string instrument) performed better than the other two groups. Among the string instruments (usually Violin or Veena) used in Carnatic music, the violin with four strings was selected as it is the most commonly taught classical string instrument in Karnataka which may be because of its ease of portability as compared to Veena. Also, violin is one of the lead instruments which are similar to vocal music; hence violinists were selected for the study.

Mysore is the cultural capital of Karnataka and has a fine Arts college. Many legends from Carnatic music of vocal and instrumental genre have contributed to the popularity of music in this region. Hence a good number of Carnatic musicians (Vocal & Violin) were available for study.

1.4.1 Need for studying temporal processing in musicians.

It is very well documented from various studies that the formally trained musicians perform better than the non-musicians in tasks of temporal processing. Musicians have performed significantly better than the non musicians in several behavioral psychoacoustic tasks like gap detection test, duration discrimination test, duration pattern test, modulation detection of sinusoidally amplitude modulated noise, frequency discrimination and other auditory processing tasks (Sangamanatha, Fernandes, Bhat,Srivastava, & Udupa, 2012; Mohamadkhani , Nilforoushkhoshk , Mohammadi , Faghihzadeh &, Sepehrnejhad, 2010;. Ramsayer & Altenmuller 2006; Thomas & Rajalakshmi, 2011; Parbery-Clark, Skoe, & Kraus, 2009; Jeremy. Donai *&* Jennings, 2016; Mishra, Panda, and Herbert (2014). However, a few studies have revealed that there was no significant difference observed between the musicians and non-musicians ((Fujisaki & Kashino, 2002; Monteiro, Nascimento, Soares, & Ferreira, 2010 ;). Hence, a lack of consensus among these studies needs more empirical evidence to clearly understand these less understood interactions. Also, there are very few studies comparing temporal processing in vocalists and violinists. Therefore, need for further studies in this area are indicated.

1.4.2 Need for studying speech perception in noise in musicians.

Speech perception in noise refers to the ability of the person to perceive speech in adverse listening conditions. Musicians, as a consequence of training that requires consistent practice, online manipulation, and monitoring of their instrument, are experts in extracting relevant signals from the complex sound scape (e.g., the sound of their own instrument in an orchestra). The effect of such musical experience is believed to be transferred on the skills that sub serve successful perception of speech in noise. Many studies have reported better speech perception skills in musicians when compared to non musicians (Parbery-Clark, Skoe, Lam & Kraus, 2009. Parbery-Clark, Skoe & Kraus, 2009; Du and Zatorre, 2016; Zendel, Rich, Tremblay, Charles-David, Belleville, Sylvie, Peretz, Isabelle, 2015). However, there are no studies which have compared the speech perception in noise performance differences among the vocalists and the violinists which indicates further research on this population with respect to speech perception in noise.

1.4.3 Need for studying auditory working memory in musicians.

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. Evidences from literature have shown that music training is capable of improving memory (Chan, Ho, Cheung 1998; Williamson, Baddeley, Hitch, 2010; George & Coch (2007); Yesil & Nal, 2017a; D’Souza, Moradzadeh & Wiseheart, 2018 a; Talsmini, Carretti & Grassi, 2016). However, a few others have reported no significant advantage (Hansen, Wallentin & Vuust, 2013; Strait, Kraus, Skoe & Ashley, 2010 ;). However, no studies have compared working memory and short term memory between vocalist and violinists. Hence, more empirical studies in this area is the need of the hour.

1.5 Aims of the study

To primary aim of the study was to compare temporal processing, auditory working memory and speech perception in noise among vocalists, violinists and non-musicians. The secondary aim of the study was to find out the effect of years of musical experience on these auditory processing skills.

1.6 Objectives

The specific objectives of the study were:

1. To compare the temporal processing abilities among violinists, vocalists and non-musicians.

2. To compare the speech perception in noise among violinists, vocalists and non-musicians.

3. To compare auditory working memory among violinists, vocalists and non-musicians.

4. To compare the effect of years of musical experience on temporal processing in vocalists and violinists.

5. To compare the effect of years of musical experience on speech perception in noise in vocalists and violinists.

6. To compare the effect of years of musical experience on auditory working memory in vocalists and violinists.

1.7 Hypothesis.

Based on the previous investigations on the temporal processing, speech perception in noise and auditory working memory in musicians and non-musicians the following null hypotheses were formulated for the present study.

- There will be no significant difference in the temporal processing abilities among violinists, vocalists and non-musicians.
- There will be no significant difference in speech perception in noise among violinists, vocalists and non-musicians.
- There will be no significant difference in auditory working memory among violinists, vocalists and non-musicians.
- There will be no significant effect of years of musical experience on temporal processing in vocalists and violinists.
- There will be no significant effect of years of musical experience on speech perception in noise in vocalists and violinists.
- There will be no significant effect of years of musical experience on auditory working memory in vocalists and violinists.

CHAPTER-II

REVIEW OF LITERATURE

Musical training has been documented to provoke flexible changes in the structure of the brain. Numerous researches have validated changes in neural parthways of auditory system, intellectual abilities, and processing of linguistic abilities in musicians when compared with non-musicians. The main focus of this research is pondering on such questions such as- are there any changes in the temporal processing, perception of speech in noise and auditory working memory among musicians and non – musicians. Furthermore, is training in music a more operative or influential Global strategy for intervention, relative to other training programs that aim to alleviate specific deficits and also which form of music training influences what type of auditory processing. These are the questions nowadays clinically applicable, as well as being theoretically important.

2.1 INTRODUCTION

The human ear is an extremely precise organ than it appears. The sound goes through the external ear through the pinna, middle ear and afterward the cochlea to eventually be handled at a more complex level in the brain. In this way the auditory data achieving the cerebrum is refreshing for the ultimate result tuning in and grasping the auditory signal.

Auditory processing has been reported basically is "what we do with what we hear" (Katz, 1992). The ASHA Task Force (1996) characterizes Fundamental Auditory Processing as "the instruments and procedures in charge of the accompanying social wonders: sound localization and lateralization; auditory discrimination; auditory pattern recognition; temporal aspects of audition including temporal resolution, temporal masking, temporal integration, temporal ordering; auditory performance decrements with competing acoustic signals; auditory execution decrements with contending acoustic signs; and auditory execution decrements with debased acoustic signs". Butler (1983) characterized that processing of auditory information as the reflection of prominence from an auditory signal and the recovery of significance.

2.1.1 Temporal processing, auditory working memory, and speech perception in noise

In our surroundings where we live, we are seldom presented to a solitary signal of auditory information; rather our auditory context necessarily develop all the while happening intricate auditory signs to extricate important data. The ideal case of this is tuning in to speech in clamor which requires a lot of psychological and perceptual abilities including discovery of time shifting perceptual signals, working memory of auditory information and stream isolation (Parbery-Clark, Skoe, Lam & Kraus, 2009).

The auditory system investigates a sound signal in three essential areas: frequency, intensity and time. Time is a vital aspect in hearing since a large portion of the sounds fluctuate after some time. Temporal processing capacities are known to be of crucial significance in every day listening condition. Impression of temporal parameter of sound is essential for a wide scope of auditory practices including musicality discernment, phoneme separation, term discrimination, periodicity and pitch segregation. Moreover, temporal processing assumes a vital job in language cognizance, impression of prosodic refinements and speech observation in uncertain conditions (Chermak & Musiek, 1997).

One of the numerous variables prompting poor speech discernment is the discounted temporal resolving power of the auditory framework (Dreschler & Plomp, 1985; Ginzel, Pedersen, Spliid & Andersen, 1982; Price & Simon, 1984; Tyler, Summerfield, Wood & Fernandes, 1982). The concept of speech unpredictable indication, and temporal contrasts in speech assume a part in various phonetic differentiations associated with word separation; for instance, phonetic complexities could be prompted through contrasts to vowels or consonant changes.

Phonetic complexities could be able to likewise be prompted through contrasts in the extent of space between the bursts signaling the proximity or absence of a stop consonant (e.g. slit versus split). In speech, data originating from various temporal areas must be incorporated. Thus, each sort of temporal processing must be considered not just inside an auditory channel but also accross auditory channels. What's more, there is reconciliation of binaural sources of information lastly, how components of speech influence temporal examination and combination at each dimension should be contemplated.

Understanding speech in unfavorable circumstances is a complex task for the human auditory framework (Beattie, Barr & Roup, 1997). Amid ordinary circumstances, the vast majority can "block out" meddling clamors that begin from different sources, concentrating just on signals of interest. At the point when unfriendly conditions disturb speech perception, communication breakdown is generally transitory, yet irritating burden in the light of the fact that all conversations offer plentiful chance to repeat words or expressions which were not first comprehended (Beattie, 1989).

A considerable amount of cognitive, social research has been done on working memory. In simple words, it can defined that working memory is the accumulation of psychological procedures that allow data to be held incidentally in an available state, in the administration of some psychological assignment. The idea of the assignment can shift generally and can incorporate quick read, or listening appreciation, thinking, or critical thinking (Nelson, 1998). Working memory is a psychological framework that unequivocally identifies with an individual's capacity to prevail upon novel data and direct consideration regarding objective important data. Working memory empowers a person to incidentally store the data and control it when important. Because of the central job that working memory plays in perception, it has turned into a primary point of growing research (Shipstead, Redick & Engle, 2012).

Broadway and Engle (2011) revealed that people with low working memory limit were less sensitive when contrasted with people with high working memory limit in temporal discrimination tasks. Studies have demonstrated that both temporal processing and working memory aptitudes share the same anatomical site, i.e., the prefrontal cortex in the brain (Rajah, Ames & D'Esposito, 2008; Kane & Engle, 2002). Accordingly, it may be very well theorized that temporal processing capacities rely upon cognitive capacities such as the working memory of the person.

There is a connection between temporal processing, auditory working memory and speech perception in noise, as confirmed by various research studies on different populations such as normal adults, geriatrics, and so on.

2.2 Structural and processing differences in musicians.

Plasticity may be described as the tuning of neuronal circuits because of ecological requests. These adjustments can incorporate reinforcing of existing neural connections, arrangement of new neurotransmitters, or the extra enrollment of cortical tissue. In spite of the fact that this versatility has essentially been reported for motor abilities (Karni, Meyer, Jezzard, Adams, Turner & Ungerleider, 1995; Pascual-Leone, Nguyet, Cohen, Brasilneto, Cammarota & Hallett, 1995), proof for the adjusting impact of involvement on the structure or association of intellectual procedures has likewise been amassing. For instance, Green and Bavelier (2003) detailed that people who play computer games had quicker reaction times on consideration tasks and preferable visual processing over non-players who were generally practically identical. Maguire, Gadi, Johnsrude, Good, Ashburner, Frackoviak & Frith (2000) found that cab drivers in London with broad processing in course finding had expanded segments of the hippocampus in charge of spatial processing. Gaser and Schlaug (2003) utilized voxel-based morphometry to think about expert musicians, novice musicians, and nonmusicians; they found expanded dark matter thickness for professional musicians with littler increments for novice musicians in locales of the motor, auditory, and visual cortex. They translated these outcomes as proof for use-subordinate basic change and appeared also that the level of progress is aligned to the level of involvement. It appears as though that an assortment of specific exercises can offer ascent to changes in the basic cerebrum structures and procedures. Playing out a bit of music is viewed as a standout amongst the most requesting and complex cognitive assignments and includes a large number of intellectual procedures. It, in this manner, includes various brain systems including the motor, auditory, official, and limbic frameworks, and, additionally, requires the combination of data from a few intellectual areas. (Munte, Nager & Beiss, 2003).

Music is also a multifaceted auditory skill and individuals who practice music invest a very long time to calibrate their aptitudes. It is not a great surprise that previous investigations have achieved melodic sound neuroplasticity as a component of melodic experience (Fujioka, Trainor, Ross, Kakigi & Pantev, 2005; Koelsch, Schroger & Tervaniemi, 1999; Musacchia, Sams, Skoe & Kraus, 2007; Pantev, Roberts et al., 2001). Due to the extreme processing and aptitude securing an musician gets since the beginning, the musician's cerebrum fills in as an incredible model to consider procedures of neural flexibility (Gaser and Schlaug, 2003; Munte et al., 2003; Schlaug, 2001; Zatorre et al., 2002). Research studies have recommended that processing of musical bits benefits auditory processing in the melodic area, as well as in speech processing (Musacchia et al., 2007; Schon, Magne & Besson, 2004; Wong, Skoe, Russo, Dees & Kraus, 2007). Predictable research studies over a concentrate scope that use techniques that cross from neurophysiology demonstrate that music processing enhances a variety of verbal and nonverbal abilities. This includes working memory (Chan, Ho & Cheung, 1998;), processing of prosody (Chandrasekaran, Krishanan and Gandour, 2009; Wong et al., 2007), phonological aptitudes (Forgeard, Schlaug, Nortan, Rosam, Iyengar & Winner, 2008), processing of suprasegmental features in speech (Strait, Kraus, Skoe & Ashley, 2009), auditory attention (Strait, Kraus, Parbery-Clark & Ashley, 2010) and separation of auditory streams (Beauvois & Meddis, 1997).

While performing auditory, motor, or somatosensory tasks, several functioning imaging contemplates appeared among musicians and non-musicians

(Elbert, Pantev, Wienbruch, Rockstroh, and Taub, 1995; Pantev, Oostenveld, Engelien, Ross, Roberts, & Hoke, 1998; Schlaug, 2001). In the same away, a few studies have accounted for auxiliary brain contrasts between musicians and non-musicians (Zatorre et al., 1998; Schlaug, 2001; Schneider, Scherg, Dosch, Specht, Gutschalk &Rupp, 2002; Hutchinson, Lee, Gaab & Schlaug, 2003). Nonetheless, no examination has sought an auxiliary contrast between musicians and non-musicians across the entire area of the brain that could be linked to the particular abilities of musicians and the broad, long-term refinement of those abilities. These auxiliary contrasts announced were not clear in clarifying if the distinction in the brain structures was because of the repeated exposure to music, inborn, or because of training. Gaser and Schlaug (2003) examined three distinct groups: Musicians (professional), Musicians (novice) and nonmusicians. The factors, for example, Intelligence Quotient, age and so on were controlled. High- resolution anatomical pictures of the whole cerebrum were obtained utilizing a polarization arranged fast securing inclination resound grouping. Pictures were then broke down utilizing VBM (Voxel-based morphometry), a completely programmed method for computational examination of contrasts in nearby gray matter volume.

There are the evidences which demonstrate that the structures of the brain of musicians and nonmusicians differ. Musicians who play instruments are very brilliant in accomplishing the multifaceted physical and mental tasks, for example, an impromptu creation, interpretation of outwardly introduced melodic images into complex consecutive finger developments, remembrance of long melodic expressions and distinguishing proof of tones without the utilization of any tone for reference. Playing an instrument requires the synchronous mix of multimodal tactile and motor data with feedback components to screen execution. Different neuroimaging, social and neurophysiological investigations have investigated these excellent and very particular sensorimotor (Hund-Georgiadis and Von Cramon, 1999), auditory (Altenmuller, 1986; Pantev, Oostenveld, Engelien, Ross, Roberts & Hoke,1998; Ohnishi, Matsuda, Asada, Hirakata, & Nishikawa, 2001; Zatorre, Belin & Penhule, 2002;), auditory– spatial (Munte, Kohlmetz, Nager, & Altenmuller, 2001), visual–spatial (Hetland, 2002), and memory (Chan, Ho, & Cheung, 1998) aptitudes of the musicians. In any case, the neural corresponds of these melodic abilities have not been completely comprehended, and furthermore no firm relationship between these aptitudes and specific brain locales have been recognized.

As proved by the different investigations referenced above, contrasts do exist in the auditory processing capacities among musicians and non-musicians and music processing thus affects temporary processing, auditory memory and speech in noise perception.

2.3 Effect of Music training on temporal processing

Fujisaki and Kashino (2002) conducted a gap detection test on absolute pitch processors and non musicians. They reported that there was no significant difference between the two groups. They reported that the musicians do not have exceptional ears in terms of resolution. Ramsayer and Altenmuller (2006) inspected the general idea that the processing of temporal data in musicians is more accurate when compared to non-musicians. For this reason, seven distinctive auditory temporal assignments were performed by 36 scholastically prepared musicians and 36 nonmusicians. Superior performance of musicians was reported with respect to auditory fusion, three temporal discrimination tasks and rhythm generalization. They reported that musicians' better performance is only for ongoing and immediate timing tasks and not for those tasks which involve a reference memory. Mohamadkhani, Nilforoushkhoshk, Mohammadi, Faghihzadeh, & Sepehrnejhad (2010) conducted Gap in Noise test on 24 musicians and 24 non-musicians. Results revealed that the musicians performed significantly better than the non musicians but there was no gender distinction between the two groups ($p>0.05$). They reported that this may be a result of the impact of melodic processing on central auditory processing.

Monteiro, Nascimento, Soares and Ferreira (2010) reflected in musicians and non-musicians on the temporal processing capabilities. The study was described by between two groups, one of which consisted of 20 musicians and 20 other non-musicians, coordinated for age and instruction were submitted for audiological evaluation and GIN testing to evaluate the temporal objectives. In the control aggregate is in the right ear (RE) or left ear (LE), the test performance of the GIN group of musicians was not critical. The connection in the control group between the normal high frequencies for the LE and the GIN test was ($p= 0.001$). For RE ($p= 0.0001$), the normal frequencies for the two ears in the musician group were measurably huge and the highest qualities. No distinction was made between the GIN test exhibitions for the two groups and the relationship between day-to-day introduction to music and GIN.

Thomas and Rajalakshmi (2011) investigated temporal resolution abilities using Gap Detection Threshold test and modulation detection threshold for sinusoidally amplitude modulated noise at different modulation rates in musicians and non musicians. They reported that the musicians performed significantly better than the non musicians and the temporal resolution abilities were directly proportional to the number of years of musical experience.

Sangamanatha, Fernandes, Bhat, Srivastava and Udupa (2012) conducted a study in which they compared children with and without musical training with adults without musical training. They compared three tests of temporal resolution- Gap Detection Threshold test, Duration Discrimination Threshold and modulation detection threshold for sinusoidally amplitude modulated noise at different modulation rates. They reported that children with music training performed at the same level as that of adults and performed significantly better than the children without musical training. Ishii, Arashiro and Desgualdo (2006) conducted random gap detection test on 78 vocal musicians subgrouped again as professional singers, well tuned and out of tune singers in the age range of 18-55 years. They concluded that there was no significant difference within the musician group (professional singers, well tuned singers and out of tune/ amateur singers) in their performance in the random gap detection test. Zendel and Alain (2012) conducted gap detection test on life long musicians (N=74) and non musicians (N= 89) in the age range of 18 to 91 years and reported that the musicians the musicians demonstrated less age related decline in central auditory processing.

Kumar, Sanju and Nikhil (2016) investigated temporal processing abilities using 3 psycho acoustical tests (duration discrimination using pure-tones, pulse-train duration discrimination, and gap detection threshold test) on 15 vocal musicians and 15 non musicians in the age range of 20 to 30 years. He reported that the musicians performed significantly better than the non musicians in all the 3 temporal processing tests. Mishra and Panda (2014) examined temporal processing abilities using GDT in musicians (n=16) and non musicians (n=28) in the age range of 18 to 32 years. They concluded that the musicians performed significantly better than the non musicians. Donai and Jennings (2016) examined temporal processing abilities using Gap In

Noise test in musicians (n=14) and non musicians (n=14) in the mean age range of 22.1 years and 23.1 years respectively. They concluded that the musicians performed significantly better than the non musicians. As evidenced by most of the studies temporal processing is superior in musicians when compared to non musicians.

2.4 Music training and its impact on speech perception in noise

Among the available tests for evaluating Auditory temporal processing (ATP), the Pitch Pattern Sequence, Speech-in-noise (SIN) perception, or the' cocktail party phenomenon,' is also a definite case of auditory scene analysis (ASA)— the potential for studying composite acoustic scenes in comprehensible objects or causes, including auditory, motor and typically visual systems as they act to separate targets. SIN ability also varies perceptibly in healthy common populations (Assmann & Summerfield, 2004). SIN shortcomings that hinder day-to-day operation and disturb the quality of life are dominant in seniors (Parbery-Clark et al., 2011) and in some younger populations (Ziegler & Goswami, 2005), creating associated highly important topics each to illuminate our essential understanding of how the sensory system sounds, and as a vital matter.

Typically, SIN presentation has been delineated to be higher among musician teams, but there is still disappointment about this claim (Boebinger, Evans, Rosen, Lima, Manly & Scott, 2015). Because of shared resources (Alain, Zendel, Hutka, & Bidelman, 2014), it was suggested that musical training could be accustomed to advancing the sensory system in ways that support and improve SIN perception. The perception of SIN appears to be strengthened by each bottom-up sound coding fidelity (Du, Zatorre & Robot, 2016; Anderson & Kraus, 2010) and also by encouraging higher-level processes such as auditory retention (Kraus, Strait & Parbery-Clark, 2012). Such effects are also affected by genetic influences behavioral characteristics such as temperament (Corrigall, Glenn, & Misura, 2013), motivation, and interactions among factors (Anderson et al., 2013). Although genetic and epigenetic factors are likely to subsidize musical and SIN-relevant psychological features, training studies on SIN perception (Alain et al., 2014) are also likely to increase the effort on experience-dependent sensory system malleability (Pantev & Herholz, 2011; Bidelman and Alain 2015) suggest that training will provide auditory control with long-lived biological edges, as well as easy sensory activity improvements and even various functions necessary for higher-order psychological features such as memory and intelligence (Moreno & Bidelman, 2014, Herholz & Zatorre, 2012).

These findings are encouraging as they validate severance and adaptability within the perception machinery of the neural and could be exploited clinically. However, the mechanisms of that musical training might improve compound auditory skills such as the perception of SIN do not seem to be well understood. Specifically, however, it is not clear that processes and representations will vary or change and those aspects of training will be accountable once improvements have been identified. The complexities inherent in understanding this drawback are illustrated by work that shows interactions between demographic variables such as age and SIN sub-processes, that counsel that depend on different indications and psychological features to change SIN performance to completely different individuals. Tasks that are used clinically and analytically to test SIN ability lead to terribly different estimates of the relative SIN scores of people, suggesting that small variations in the style of listening tasks affect the degree to which people will solve SIN problems (Wilson, McArdle & Smith, 2007, Parbery-Clark et al., 2012). In addition, studies that record neuroscience responses such as functional magnetic resonance imaging (fMRI) or electroencephalography (EEG) in addition to musicians ' behavior are few and inadequate for some specific SIN task styles, creating incomplete understanding of the neural mechanisms that support SIN subtasks for associated degree.

Several recent studies have investigated the musician's perception improvement in SIN, but they vary in their task style. One suggests that setting aside the potential musical developments on advanced SIN behavior is to think about initially what exactly is being asked of a psychological feature system by the character of the task given to it (Coffey & Herholz, 2013); Auditory stream segregation, as well as linguistic communication, provides a variety of auditory indications on the separation of target whether, spatial location, spectral and temporal regularity, and modulation (Moore & Gockel, 2002). It is influenced by attention (Thompson, Carlyon & Cusack, 2011) and accelerated by vision data (Suied, Bonneel and Viaud-Delmon, 2009) and upcoming engine processes . Also at work are prophetic factors: SIN performance is understood to be pretentious through acquired data as well as language syntax and linguistics (Golestani, Rosen & Scott, 2009, Pickering & Garrod, 2007), acquaintance with the vocal sound property of the speaker (Souza, Gehani, Wright, & McCloy, 2013), preceding target data and previous target data which could be used to predicting, restricting and measuring incoming data interpretation.

Therefore, the properties of each target as well as the distracting stream are very important to what proportion the distractor will decompose the system and how it will reconstruct sound sources and separate the target sound. These characteristics vary significantly between existing studies of SIN benefits in musicianship; as an example, listeners are also offered whole sentences, single words or phonemes as targets, and these are also cloaked by noise created from similar frequencies but low data content (i.e. energetic masking) as distinct from competitor information-rich sound streams, kind of a second speaker. If we tend to understand better those aspects of SIN perception could be enriched by expertise, these dissimilarities should be taken into account.

A review article by Coffey, Mogilever & Zatorre (2017) has systematized results of a few recent studies on music influence on speech in noise perception based on their study design. They have also summarized the results of twenty nine studies between 2003 and 2016 and have tried to highlight the future research needs in this area. In summary, inspite of variations in the target and distractor features and differences in the visual, spatial and linguistic information, there is strong research evidence on musician advantage in speech in noise perception.

However, there are no conclusive findings in regard to how the music training enhances SIN performance. SIN perception requires multiple cues and due to lack of specific paradigms in the existing studies the findings are still inconclusive. In the current literature only a few studies have used specific cues. For instance, Fuller et al. (2014) studied the influence of varying pitch cues on and Parbery-Clark et al. (2009) used several clinical tasks that varied in noise and target properties. This highlights the future need for study designs with specific research question.

The study suggests that having research in this line is important for multiple reasons including better understanding of different levels of auditory processing, influence of experience on the cognition, and multimodal interaction and further to provide inputs regarding intervention of SIN perception deficits. To develop better insights on using musical training as clinical intervention for speech in noise perception deficits, it is important to conduct more studies with neuro-imaging techniques. These tools become the means for better understanding of sub-processes involved in the SIN perception.

To the end, authors have suggested various research approaches for the future including a) use of task decomposition and systematic variation of the tasks, b) use of various stimuli varying from phoneme to sentence and also tones, c) use of neuro-imaging techniques which can give information on both spatial and temporal data, d) use of stimulus reconstruction and neural decoding methods, e) influence of various levels of listening difficulty etc.

Although the results lack ample reliability and are not clearly intended for one mechanism for improving musician SIN, the bulk of the evidence indicates that there is such a musician advantage that this development cannot be explained on the idea of nonverbal ratio, memory, or different confounding. Thus, the stingiest clarification for the few studies that did not realize effects is a few mixtures of musician and SIN task heterogeneity, sampling error, and impact size (Boebinger et al. 2015)

Enhanced SIN perception ascertained in musicians may be due to advanced higher-level functions (Boebinger et al., 2015) such as auditory attention or auditory reminiscence capability (Strait, Kraus, Parbery-Clark and Ashley, 2010, Carey, Rosen, Krishnan, Pearce, Shepherd, Aydelott, & Dick, 2015, Chan et al., 1998, Ho, Cheung & Chan, 2003, Brandler & Rammsayer, 2003). There are advanced connections between musical training and psychological feature talents (Schellenberg & Peretz, 2008). Anderson et al. (2013) used structural equation modeling to measure the interactive contributions of psychological feature ability (as measured by auditory memory, auditory immediate memory, and auditory attention) and various SIN performance factors, and did not hide the fact that psychological feature ability significantly explained SIN scores, a sway modulated by previous musical expertise. Auditory memory has been steered as a major intermediary that supports the auditory benefits of musicians, as well as the perception of SIN as reviewed in Kraus et al. (2012). Musicians tend to have higher recording skills than non-musicians (Parbery-Clark et al., 2011a, Parbery-Clark et al., 2011b, Kraus et al., 2012). Musicians showed additional brain activity in functional magnetic resonance imaging studies (Pallesen, Brattico, Bailey, Korvenoja, Koivisto, Gjedde, & Carlson, 2010) in comparison with non-musicians (i.e. anterior cortex, lateral membrane bone cortex, insula, right basal ganglion and anterior cingulate gyrus) while recalling performance in cortical management areas. Successively, auditory memory is associated with the length and temporal order of exposure to musical training and the rhythm process (Bailey & Penhune, 2010) another talent that has been proven to be a causative part of language process and acquisition.

In addition, selective auditory attention is increased in musicians (Strait & Kraus, 2011), which may be a crucial mechanism for which sounds will be most fully processed and dropped in awareness. However, higher information content within the distractor decreases well, an attendant will solve SIN problems. Swaminathan et al. (2015) studied this impact in additional depth in musicians and non-musicians by masking sentences with forward and backward speech, and found that musicians were less vulnerable to informational masking, suggesting that they were highly prepared to attend to the target by selection (as well as suppressing linguistic knowledge supported by the distractor). Additionally, Clayton et al. (2016) confirmed the relationships between domain-general factors as well as each selective attention and memory handling in musicians ' SIN perception by evaluating the applied mathematical relationships between SIN scores and a range of cognitive actions.

Computing regularities at incoming sound's intervals is another central method that can be larger in musicians, possibly through a superior applied math data process (Shook, Marian, Bartolotti and Schroeder, 2013). Varnet et al. (2015) investigated whether or not musicians and non-musicians differed in their ability to distinguish between two phonemes given in speech-spectrum noise (/ga/, /da/) and modelled that each cluster was hooked in. While using connected ways to non-musicians, musicians performed higher, focused precisely on the acoustic signals that distinguished the phonemes, and quickly learned more throughout the experiment than their non-musical counterparts (Varnet, Wang, Peter, Meunier & Hoen, 2015). These results argue that top-down reinforcement of incoming relevant sounds or destruction of inappropriate sounds is also accelerated by higher mechanisms in musicians that extract spectral-temporal regularities.

Biology partly determines cognitive factors that auditory sustenance operates. For example, in an excessively twin study of musical training, Mosing et al. (2015) found that, despite variations in musical applications, the link between application and ratio can largely be accounted for by dominant genetic and shared environmental influences. However, in longitudinal studies (e.g. Moreno, Bialystok, Barac, Schellenberg, Cepeda & Chau, 2011, reviewed in Moreno and Bidelman, 2014), evidence of musical training effects on central functions as well as auditory memory was incontrovertible. Therefore, there is likely to be associated degree interaction between genetic and various predispositions with experience-dependent modulation of brain electronic equipment that offers rise to effects related to training (Zatorre et al, 2002).

Pitch indications are likely to help people improve music-related SIN, as long as musical activities almost always involve extensive production and pitch sound planning, which musicians have superior pitch discrimination talents, an ability that shows a transparent training impact (Micheyl, Delhommeau, Perrot and Oxenham, 2006). The sensory system uses periodicity to segregate market streams, to create and recognize auditory objects (Parbery-Clark et al., 2011). Pitch is exposed to elemental frequency coding the slowest periodic continuances of that sound, and may be measured by the frequency-following response to persecution electroencephalogram (Skoe & Kraus, 2010). The recent studies examining cluster variations in early sound measures as well as the FFR and their relationship with SIN perception underlie the name of highly reliable sound coding and its hardness in the presence of noise to support this talent. For example, Coffey et al. (2016) examined the correlation between SIN performance and also the strength of the FFR elemental frequency illustration in numerous animal tissue and neural auditory brain structures victimization magnetoencephalography (MEG) and found that SIN was linked to FFR strength throughout the sensory system. SIN scores were jointly associated with the age at which training began among those with musical expertise, which meant a skill sway. In order to check their influence on SIN perception across teams Fuller et al. (2014), varied the degree to which SIN tasks were hooked in to pitch points. Results showed that variations in musicians versus non-musicians were larger in conditions that relied on additional pitch indications. Tierney et al. (2015) measured the FFR (presented in silence) in adolescents before and when a quantity of musical training and found that musically trained people showed faster neural responses to sound compared to a sway cluster and improved SIN performance during training. These results support the hypothesis that in addition to being a causative role of musical training on basic sound illustration subserving SIN perception, superior process of pitch signs in musicians plays a vital role in SIN performance.

Although only a few of the studies reviewed contained spatial indications (Strait et al., 2010, Parbery-Clark et al., 2009, Swaminathan et al., 2015, Clayton et al., 2016, Strait et al, 2009), spatial data is mostly accessible in realistic listening conditions to populations with traditional binaural hearing and is well-established to greatly improve their performance. Some musical activities such as conducting an associate degree orchestra (and perhaps participating in an ensemble) appear to compliment auditory localization mechanisms (Münte et al., 2001), suggesting that an increased process of auditory spatial indications could represent another potential supply of musician SIN improvement.

Swaminathan et al. (2015) have conducted a research and found the impact of spatial separation and situated the advantage of a musician only when each target and distractor emanated from separate locations, under the condition that traditional speech (i.e. high data masking) was used. In distinction, they found a gaggle distinction with reversed speech (i.e. low data masking) only when spatial indications were absent, suggesting that the low information / high energetic masking condition would bring an artistic advantage only within the toughest co-located listening state of affairs. Clayton et al. (2016) used a high data masking style (forward speech) and jointly found a musician's advantage over a live SIN perception once the target and the distractor were separated rather than co-located; the authors speculated that there could be an interaction between the task's level of struggle and also the degree to which each cluster could make use of the accessible indicators. Parbery-Clark et al, (2009) found cluster variations within the HINT task only when there was a co-location of speech and noise, and not when the distractor was delivered 90 ° to the left or right of the target, given straight ahead. These conflicting results advise that a musician advantage is also partially fuelled by the enhanced spatial auditory skills of musicians (Clayton et al., 2016).

2.4.1 Multi-sensory integration of visual and motor systems

Musicians should present visual signals to interconnect temporal order and communicative data with various musicians, browse music, and typically follow a conductor (Clayton et al., 2016). They need to arrange and manage their activities in order to provide sound; thus, the visual and motor systems might be sources of improvement for the musician.

Only a couple of revised investigations included associate audiovisual status (Musacchia et al., 2007, Musacchia et al., 2008). In unimodal and audiovisual conditions (in silence) Musacchia et al. (2007) provided auditory stimuli. Basic sound coding procedures (i.e. the elemental frequency within the FFR) were known to distinguish between groups in the audiovisual condition, but were usually a gift that was smaller and less clear to the unimodal auditory condition, suggesting that musicians are highly willing to improve audiovisual integration even at terribly early stages of the sound process. This result is based on the observation that musicians have smaller windows of temporal integration to detect misaligned auditory and visual targets (Lee & Noppeney, 2011; Lee & Noppeney, 2014). These studies did not relate audiovisual results to the perception of SIN, it is unknown about the impact of this improvement. Zion Golumbic, Cogan, Schroeder, & Poeppel (2013), studied whether or not congruent visual input of associate degree attended speaker improved the neural illustration of natural continuous speech in connected work (which failed to investigate musicianship). Their results reinforce the name of visual input in the unclearness of auditory sensory activity breakdown, which they speculated might act to direct basic cognitive process resources at times when vital acoustic input is anticipated (Zion Golumbic et al, 2013).

Although none of the revised studies specifically examined the role of the motor system through the relationship to motor behavioral modifications, musicians and non-musicians dissent in enlisting dorsal brain regions that are known to represent motor aspects of speech once they listen to words in noise (Du and Zatorre, 2016). In addition to tough listening conditions, the motor system has been recruited to a greater extent, suggesting it helps to reimburse deprived sensory representations (Du et al., 2016). Once full sentences are used, rhythm may increase sensitivity to temporal order patterns that are vital to auditory perception and function as a proxy for grammatical processes, thereby increasing the ability of the brain to see if a candidate word sequence breaches a grammatically expected rhythm (Slater & Kraus, 2016). Danceable process narrates the synchronization of low-frequency animal tissue activity with slow temporal speech modulations that could help SIN perception by enhancing the strength of the brain's target signal illustration (Schön & Tillmann, 2015). The assimilation of auditory processes with the visual and motor system is each a vital feature of musical application (Zatorre et al., 2007) and is relevant to realistic SIN perception; it is therefore acceptable to further examine these associations in musicians.

2.4.2 Task issue interaction, connection and knowledge of cue

Du et al (2016) results advance a notable complication that can lead to a number of identified discrepancies in the results of the cluster: listeners recruit brain regions to completely different degrees in line with their expertise (Du & Zatorre, 2016), demographics such as age (Du et al., 2016), task level (i.e. SNR between target and source; Du et al., 2014, Wong et al., 20). For example, in an excessively aging study of SIN perception, Du et al. (2016) knew that older adults had higher activation of frontal speech motor areas as measured by functional magnetic resonance imaging throughout the identification task of the language unit than younger adults. This result was inferred as a countervailing mechanism by which older adults learned to rely on preserved specificity of speech sound to achieve similar levels of SIN performance to their younger counterparts. Basic coding measures jointly demonstrate similar difficulty-dependent relationships, as an example, musician-related cluster variations within the frequency-following response are much clearer once measured in troubled, creaky conditions than in silence (Parbery-Clark et al., 2009, Strait and Kraus, 2011). These findings are consistent with previous work, which used structural equation modeling to gage interacting peripheral hearing influences, central process, psychological feature ability, and life experiences to understand SIN, and showed that older musicians rely on completely different indications than non-musicians matched by age (Anderson et al., 2013). Whereas Du et al's functional magnetic resonance imaging work suggests an increased dependence on frontal motor networks in musicians as related to non-musicians and across teams as a problem (Du and Zatorre, 2016), different work investigates the connection between difficulty level (SNR) and electroencephalogram measurements (P1, N400) steered instead that as strain increases, musicians coupe. These discrepancies can be resolved through neuroimaging ways that can bridge spatial and temporal resolutions, such as combined EEG-fMRI or large integer resolutions. The majority of studies have used various SIN's paradigms or accuracy-based behavioral measures instead of setting SNR levels, which may obscure a number of these effects. However, the area of experimental style will be increased by considering SNR in addition to the psychological feature, higher delineated acoustic, spatial, and multisensory factors.

2.4.3 Neuroimaging application to SIN perception

Acceptance of musician development in SIN perception could revert to the relative prominence of multiple mechanisms that contribute to the present advanced task in excessively different listening conditions, or for clinical functions, those most difficult in living standards. However, the difficult multi-faceted nature of SIN perception implies that a wide-ranging understanding of it will be difficult to realize step by step exploring mixtures of target and distracting assets, spatial and multisensory indications, linguistic and musical variation in expertise, and the level of issues that influence behavioral SIN outcomes. Another powerful approach is to investigate the psychological feature mechanisms that support SIN perception with neuroimaging.

EEG provides the satisfactory temporal resolution required to review rapid neural activity oscillations, but to limit the brain structures concerned, it also requires ways to provide spatial data such as functional magnetic resonance imaging. Collective results from auditory perception studies have demonstrated that it is supported by multi-brain region networks. Received auditory data from the neural structure and neural structure allows initial allocation of auditory cortices within the temporal lobes for spectro-temporal analysis, and from there on 2 neural pathways: an allocated ventral stream that processes comprehensive speech signals (middle gyrus, lower temporal sulcus) and a left-lateralized dorsal stream that maps acoustic speech signals. FMRI-based experimental styles are accustomed to studying SIN perception in specific populations, as an example of older adults, who has been found to have inflated activity in dorsal areas and decreased activity in the cortical region relative to younger controls, resulting in frontal compensation for deteriorating sensory activity (Wong et al., 2007). Connected work on the neural process of different speech masker styles suggests that the sensitivity of behavioral outcomes to small variances in task style is parallel to changes in the reliance of these tasks on different brain organizations (Scott et al., 2009).

Musical achievements include several identical brain structures as they are energetic in auditory perception, as well as the cortical region, premotor and additional motor areas and frontal areas (Zatorre et al., 2007). These areas are successively linked to brain regions concerned with SIN perception: the upper gyrus, middle gyrus, lower gyrus, premotor cortex, and membrane bone areas (Du et al., 2016, Wong et al., 2009). However, the mechanisms by sharing brain structures might have an effect on the perception of SIN do not seem clear. These results ensure that dorsal and ventral stream areas are involved and divided. Inflated dorsal activation with poor performance and increased masking of noise. Dorsal root action might help SIN perception by providing pronunciation prophecies to restrict perception in degraded conditions. Only one of the revised studies of musicians versus SIN perception used functional magnetic resonance imaging in an extremely phoneme-in-noise style (Du & Zatorre, 2016). The results support that advanced SIN perception in musicians is also linked to the resilient specificities of speech sound of each of the ventral and dorsal auditory streams in both hemispheres, except for the heaviest conditions it is the dorsal, motor-related structures that play the primary role.

Hearing speech in noise is an uncomfortable task for everyone. Children and older adults are particularly vulnerable to the harmful effects of background noise. Children with learning problems may show rejection of noise as an essential side effect (Sperling, Lu, Manis, & Seidenberg, 2005). Musicians, on the other hand, show upgraded capacity for noise avoidance (Parbery-Clark, Skoe, & Kraus, 2009). Several scientists argue that seeing tangible data in underlying noise is a perplexing undertaking, including the ability to remove noise includes in the signal while stifling insignificant subtleties, incidentally storing this data while overlooking noise, processing a stream from a single source among different sources (e.g., voice of a speaker), and using phonetic setting to' fill in' These parts of speech in the observation of noise are improved in musicians and inadequate in young people with learning impairment.

Musicians are specialists in separating important signs from the complex soundscape (e.g., the sound of their own instrument in an ensemble) as a result of processing that requires predictable practice, online manipulation, and checking of their instrument. Literature shows that the impact of melodic experience is exchanged on the abilities that subserve the fruitful noise and beyond impression of speech. A current Kraus laboratory study on musicians found an unmistakable speech-in-noise advantage, as estimated by state-approved noise hearing trial (HINT, Hearing in-noise test; QuickSIN) (Parbery-Clark, Skoe, Lam et al., 2009). The quantity of long periods of predictable practice with a melodic instrument was consistent across all members with execution on QuickSIN, auditory working memory, and separation of recurrence.

These relationships strongly suggest that such practice calibrates intellectual and tangible abilities, prompting a general preferred point of view in musicians ' noise perception of speech. The results of the examination suggest that melodic experience in testing listening conditions improves the ability to hear speech. SIN execution is a brain boggling undertaking that requires prompt perceptual discovery, isolation from streams, and working memory. Musicians performed superior to non-musicians in conditions where objective and foundation noise were displayed from a similar source, meaning that parsing was gradually dependent on the acoustic signals in the stream.

Changes in central auditory processing may also influence the perception of SIN. Aging influences the pitch signal processing capability (Helfer & Vargo 2009). The ability to see speech in all three SNRs (0 dB,-5 dB and-10 dB) within the sight of the noise is better as the musicians ' experience has expanded. It has been discovered that as the musician's experience further expanded the ability to see speech in the sight of foundation noise, especially at lower SNRs (Thomas & Rajalakshmi, 2011).

In order to discover the impact of melodic experience on the neural representation of speech in noise, Parbery-Clark, Skoe and Kraus (2009) contrasted subcortical neurophysiological reactions with speech in quiet and in noise in a gathering of super-prepared controls by musicians and non-musicians. Speech evoked auditory brainstem reactions for speech syllable / da / demonstrated that musicians showed more basic noise reactions than in control group. They also found that before reaction timing and progressively powerful brainstem reactions to speech in base noise were both associated with better speech in noise observation as estimated by HINT. They assumed that melodic experience resulted in an increasingly strong subcortical representation of speech in the sight of foundation noise, which could add further to strengthening the social advantage of musicians for speech in recognition of noise. Musicians also showed progressively powerful reactions within the sight of foundation noise to the relentless state segment of improvement. By figuring the level of proximity between the advancement waveform and the sub-cortical representation of speech sound, musicians were found to have higher noise-boosting to-reaction connections than non-musicians. More notable improvement is characteristic of progressively accurate neural interpretation of stimulus highlights. One conceivable clarification for this musician's advancement in noise could be based on Hebbian rule, which establishes that the relationship between neurons that are all the while dynamic is strengthened and those that are not weakened in this way (Hebb, 1949). Wide melodic processing is supposed to prompt more notable neural cognition. This strengthening of the hidden neural hardware would prompt a higher base up, feeding forward signal representation.

It is well documented that the auditory cortex sharpens the subcortical tangible representations of sounds by improving the objective signal and suppressing by efferent processing the insignificant contending foundation noise (Suga et al., 1997; Luo et al., 2008). The use of fine-grained acoustic data by the musician and deep-rooted involvement in parsing all the melodic lines while occurring can refine the neural code in the best possible way down to such an extent that applicable acoustic highlights are upgraded in tangible processing from the get-go. This upgraded encoding improves the quality of the subcortical signal, resulting in an increasingly strong representation of the acoustic objective signal in noise. A vital factor in SIN observation is the subcortical encoding of the F0. In addition to the auditory article, the F0 and other pitch prompts distinguish proof, allowing the audience to "tag" the objective voice with an explicit personality and pursue this specific voice from among contending voices or different noises. The ability to recognize contending data floods is partially dependent on the F0, as shown by improved vowel segregation with a more notable F0 division between simultaneous vowels (Assmann & Summerfield, 1987) and sentences (Bird & Darwin 1998).

The enhanced reaction relationship improvement in the noise condition was identified with musician's more prominent neural representation, but not the key recurrence in noise. Musicians invest hours in delivering, controlling, and taking care of melodic sounds that are frighteningly rich throughout their preparation. The unreasonable complexity of music is incompletely inferable after a while from the closeness and relative quality of sounds as well as the adjustment in music. Musicians have improved cortical reactions to their essential instrument by proposing that their tuning in and processing background adjust the neural reactions to explicit timbres (Pantev et al., 2001; Margulis et al., 2009).

2.5 Effect of music training on auditory memory

Multiple studies have reported superior performance in auditory working memory tasks such as forward digit span in musicians compared to non-musicians. Factors such as sensory modality and difficulty level of the task have been reported to influence the performance. However, specificity as to what music cue results in such improvements is lacking in the literature.

Talamini, Carretti and Grassi (2016) assessed the working memory performance of musician and non-musicians using digit span test presented aurally, visually and audio-visually. Further, as a concurrent task articulatory suppression was also used to check the performance. The profile of musical perception skills test was used to assess the performance. Irrespective of the sensory mode and competing task, in general, musicians showed better performance in the tasks supporting the literature evidence for enhancements of verbal working memory performances in musicians over non-musicians.

On analysis of difference between sensory modalities they found auditory and audiovisual inputs showed better performance. They relate their results to the fact that musical experience results in integration of information from different sensory modalities (e.g., Paraskevopoulos, Kuchenbuch, Herholz, & Pantev, 2012; Paraskevopoulos, Kraneburg, Herholz, Bamidis, & Pantev, 2015). Important question that arises in this context is, is it the overall better cognitive ability of musicians which is leading to better working memory performance in them? However, cognitive tests were used as a control in this study and they did not find any difference in the general cognitive abilities between musicians and non-musicians.

Hansen, Wallentin and Vuust (2012) conducted digit span and spatial span test on expert musicians, amateur musicians and non musicians. Results revealed that the expert musicians outperformed the non musicians in the digit span test but no group differences were found on spatial span. Suarez, Elangovan and Au (2015) conducted tasks related to visual motor coordination, visual scanning ability, visual processing speed and spatial memory on 24 musicians and 30 non musicians. The results revealed that the musicians performed significantly better in all the tasks except phonological and visual memory tests. They concluded that music training improves certain working memory skill and not all of them in general. George and Coch (2011) investigated behavioral tests like visual, phonological and executive memory on musicians and non musicians. They concluded that musicians outperformed the non musicians in all the tests which reveal that the long term music training is related to improvements in working memory.

Lee, Lu and Ko (2007) investigated the effect of musical training on children (mean age: 12 years) with children of the same mean age and also with the adults (mean age: 22 years) who had received musical training and to their controls. There was a significant difference in the performance of children and adults with and without musical training. The musician group of both the groups outperformed the non musicians. Talamini, Carretti and Grassi (2016) compared the musicians and non musicians using the forward digit span and the backward digit span tests presented aurally, visually and audio visually. The results revealed that the musicians outperformed the non musicians regardless of the mode of presentation. Pallesen, Brattico, Bailey, Korvenojo, Koivisto, Gjedde and Carlson (2010) compared the musicians and non musicians' relationship between the task performance and the magnitude of BOLD response. The BOLD response was more positive in musicians as compared to the non musicians, especially during the most challenging task. They concluded that the superior performance can be attributed to the musical training. Williamson, Baddeley and Hitch (2010) used verbal and music serial recall of letter and tone sequences to compare the cognitive abilities of musicians and non musicians. The musicians outperformed the non musicians in all the tasks. As mentioned in the above studies, all the studies have indicated a positive impact of musical training on musicians with respect to their cognitive abilities.

But a few studies have reported no significant difference between musicians and non musicians with respect to their cognitive abilities due to musical training

(Okhrei, Kutsenk & Makarchuk , 2016; Rodrigues, Loureiro & Caramelli , 2014; Bailystok & DePape, 2009 ;). To conclude, consistency has not been observed in the performance of musicians in all the different tasks of auditory memory when compared to non musicians.

CHAPTER-III

METHODS

A non-experimental comparative research design involving both within and across group comparisons was used to evaluate the objectives of the study. This study was a cross-sectional study. Across group design was used to compare the performance among the violinists, vocalists and non-musicians. Within group comparisons were used to compare performance of the subgroups (i.e., junior group, senior group & the vidwath group) made within the group of musicians (violinists and vocalists).

3. 1. Participants

Ninety participants were considered for this study. All participants were in the age range of 18 to 45 years and they were native speakers of Kannada. A purposive / convenience sampling procedure was used. A structured questionnaire was administered to find out about the musical background and general health of the subjects. Questionnaire (Annexure I) inquiries included:

- Basic information concerning age, education, working experience,
- Medical history (past middle ear diseases and surgery, etc.),
- Musical history (initiation age, form of musical training, musical experience, music proficiency).
- Lifestyle (smoking, noisy hobbies, etc.), and
- Self-assessment of hearing status.

3.1.1. Inclusion Criteria

- Otoscopic examination showing a clear ear canal and cone of light.
- All participants had normal hearing (octave frequencies from 0.125– 8 kHz bilaterally, pure tone average ≤15 dB HL).
- Normal middle ear function ('A' type tympanogram at 226Hz probe tone with normal acoustic reflexes in both ears).
- A brief case history was noted to rule out those participants with history of middle ear pathology or surgery and any complaint of any neurological problems.
- Speech Recognition Threshold of ±12 dB (re. PTA of 0.5, 1 and 2 KHz) in both ears.
- Speech Identification Scores of > 90% at 40 dB SL (re. SRT) in both ears.
- No illness on the day of testing.
- All subjects should be graduates or pursuing graduation.

3.1.2. Exclusion Criteria: Participants with presence/report of any neurologic or structural abnormalities (ascertained by the researcher) have not been considered.

For the first 3 objectives, a total of 90 participants in the age range of 18 to 45 years were included who were again divided into three groups consisting of 30 members each.

Table 3.1.

Description of participants in each group

Group 1	Vocalists	Have passed the Junior proficiency exam in Carnatic vocal music. Musical training initiation before the age of 12 years.
Group 2	Violinists	Have passed the Junior proficiency exam in Carnatic violin music. Musical training initiation before the age of 12 years.
Group 3	Non musicians	Age matched individuals with no formal music training/experience.

Table 3.2.

Demographic details of 30 Violinists.

Participants	Chronological age (years)	Gender	Age of music initiation (years)	Musical proficiency
Violinist 01	22	M	7	Junior
Violinist 02	27	M	5	Junior
Violinist 03	22	F	8	Junior
Violinist 04	26	M	9	Junior
Violinist 05	24	M	6	Junior
Violinist 06	22	F	11	Junior
Violinist 07	20	F	6	Junior
Violinist 08	19	F	7	Junior
Violinist 09	20	M	8	Junior
Violinist 10	19	M	6	Junior
Violinist 11	22	M	5	Senior
Violinist 12	22	F	7	Senior
Violinist 13	27	M	8	Senior

Violinist 14	28	M	9	Senior
Violinist 15	27	M	5	Senior
Violinist 16	26	F	7	Senior
Violinist 17	22	F	6	Senior
Violinist 18	21	M	10	Senior
Violinist 19	22	F	7	Senior
Violinist 20	28	M	8	Senior
Violinist 21	42	M	9	Vidwath
Violinist 22	44	F	10	Vidwath
Violinist 23	40	F	5	Vidwath
Violinist 24	38	M	8	Vidwath
Violinist 25	44	M	7	Vidwath
Violinist 26	41	F	6	Vidwath
Violinist 27	42	M	9	Vidwath
Violinist 28	44	F	7	Vidwath
Violinist 29	43	F	7	Vidwath
Violinist 30	42	F	7	Vidwath

Note: M- Male, F- Female

Table 3.3.

Demographic details of 30 Vocalists.

Participants	Chronological age (years)	Gender	Age of music initiation (years)	Musical proficiency
Vocalist 01	22	F	8	Junior
Vocalist 02	21	F	5	Junior
Vocalist 03	18	F	6	Junior
Vocalist 04	19	M	9	Junior
Vocalist 05	21	M	5	Junior
Vocalist 06	19	F	8	Junior
Vocalist 07	18	F	4	Junior
Vocalist 08	22	M	7	Junior
Vocalist 09	24	F	6	Junior
Vocalist 10	22	M	7	Junior
Vocalist 11	24	M	7	Senior
Vocalist 12	23	M	8	Senior
Vocalist 13	22	F	8	Senior
Vocalist 14	21	F	10	Senior
Vocalist 15	25	M	8	Senior
Vocalist 16	22	F	10	Senior
Vocalist 17	25	M	6	Senior
Vocalist 18	22	F	9	Senior
Vocalist 19	29	F	5	Senior
Vocalist 20	30	F	7	Senior
Vocalist 21	41	M	7	Vidwath
Vocalist 22	42	M	10	Vidwath
Vocalist 23	44	F	6	Vidwath
Vocalist 24	39	F	8	Vidwath
Vocalist 25	43	M	7	Vidwath
Vocalist 26	42	M	6	Vidwath
Vocalist 27	40	F	6	Vidwath
Vocalist 28	42	F	9	Vidwath
Vocalist 29	44	F	4	Vidwath
Vocalist 30	44	F	5	Vidwath

Note: M- Male, F- Female

Table 3.4.

Demographic details of 30 Non-musicians.

Participants	Chronological age (years)	Gender	Age of music initiation (years)	Musical proficiency
Non Musician 01	19	M	Not Applicable	Not Applicable
Non Musician 02	34	M	Not Applicable	Not Applicable
Non Musician 03	22	F	Not Applicable	Not Applicable
Non Musician 04	26	F	Not Applicable	Not Applicable
Non Musician 05	24	F	Not Applicable	Not Applicable
Non Musician 06	21	M	Not Applicable	Not Applicable
Non Musician 07	19	M	Not Applicable	Not Applicable
Non Musician 08	19	F	Not Applicable	Not Applicable
Non Musician 09	20	M	Not Applicable	Not Applicable
Non Musician 10	19	F	Not Applicable	Not Applicable
Non Musician 11	28	M	Not Applicable	Not Applicable
Non Musician 12	22	F	Not Applicable	Not Applicable
Non Musician 13	24	F	Not Applicable	Not Applicable
Non Musician 14	28	M	Not Applicable	Not Applicable
Non Musician 15	27	M	Not Applicable	Not Applicable
Non Musician 16	26	F	Not Applicable	Not Applicable
Non Musician 17	22	F	Not Applicable	Not Applicable
Non Musician 18	18	M	Not Applicable	Not Applicable
Non Musician 19	22	M	Not Applicable	Not Applicable
Non Musician 20	23	F	Not Applicable	Not Applicable
Non Musician 21	42	F	Not Applicable	Not Applicable
Non Musician 22	44	F	Not Applicable	Not Applicable
Non Musician 23	38	M	Not Applicable	Not Applicable
Non Musician 24	38	M	Not Applicable	Not Applicable
Non Musician 25	22	F	Not Applicable	Not Applicable
Non Musician 26	41	M	Not Applicable	Not Applicable
Non Musician 27	42	F	Not Applicable	Not Applicable
Non Musician 28	42	M	Not Applicable	Not Applicable
Non Musician 29	43	F	Not Applicable	Not Applicable
Non Musician 30	37	F	Not Applicable	Not Applicable

Note: M- Male, F- Female

Table 3.5.

Participants' chronological age and initiation age of musical training.

	Non musicians(n=30)	Violinists (n=30)	Vocalists (n=30)	Violinists	Vocalists
Mean	28.40	29.53	28.93	7.33	7.03
SD	8.96	9.84	9.36	1.58	1.71
Range	18-44	18-44	19-44	5-11	4-10

Note: SD = Standard deviation

Table 3.6.

Chronological age of the participants in sub groups of violinists

	Junior (n=10)	Senior (n=10)	Vidwath (n=10)
Mean	22.1	24.5	42
SD	2.80	2.91	1.94
Range	19-27	21-28	38-44

Note. SD = Standard deviation

Table 3.7.

Chronological age of the participants in sub groups of vocalists

	Junior (n=10)	Senior (n=10)	Vidwath (n=10)
Mean	20.6	24.1	42.1
SD	2.01	3.07	1.72
Range	18-24	21-30	39-44

Note. SD = Standard deviation

Individuals in group 1 and group 2 must have passed the junior proficiency exam (Karnataka Secondary Education Board) in their respective field and they were practicing music consistently (at least 3-4 hours a week) until the day of testing. Musical training initiation age must be before the age of 12 years for both the groups.

All participants were made to fill up a written informed consent. Group 3 was the age matched graduate subjects who had no formal music training/ experience. Thus, none of the nonmusicians were occupied with music to a greater extent than occasionally listening to music.

To investigate the effect of years of musical experience on temporal processing (Objective 4), speech perception in noise (Objective 5) and Auditory Working Memory (Objective 6) in both the groups (violinists and vocal musicians), the same 30 vocalists and 30 violinists were considered. Each of these two groups was again divided into three sub groups based on their musical proficiency, i.e. junior (N=10), senior (N=10) and vidwath (N=10).There is 3 levels of proficiency in Carnatic music: a) Junior b) Senior, and c) Vidwath. Beginners start at Junior level and to move to the next level (i.e. Senior and then Vidwath) they have to pass exams conducted by the Karnataka Secondary Education Board. There were 10 participants in each sub group.

The participants were included in the study after obtaining their informed written consent for willingness to take part in the study.

The method adopted was approved by the institutional ethical committee and conformed to the ethical guidelines streamlined for bio-behavioral research projects involving human subjects (Approval letter dated 09.05.2013). For this Ethical Guidelines for Bio- Behavioral Research developed by Venkatesan & Basavaraj (2009) was used.

3.2. Test Environment

Pure tone Audiometry and Immittance Audiometry testing have been carried out in an air conditioned sound treated double room situation as per the standards of ANSI S3.1 (1991). The remaining tests were carried out in an air conditioned, acoustically treated room (Electro physiology Lab at the institute).

3.3. Instrumentation and Software

- Otoscope
- A calibrated 2 channel Inventis Piano diagnostic audiometer with TDH-39 headphones and B-71 bone vibrator was used for performing the pure tone and speech audiometry.
- Calibrated GSI Tympstar (version 2) middle ear analyzer was used for tympanometry and reflexometry.
- MATLAB version 7.9 software (The Math Works, Inc., MA, USA, 2009) installed in a laptop (Dell Inspiron).
- A laptop (Dell Inspiron) was used to deliver the stimulus for all the temporal processing tests, auditory working memory test and speech perception in noise test.
- A Sennheiser HDA-200 high fidelity headphone (Wedenmark, Germany) was used for delivering the stimulus from the laptop to the subject.
- Adobe Audition 3 (version 3.0.1) installed to a HP laptop (Intel i5 processor, 8 GB RAM) was used to digitally mix the recorded audio stimulus.
- APEX 3 program developed at ExpORL (Francart, van Wieringen, & Wouters, 2008) installed in a laptop (Dell Inspiron).

3.4. Test Stimuli and Procedure

The complete procedure was divided into two phases.

Phase 1: This phase included tests to ascertain normal hearing sensitivity in all subjects and took approximately 35 to 40 minutes. The following tests were carried out.

Otoscopy and a structured interview were carried out to know about the general health of the subject and also about the musical background (if the subject was a musician). Air conduction thresholds for octave frequencies from 250 Hz to 8000 Hz and bone conduction thresholds for octave frequencies from 250 Hz to 4000 Hz was obtained with modified version of Hughson Westlake procedure (Carhart & Jerger, 1959).

Speech recognition threshold (SRT) was estimated using Kannada paired words (Rajashekar, 1976) using the standardized procedure. Speech Identification Score was estimated at 40 dB SL (re: SRT) using the Kannada word list developed by Yathiraj and Vijayalakshmi (2005). The total number of correctly identified words was noted down as the SIS and was converted into percent correct responses.

The middle ear functioning was evaluated based on tympanometry and acoustic reflex thresholds. Admittance was measured using a 226 Hz probe tone with a pump speed of 200 daPa/sec. Ipsilateral and contralateral acoustic reflex thresholds were obtained for pure tones of 500 Hz, 1 kHz and 2 kHz.

Phase II: Only if a participant fulfilled all criteria for normal hearing sensitivity, as assessed using the tests in Phase I, Phase II was conducted.

a) The following tests were carried out to assess temporal processing.

- Gap Detection Threshold in Noise (GDT)
- Duration discrimination Test (DDT)
- Duration Pattern Test (DPT)
- Modulation detection threshold for sinusoidally amplitude modulated noise (SAM)

b) Test carried out to assess speech perception in noise: Speech in noise test (using Kannada sentences) (Avinash, Meti & Kumar, 2009)

c) The following tests were carried out to assess Auditory Memory.

- Forward Digit Span Test (FDS)
- Backward Digit Span Test (BDS)
- Verbal retention for Meaningful pairs Test (VRMP)
- Verbal retention for Non-Meaningful pairs Test (VRNMP)

FDS and BDS were used to assess auditory working memory and VRMP and VRNMP were used to assess short term auditory memory.

All tests were conducted monaurally in both the ears. For all the tests, the stimulus was presented at 70 dB SPL or at the most comfortable level using calibrated Sennheiser HAD 200 circumaural headphones. The headphone was calibrated once at the beginning of the data collection and periodically thereafter (once in every two months) to produce a 70 dB SPL for a 1kilo Hertz pure tone in a 6cc coupler. For the purpose of calibration, a 1 kilo Hertz pure tone was generated at the same root mean square level as the test signal. The calibration procedure included connecting of the headphone output to a 6cc coupler (B & K, Type 4152) with circumaural adaptorplate which was then connected to a sound level meter (B & K, Type 2270) and microphone (B& K, Type 4144, 1inch pressure field microphone). Later, the volume control in the laptop was set to produce70 dB SPL on the sound level meter. All the tests were conducted in a random order. After each test a 5–10 minutes rest period was given to ensure that participants remained alert and the entire test battery was completed in two or three sessions. Practice trials were given to all the subjects before the beginning of each test.

3.4.1. Tests to assess temporal processing

a) **Gap Detection Threshold (GDT):**

Stimuli: Gap detection threshold in noise test consisted of a standard stimulus of 750 msec duration Gaussian noise with a silence of standard duration placed at its temporal center. The variable stimulus had variable gap duration and the length of its gap was changed as a function of the subject's performance. All noises had a 0.5 msec cosine ramp at both onset and offset.

Instructions: Participants were instructed to listen to the three intervals of noise carefully, identify the variable stimulus and indicate the response verbally as in which interval (first, second or the third interval) contained the variable stimulus.

Procedure: Three Interval Alternate Forced Choice Method (3IAFC) was used to obtain the gap detection threshold with 8 reversals. The presentation level of the stimulus was 70 dB SPL or at the most comfortable level, monaurally.

Scoring: The minimum gap that the subject detected was considered as the gap detection threshold. A staircase procedure run under Apex 3 software was used to provide an estimate of the 70.7% correct response level (Levitt, 1971).

b) Duration Discrimination Test:

Stimuli: The minimum difference in duration required to perceive the two otherwise identical stimuli was measured in the duration discrimination test. The standard stimulus was a pure tone of 250 msec and the duration of the variable stimulus was based on the responses of the subject.

Instructions: Participants were instructed to listen to the three intervals of noise carefully, identify the variable stimulus and indicate the response verbally as in which interval (first, second or the third interval) contained the variable stimulus.

Procedure: Three Interval Alternate Forced Choice Method (3IAFC) was used to obtain the duration discrimination threshold with 8 reversals. The presentation level of the stimulus was 70 dB SPL or at the most comfortable level, monaurally.

Scoring: A staircase procedure run under Matlab version 7.9 software was used to provide an estimate of the 70.7 % (Levitt, 1971) correct response level.

c) Duration Pattern Test:

Stimuli: The DPT consists of a 1000 Hz pure tone of two different durations (Gauri & Manjula, 2003). The short duration tone was of 250 msec and the longer duration tone was of 500 msec. Six different patterns were generated by combining these two durations in three tone patterns (long long short, short short long, long short long, short long long, short long short, long short short). The inter-stimulus interval was 250 msecwithin a sequence and there was a gap of 6seconds between two tone sequences.

Instructions: The subjects were instructed to listen to 3 tones carefully and repeat the sequence heard verbally as long, long, short / short, long, short or however they perceived the stimulus to be.

Procedure: 30 test items were administered after a few practice trials. The stimuli were presented at 70 dB SPL or at the most comfortable level through headphones.

Scoring: Each correct response was given a score of 1 and each wrong response was given a score of 0. Total scores out of 30 were considered.

d) Modulation detection threshold for sinusoidally amplitude modulated noise:

Stimuli: This test was carried out using the maximum likelihood procedure (MLP) toolbox (Grassi & Soranzo, 2009) in Matlab version 7.9. Unmodulated and sinusoidally amplitude-modulated (SAM) Gaussian noise of 500 ms duration with a ramp of 20 ms was used as stimulus. The SAM Gaussian noise was presented at six different modulation frequencies (4, 8, 16, 32, 64, and 128 Hz), and modulation detection thresholds were estimated using the 3IAFC method.

Instructions: Participants were instructed to listen to the three intervals of noise carefully, identify the variable stimulus and indicate the response verbally as in which interval (first, second or the third interval) contained the variable stimulus.

Procedure: On each trial, two unmodulated and one modulated stimuli were successively presented with an interstimulus interval of 500 msec. The subject's task was to indicate which interval contained the modulated noise. Modulation depth was varied between 0 to –30 dB (where 0 dB had 100% modulation depth and –30 dB had virtually no modulation) based on the subject's response up to a 70.7% criterion level.

Scoring: The minimum modulation depth needed to detect a modulated signal was considered to be the modulation detection threshold. This test was carried out using the maximum likelihood procedure (MLP) toolbox (Grassi & Soranzo, 2009) in Matlab. The modulation detection thresholds were expressed in dB using the following equation:

Modulation detection threshold in dB=20 $\log_{10}$ m

m= modulation detection threshold in percentage.

3.4.2. Test to assess perception of speech in noise

a) Speech Perception in Noise (using Kannada sentences).

Stimuli: Speech Perception in Noise – using Kannada sentences, (Avinash, Meti & Kumar, 2009) was administered using the 60 sentences based on the subjects rating of predictability given by the authors. The test contains 60 sentences that are distributed randomly in 12 lists with 7 sentences in each list. Some of the sentences in the test have been used in more than one list. These sentences have been recorded by a native male Kannada speaker using the Pratt software (Boersma & Weenink, 2005).

An eight talker speech babble noise has been used in the test to generate sentences with different SNRs in the test. In each list first sentence was at +20 dB SNR and SNR was reduced in 5 dB steps for the subsequent sentences. Thus in each list, first sentence was at +20 dB SNR, second sentence was at +15 dB SNR, third sentence was at +10 dB SNR, fourth sentence was at +5 dB SNR, fifth sentence was at 0 dB SNR, sixth sentence was at -5 dB SNR and last sentence was at -10 dB SNR. These SNRs encompasses the range of normal to severely impaired performance in noise. Sentences used in the test were high probability items for which the key words are somewhat predictable from the context.

Instructions: The subject was instructed to listen to the sentences carefully and to avoid the back ground noise present along with it. They were asked to verbally repeat back the sentence heard immediately after the presentation of the sentence.

Procedure: Each sentence in the test has five key words that were scored as correct/incorrect. These sentences were presented at 70 dB SPL or at most comfortable level through the laptop. The listener’s task was to repeat the sentences presented and each correctly repeated keyword is awarded one point for a total possible score of 35 points per list.

Scoring: Each correctly repeated keyword was awarded 1 point and the maximum score was 35 in each list. To calculate SNR at which 50% scores were obtained, the following formula as recommended in the study by Avinash, Meti and Kumar (2009) was used. SNR at which 50% scores are obtained = 22.5-(total words correct)

3.4.3. Tests to assess Auditory Working Memory

The test materials were prepared newly for the study purpose in Kannada language (South Indian language, spoken mainly in the state of Karnataka, India). Two tests for auditory working memory (FDS & BDS) and 2 tests for auditory memory were used (VRMP & VRNMP).

a) Forward Digit Span (FDS) test.

Stimuli: Bi-syllabic digits in Kannada were recorded by an adult native fluent female speaker with a clear voice and articulation. The digits (except 2 & 9 because they are trisyllabic) were recorded with a Shure dynamic microphone placed 10 cm away from the speaker's mouth using the Computerized Speech Lab (CSL) model 4500 software systems in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44,100 Hz. The speaker was instructed to pronounce the words in a natural, clear manner and neutral intonation, while maintaining constant vocal effort. The independent recordings of each digit were made into a series of digits as required using the Adobe Audition 3 software. The interstimulus interval between the two digits was 250 ms.

Instructions: The subjects were instructed that they will be hearing a series of digits like 3, 7, 1, and they should listen to it carefully and verbally repeat it back immediately in the same sequence.

Procedure: Stimuli was presented monaurally through calibrated headphones at 70dB SPL with a series of digits (e.g., '8, 1') and the subjects were instructed to immediately repeat them in the same given order. The inter-stimulus interval between two digits was 250ms. Care was taken that no digit was repeated successively and also there was no recognizable pattern in the series of digits. If they were able to verbally repeat it back successfully, they were given a longer list (e.g., '7, 2, 4'). This procedure would continue until the subject failed to repeat the given list. When the participant failed then another list with the same number of digits would be presented. If the participant could repeat it correctly in the same sequence then he/she could go to the next series else the previous series (where he could repeat it successfully) would be considered as his/her digit span memory. The minimum length of the series was 2 and the maximum length of the series consisted of 10 digits.

Scoring: Each series was given a score of 1 if the subject could repeat it back in the same sequence and the subjects score would be the total score of the series he/she could repeat successfully.

b) **Backward Digit Span (BDS) test*:*** In the BDS test, the stimuli and procedure was similar to that mentioned above in forward digit span test but the subject had to reverse the order of the digits presented in their verbal response. Scoring also remained the same as FDS test.

c) **Verbal retention for Meaningful pairs test (VRMP).**

Stimuli: For this test, more than 400 meaningful and related Kannada bi-syllabic pairs were prepared using common sources such as text books, magazines and local newspapers. Words related to politics were avoided. Nouns and words indicating numbers were also eliminated from the pool. The list of collected pairs was then given for familiarity rating. Fifteen native adult Kannada speakers (audiologists/ speech language pathologists) rated all the words using a five point rating scale. Rating scale used was ‘extremely familiar’, ‘very familiar’, ‘moderately familiar’, ‘slightly familiar’ and ‘not familiar’. Reponses from all the individuals were compiled and pairs that were rated as extremely familiar and very familiar by at least 70% of the participants were made a list. This list was again given to another set of 15 native adult Kannada speakers (audiologists/ speech language pathologists) to rate them on the basis of how much the two words in the pair was associated with respect to each other. The rating scale used was extremely associated, very much associated, moderately associated, slightly associated and not associated. Reponses from all the

15 individuals were compiled and pairs that were rated as extremely associated and very much associated by at least 70% of the participants were made a list.

All the selected pairs were recorded by a native female speaker with normal voice and clear articulation. The recording was done using Computerized Speech Lab (CSL) model 4500 software systems with a Shure dynamic microphone kept 10 cm away from the speaker's mouth in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44100 Hz. The speaker was instructed to pronounce the words in a natural, clear manner and neutral intonation, while maintaining constant vocal effort.

The recorded pairs were made into 7 lists with the first list having 3 pairs, 2nd list having 6 pairs, 3rd list having 9 pairs and hence the 7th list having 21 pairs (Annexure 2). The inter stimulus gap between two pairs was 250ms.

Instructions: The subject was instructed that he/she would be presented with a series of pairs. He/she has to listen to the pairs carefully and once the list ends, the researcher would say the first word of the pair to which the participant had to immediately respond verbally with its compliment which was in the list previously presented. He/she was instructed that he/she should not take more than 5 seconds to respond.

Procedure: These pairs were presented to the subject through calibrated headphones starting from list 1monaurally at 70dBSPL or at the most comfortable level. Subject's task was to listen to the entire list first and later researcher would say the first word of the pair to which the participant had to immediately respond with its compliment which was in the list previously presented. The response time limit was set not to exceed 5 seconds. If the subject could achieve a score of 80 % or more in that list, then he/she would be presented with the next list containing 6 pairs and the same procedure continued until the subject's score was below 80% in the presented list. Based on the observations made in the pilot study, the cut off score was kept at 80%, to avoid ceiling effect.

Scoring: Each list was given a standard score of 1 and the participant was given the total score based on where he/she could obtain 80% or above before failing in the consecutive list.

d) Verbal retention for Non- Meaningful Pairs Test (VRNMP).

Stimuli: For this test, 700 meaningful bi-syllabic Kannada words were taken from corpus of words collected for development of word lists for adults in Kannada language (Puttabasappa, Periannan, Kumar & Chinnaraj, 2015). These words were randomly paired using the Matlab version 7.9 software. Word pairs were analyzed for dissimilarity by taking the ratings of 15 adult native Kannada speakers (Audiologists / Speech Language Pathologists). A 5 point rating scale was used. Rating scale used was 'extremely un- associated', 'Very much un-associated', 'moderately un-associated', 'slightly un-associated' and 'associated'. Reponses from all the 15 individuals were compiled and pairs that were rated as extremely un-associated and very much un associated by at least 70% of the participants were made a list.

All the selected pairs were recorded by a native female speaker with normal voice and clear articulation. The recording was done using Computerized Speech Lab (CSL) model 4500 software systems with a Shure dynamic microphone kept 10 cm away from the speaker's mouth in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44100 Hz. The speaker was instructed to pronounce the words in a natural, clear manner and neutral intonation, while maintaining constant vocal effort.

Later, recorded word pairs were divided into 10 lists with 1st list containing 2 word pairs, 2nd list containing 3 word pairs, 3rd list containing 4 word pairs and hence the 10th list was containing 11word pairs (Annexure 3). The inter stimulus gap between two pairs was 250ms.

Instructions: The subject was instructed that he/she would be presented with a series of pairs. He/she has to listen to the pairs carefully and once the list ends, the researcher would say the first word of the pair to which the participant had to immediately respond verbally with its compliment which was in the list previously presented. He/she was instructed that he/she should not take more than 5 seconds to respond.

Procedure: These pairs were presented to the participants starting from list 1. After listening to the each list, researcher would say the first word of the pair to which the participant had to immediately respond with its compliment. The response time limit was set not to exceed 5 seconds. If the participant could achieve a score of 50 % or more in that list, he/she would be presented with the next list containing 3 pairs and the same procedure continued until the participants' score was below 50% in the presented list. Based on the observations made in the pilot study, the cut off score was kept at 50%, to avoid floor effect.

Scoring: Each list was given a standard score of 1 and the participant was given the final score based on where he/she could obtain 50% or above before failing in the consecutive list.

3.5 Standardization of the VRMP and VRNMP tests

Test Selection:

Since, there were no tests in Kannada language to test memory using words, a memory test was intended to be developed by adapting the already existing test in the PGI Memory Scale -English version (Pershad & Wig,1976). This test can be administered on anyone in the age range of 20 to 40 years. However, it is not a self-administered test. This test consists of 10 subtests of which 8 test are verbal and 2 non-verbal. This test battery consists of 10 sub tests out of which the 7^{th} and the 8^{th} tests are Verbal Retention of Similar Pairs and Verbal Retention of Dissimilar Pairs respectively. The verbal retention of similar pairs consists of a list 5 word pairs which are similar/ related to each other (e.g. Tree- flower, sweet-sour, man- woman, day-night, black- white). The entire list is read out to the subject at the rate of 2 seconds per pair and with a pause of 5 seconds between each pair. After reading out the last pair, a 10 second interval is given after which the first word of the pair is presented verbally to the subject to which he must recall and respond verbally with its pair.

The verbal retention of dissimilar pairs also consists of 5 word pairs but the pairs are dissimilar to each other (E.g. Table- black, Tree- high, lamp- uneven, child-bitter, dream-deep). The instruction and administration of this test is the same as the above mentioned test, but the difference is that the pairs are to be presented in the same order for each of the trial. If the subject fails to give correct answer, he/ she have to be corrected and the next word has to be presented. Even if all the answers given by the subject are correct in the first trial, even then the other two trials are to be completed but in no case, pairs can be repeated; only incorrect answers are to be corrected.

Table 3.8.

Dissimilar word pair list and the order of the 3 trials.

Pairs	Trial 1	Trial 2	Trial 3
Table- black	4	2	1
Tree- high	2	1	5
Lamp- uneven	1	5	3
Child- bitter	3	4	2
Dream- deep	5	3	4

Scoring:

a. **Verbal retention for similar pairs.**

One mark is given for each correct reproduction of the associated word of the pair and hence the maximum score of this list is 5.

b. Verbal retention for dissimilar pairs.

One mark is given for each of the correct recall of words of the pair, separately for each trail. Hence, the maximum score for this test is 15.

3.6Verbal retention for Meaningful pairs test (VRMP)

Test preparation:

Stimuli: For this test, more than 400 meaningful and related Kannada bi-syllabic word pairs were prepared using common sources such as text books, magazines and local newspapers. Words related to politics were avoided. Nouns and words indicating numbers were also eliminated from the pool. The list of collected pairs was then given for familiarity rating. Fifteen native adult Kannada speakers (audiologists/ speech language pathologists) rated all the words using a five-point rating scale. Rating scale used was ‘extremely familiar’, ‘very familiar’, ‘moderately familiar’, ‘slightly familiar’ and ‘not familiar’. Reponses from all the individuals were compiled and pairs that were rated as extremely familiar and very familiar by at least 70% of the participants were made a list. This list was again given to another set of 15 native adult Kannada speakers (audiologists/ speech language pathologists) to rate them on the basis of how much the two words in the pair was associated with respect to each other. The rating scale used was extremely associated, very much associated, moderately associated, slightly associated and not associated. Reponses from all the 15 individuals were compiled and pairs that were rated as extremely associated and very much associated by at least 70% of the participants were made as a list.

All the selected pairs were recorded by a native female speaker with normal voice and clear articulation. The recording was done using Computerized Speech Lab (CSL) systems in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44100 Hz. The speaker was instructed to pronounce the words in a natural, clear manner and neutral intonation, while maintaining constant vocal effort at the rate of 2 seconds per pair. The recorded pairs were made into 7 lists with the first list having 3 pairs, 2^{nd} list having 6 pairs, 3^{rd} list having 9 pairs and hence the 7^{th} list having 21 pairs. The inter stimulus gap between two pairs was 250ms.

Instructions: The subject was instructed that he/she would be presented with a series of pairs. He/she has to listen to the pairs carefully and once the list ends, the researcher would say the first word of the pair to which the participant had to immediately respond verbally with its compliment which was in the list previously presented. He/she was instructed that he/she should not take more than 5 seconds to respond.

Procedure: These pairs were presented to the subject through calibrated headphones starting from list 1monaurally at 70dB SPL or at the most comfortable level. Subject’s task was to listen to the entire list first and later researcher would say the first word of the pair to which the participant had to immediately respond with its compliment which was in the list previously presented. The response time limit was set not to exceed 5 seconds. If the subject could achieve a score of 80% or more in that list, then he/she would be presented with the next list containing 6 pairs and the same procedure continued until the subject’s score was below 80% in the presented list. Based on the observations made in the pilot study, the cut off score was kept at 80%, to avoid ceiling effect.

Scoring: Each list was given a standard score of 1 and the participant was given the total score based on where he/she could obtain 80% or above before failing in the consecutive list.

3.7 Verbal retention for Non- Meaningful Pairs Test (VRNMP)

Stimuli: For this test, 700 meaningful bi-syllabic Kannada words were taken from corpus of words collected for development of word lists for adults in Kannada language (Manjula, Jawahar, Sharath Kumar & Geetha 2015). These words were randomly paired using the Matlab version 7.9 software. Word pairs were analyzed for dissimilarity by taking the ratings of 15 adult native Kannada speakers (Audiologists / Speech Language Pathologists). A five-point rating scale was used. Rating scale used was ‘extremely un- associated’, ‘Very much un-associated’, ‘moderately un-associated', 'slightly un-associated' and 'associated'. Reponses from all the 15 individuals were compiled and pairs that were rated as extremely un-associated and very much un associated by at least 70% of the participants were made as a list.

All the selected pairs were recorded by a native female speaker with normal voice and clear articulation. The recording was done using Computerized Speech Lab (CSL) systems in an acoustically treated room. The waveforms were digitized with a 16 bit A/D converter at a sampling frequency of 44100 Hz. The speaker was instructed to pronounce the words in a natural, clear manner and neutral intonation, while maintaining constant vocal effort at the rate of 2 seconds per pair. Later, recorded word pairs were divided into 10 lists with 1^{st} list containing 2 word pairs, 2^{nd} list containing 3 word pairs, 3^{rd} list containing 4 word pairs and hence the 10^{th} list was containing 11word pairs. The inter stimulus gap between two pairs was 250ms.

Instructions: The subject was instructed that he/she would be presented with a series of pairs. He/she has to listen to the pairs carefully and once the list ends, the researcher would say the first word of the pair to which the participant had to immediately respond verbally with its compliment which was in the list previously presented. He/she was instructed that he/she should not take more than 5 seconds to respond.

Procedure: These pairs were presented to the participants starting from list 1. After listening to each list, researcher would say the first word of the pair to which the participant had to immediately respond with its compliment. The response time limit was set not to exceed 5 seconds. If the participant could achieve a score of 50 % or more in that list, he/she would be presented with the next list containing 3 pairs and the same procedure continued until the participants' score was below 50% in the presented list. Based on the observations made in the pilot study, the cut off score was kept at 50%, to avoid floor effect.

Scoring: Each list was given a standard score of 1 and the participant was given the final score based on where he/she could obtain 50% or above before failing in the consecutive list.

3.8 Standardization of the test

3.8.1 Reliability

Test retest reliability: This was done to check the reliability of the above two tests (verbal retention for meaningful and non-meaningful pairs). Both the tests were administered on 30 subjects and after an interval of 15 days; both the tests were re administered. Reliability test was carried out and the Cronbach's alpha was found to be greater than 0.7 for both the tests depicting a good reliability of both the tests.

3.8.2 Validity

a. *Face Validity*: Simply put, face validity of a test can be defined as if the test "looks like" it is going to measure what it is supposed to measure. The face validity of both the tests was done by giving the two tests to 5 subject experts (psychologists).

b. Content validity.

- Verbal Retention for meaningful pairs test:

After the bisyllabic meaningful word pairs were prepared, fifteen native adult Kannada speakers (audiologists/ speech language pathologists) rated all the words using a five point rating scale. Rating scale used was 'extremely familiar', 'very familiar’, ‘moderately familiar’, ‘slightly familiar’ and ‘not familiar’. Reponses from all the individuals were compiled and pairs that were rated as extremely familiar and very familiar by at least 70% of the participants were made a list. This list was again given to another set of 15 native adult Kannada speakers (audiologists/ speech language pathologists) to rate them on the basis of how much the two words in the pair was associated with respect to each other. The rating scale used was extremely associated, very much associated, moderately associated, slightly associated and not associated. Reponses from all the 15 individuals were compiled and pairs that were rated as extremely associated and very much associated by at least 70% of the participants were made as a list.

- Verbal Retention for non-meaningful pairs test:

After the bisyllabic words were paired randomly, word pairs were analyzed for dissimilarity by taking the ratings of 15 adult native Kannada speakers (Audiologists / Speech Language Pathologist). A five-point rating scale was used. Rating scale used was ‘extremely un- associated’, ‘Very much un-associated’, ‘moderately un-associated’, ‘slightly un-associated’ and ‘associated’. Reponses from all the 15 individuals were compiled and pairs that were rated as extremely un-associated and very much un associated by at least 70% of the participants were made as a list.

c. Concurrent Validity:

The overall sample, combining musicians (n=60) and non musicians (n=30), the data was subjected to Spearman Correlation Coefficient test to evaluate the correlation between the memory tests developed in the current study (VRMP &VRNMP) with the standardized established memory tests (DSF & DSB) used in the present study on the same population. The results indicate significant positive correlation (p < 0.001) between the developed and the established tests as shown in the Table 3.9. The table depicts that strong positive correlation is noticed for VRMP and VRNMP i.e., 0.63 and other tests exhibited moderate correlation.

Table 3.9. Results of Spearman Correlation Co efficient test.

	FDS	BDS	VRMP	VRNMP
FDS	r =1.00	r =0.44 (.000*)	r =0.55 (.000*)	r =0.51 (.000*)
BDS	r = 0.44 (.000*)	r =1.00	r =0.56 (.000*)	r =0.49 (.000*)
VRMP	r =0.55 (.000*)	r =0.56 (.000*)	r =1.00	r =0.63 (.000*)
VRNMP	r =0.51 (.000*)	r =0.49 (.000*)	r =0.63 (.000*)	r =1.00

Note: (.000*) = p value

3.9 Statistical Analysis

SPSS software (version 22) was used for statistical analysis. Descriptive statistics (Mean, Median and Standard Deviation) was carried out. To verify if the data is normally distributed, Shapiro-Wilk's test for normality was administered. Scores of tests were found to be non-normally distributed (p < 0.05) and hence non-parametric Kruskal-Wallis test was opted. Overall, results revealed a significant difference between groups in all tests. Further, Mann-Whitney U test was used for pair wise comparison for all the tests.

The non-parametric Mann Whitney U test was carried out to see the significant difference between the two ears and the test revealed no significant difference between the two ears. Hence the total number of ears was considered for the statistical analysis which gives us 60 ears in each of the three groups.

The data of the total 180 ears' of all the tests were subjected to Shapiro-Wilk's test for normality with respect to the three groups. The results revealed that the data was not normally distributed (i.e, $p < 0.05$).Hence, the non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e, Violinists, Vocalists & Non-Musicians). The test results revealed that there was a significant difference between all the three groups in all the tests administered. Hence, to see the pair wise significant difference between the groups, a Mann-Whitney U test was carried out.

Since multiple pair wise comparison was carried out, the significance levels are considered Bonferroni-Alpha corrected, i.e., *p* value is compared with level of significance (Alpha corrected) 0.016 is observed. (Therefore, here if $p < / = 0.016$, there is a significant difference among the groups).

CHAPTER-IV

RESULTS

The previous chapter revealed the research methodology adopted for the present study. The measuring instruments were discussed and statistical analyses were indicated. This chapter presents the analyses of the data which were obtained through gathering information during testing conditions. The data collected has been analyzed using descriptive statistics such as Total, mean, median, mean rank and Standard Deviation of three independent groups, i.e., Violinists, Vocalists, and Non-musicians.

The non-parametric Mann Whitney U test was carried out to see the significant difference between the two ears and the test revealed no significant difference between the two ears. Hence the total number of ears was considered for the statistical analysis which gives us 60 ears in each of the three groups.

The data of the total 180 ears' of all the tests was subjected to Shapiro-Wilk's test for normality with respect to the three groups. The results revealed that the data is not normally distributed (i.e., $p<0.05$). Hence, the non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between all the three groups in all the tests administered. Hence, to see the pair wise significant difference between the groups, a Mann-Whitney U test was carried out.

Since multiple pair wise comparison was carried out, the significance levels are considered Bonferroni-Alpha corrected, i.e., p value is compared with level of significance (Alpha corrected) 0.016 is observed. (Therefore, here if p < / = 0.016, there is a significant difference among the groups) and p values reflect 2-tailed tests.

4.1. Results of tests for temporal processing among violinists, vocalists and non-musicians.

Note: Error Bars in all the figures represent Standard Deviation.

a) **Gap Detection Test (GDT):** Based on descriptive statistics the mean, median and standard deviation of the results obtained from GDT are depicted in the table below 4.1. The mean scores were noticeably high for the non-musicians (3.08 ms) group when compared to the violinists (2.09 ms) and vocalists (1.96 ms) as shown in Figure 4.1.

Table 4.1

Descriptive statistics (Mean, Median and Standard Deviation) for Gap Detection Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Violinists	1.96	1.97	.49
Vocalists	2.09	1.85	.36
Non-Musicians	3.08	3.50	.57

Note: SD-Standard Deviation.

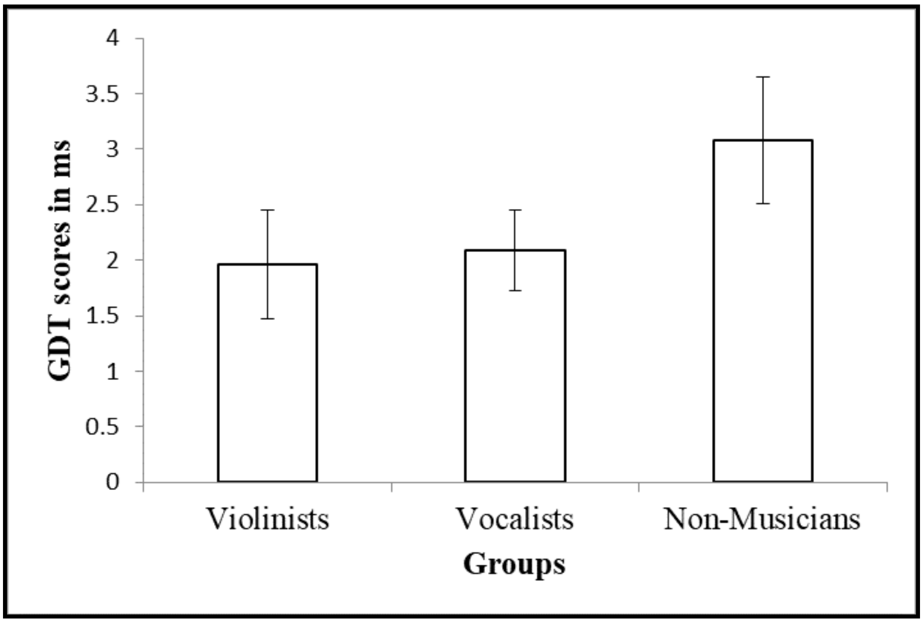

Figure 4.1: Mean and standard deviation of gap detection test among violinists, vocalists, and non-musicians.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 96.92$, $p<0.016$).

The results of the non-parametric post hoc Mann Whitney U test as shown in Table 4.2 below, revealed that there was a significant difference between violinists and non-musicians in their Gap Detection test thresholds (|Z|= 8.34, p= .016</=.016). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians in their Gap Detection thresholds (|Z|= 8.69, p= .016</=.016). But the results have shown that there was no significant difference between violinists and vocalists in their gap detection test scores (|Z|= 0.45, p= .65>.016).

Table 4.2

Results of Post Hoc Mann Whitney U test of Gap detection test scores across three groups

Subgroups	Mean Rank	|Z|	p value
Violinists	61.92	0.45	.65
Vocalists	59.08		
Vocalists	33.16	8.69	.016
Non-musicians	87.84		
Violinists	34.20	8.34	.016
Non-musicians	86.80		

b) **Duration Discrimination Test:** As shown in table 4.3, descriptive statistics for the Duration Discrimination Test are presented. The mean scores were noticeably high for the non-musicians (69.38ms) group when compared to the violinists (30.28ms) and vocalists (29.58ms) as shown in the Figure 4.2.

Table 4.3

Descriptive statistics for Duration Discrimination Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Violinists	30.28	28.50	8.01
Vocalists	29.58	28.50	4.71
Non-Musicians	69.38	69.50	13.98

Note: SD-Standard Deviation.

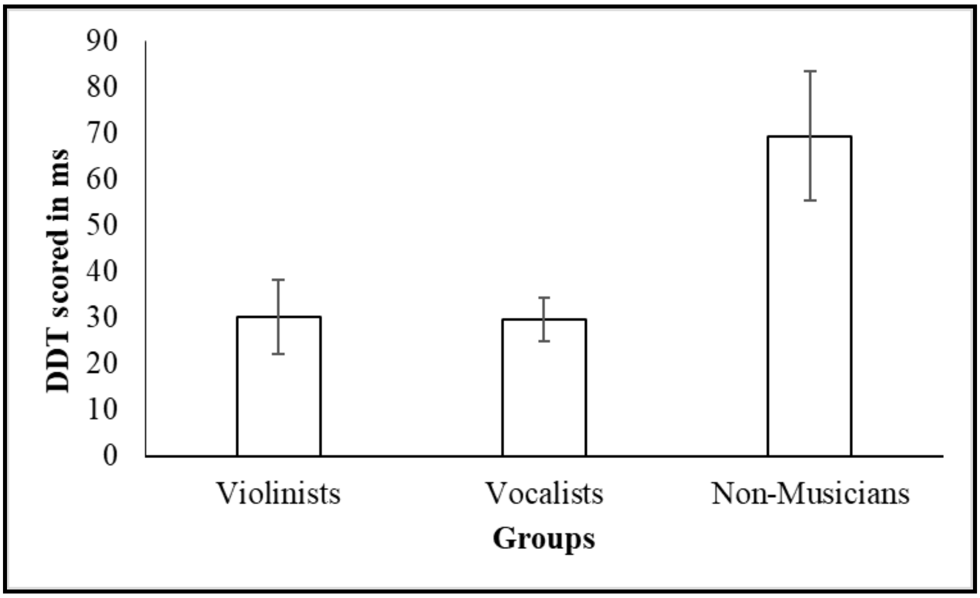

Figure 4.2: Mean and standard deviation of duration discrimination test among violinists, vocalists and non-musicians.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 107.70$, $p<0.016$)

The results of non parametric post hoc Mann Whitney U test as shown in table 4.4 below, revealed that there was a significant difference between violinists and non-musicians in their Duration Discrimination threshold ($|Z|= 8.91$, $p= .001<.016$). The post hoc results also found that there was a significant difference between vocalists and non-musicians in their Duration Discrimination threshold ($|Z|= 9.02$, $p= .001<.016$). But the results have shown that there was no significant difference between violinists and vocalists in their Duration Discrimination threshold ($|Z|= 0.09$, $p= .92>.016$).

Table 4.4.

Results of Post Hoc Mann Whitney U test in Duration Discrimination test scores across three groups -Violinists, Vocalists and Non-musicians.

Subgroups	Mean Rank	|Z|	*p* value
Violinists	60.21	.092	0.927
Vocalists	60.79		
Vocalists	31.84	9.028	.001
Non-musicians	89.16		
Violinists	32.20	8.917	.001
Non-musicians	88.80		

c) **Duration Pattern Test**: As shown in table 4.5, descriptive statistics for the Duration Pattern Test, the mean scores were noticeably low for the non-musicians (28.85) group when compared to the violinists (29.75) and vocalists (29.77) as shown in the Figure 4.3.

Table 4.5.

Descriptive statistics (Mean, Median and Standard Deviation) for Duration Pattern Test of Temporal Processing.

Groups	Mean	Median	SD
Violinists	29.75	30.00	.43
Vocalists	29.77	30.00	.42
Non-Musicians	28.85	29.00	.89

Note: SD - Standard deviation

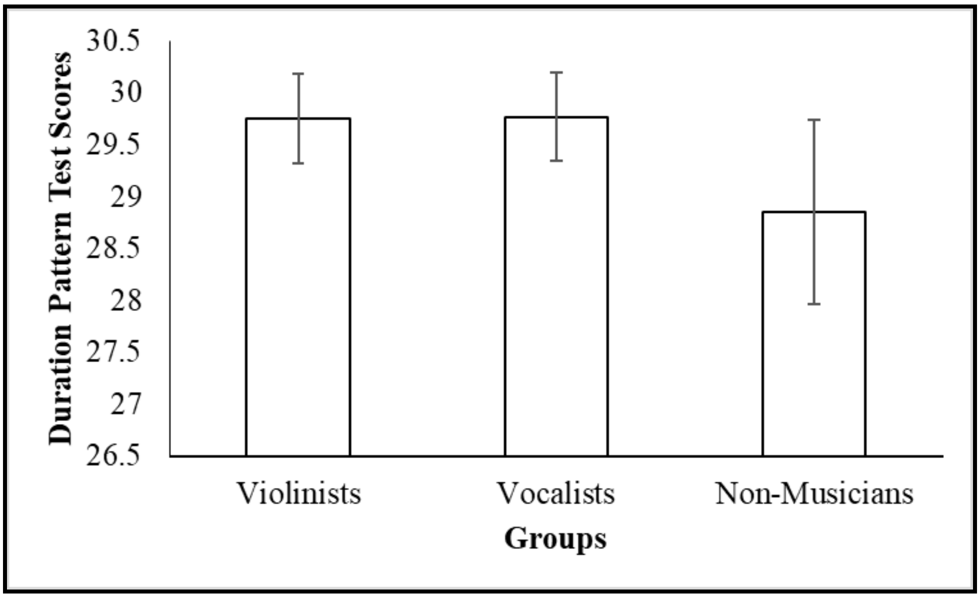

Figure 4.3. Mean and standard deviation of duration pattern test among violinists, vocalists, and non-musicians

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 50.45$, $p<0.016$). The results of non-parametric Post Hoc Mann Whitney U test as shown in Table 4.6, revealed that there was a significant difference between violinists and non-musicians in their Duration Pattern test scores of temporal processing ($|Z|= 5.82$, $p= .001<.016$). The Post Hoc test results also found that there was a significant difference between vocalists and non-musicians in their Duration Pattern test scores of temporal processing ($|Z|=5.94$, $p= .001<.016$). But the results have shown that there was no significant difference between violinists and vocalists in their Duration Pattern test scores of temporal processing ($|Z|= 0.21$, $p= .83>.016$).

Table 4.6.

Results of Post Hoc Mann Whitney test in Duration Pattern test scores across three groups of Violinists, Vocalists and Non-musicians

Subgroups	Mean Rank	|Z|	p value
Violinists	60.00	0.21	0.83
Vocalists	61.00		
Vocalists	77.68	5.94	0.00
Non-musicians	43.32		
Violinists	77.38	5.82	0.00
Non-musicians	43.63		

d) Sinusoidally Amplitude Modulation Noise test: This particular test was administered at 6 different frequencies. They are 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128Hz among 3 groups. As shown in table 4.7, descriptive statistics for the Sinusoidal Amplitude Modulation Noise test at 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128 Hz are presented. The mean scores were noticeably low for the non-musicians group when compared to the violinists and vocalists as shown in the Figure 4.4.

Table 4.7

Descriptive statistics (Mean, Median and Standard Deviation) for Sinusoidally Amplitude Modulation Noise test at 4Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz and 128 Hz of Temporal Processing.

Frequencies		**4 Hz**	**8 Hz**	**16 Hz**	**32 Hz**	**64 Hz**	**128 Hz**
Violinist	**Mean**	-22.50	-20.63	-22.25	-21.76	-20.96	-20.42
	SD	2.36	9.01	2.02	1.66	1.44	1.53
	Median	-23.30	-23.15	-22.60	-21.90	-21.15	-20.65
Vocalist	**Mean**	-22.67	-21.59	-22.21	-21.86	-20.89	-20.36
	SD	2.36	6.63	2.05	1.64	1.48	1.55
	Median	-23.75	-23.25	-22.35	-21.90	-21.15	-20.65
Non-Musicians	**Mean**	-18.17	-18.29	-15.02	-14.18	-12.61	-11.84
	SD	2.06	1.74	2.32	2.05	1.87	1.96
	Median	-18.75	-17.95	-14.40	-15.15	-11.95	-10.85

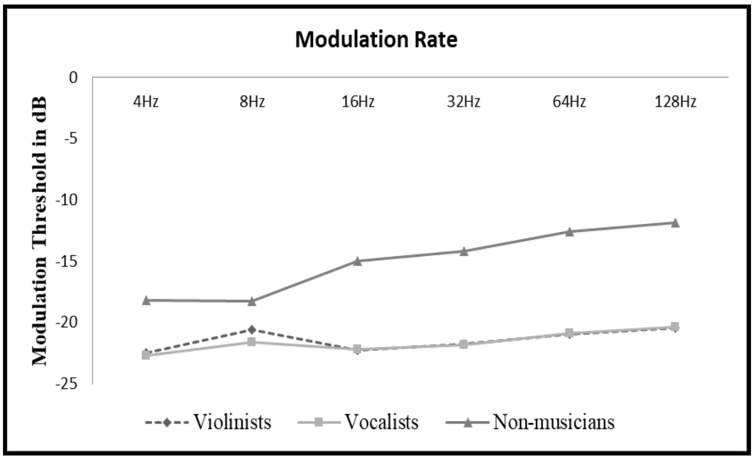

Figure 4.4. Mean of Sinusoidally Amplitude Modulation Noise test results among Violinists, Vocalists, and Non-musicians.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., violinists, vocalists, and non-musicians). The test results revealed that there was a significant difference between the three groups as shown below in the Table 4.8.

Table 4.8.

Results of Kruskal-Wallis (H) test and its significance across three groups in their Sinusoidally Amplitude Modulation Noise testof Temporal Processing.

Frequency	χ^2	p value
4 Hz	80.43	0.01
8 Hz	72.41	0.01
16 Hz	114.88	0.01
32 Hz	119.59	0.01
64 Hz	119.72	0.01
128 Hz	119.98	0.01

The results of non-parametric Post Hoc Mann Whitney test U revealed that there was significant difference between violinists and non-musicians (Table 4.9) in their Sinusoidally Amplitude Modulation Noise test scores of temporal processing. The Post Hoc results also found that there was a significant difference between vocalists and non-musicians (Table 4.10) in their Sinusoidal Amplitude Modulation Noise test scores of temporal processing. But the results have shown that there is no significant difference between violinists and vocalists (Table 4.11) in their Sinusoidally Amplitude Modulation Noise test scores of temporal processing.

Table 4.9

Results of Post Hoc Mann Whitney U test for SAM test between Violinists and Non-musicians.

Violinists Vs Non-Musicians	**|Z|**	**p value**
4 Hz	7.73	0.01
8 Hz	7.13	0.01
16 Hz	9.26	0.01
32 Hz	9.45	0.01
64 Hz	9.46	0.01
128 Hz	9.46	0.01

Table 4.10

Results of Post Hoc Mann Whitney U test for SAM test between Vocalists and Non-musicians.

Vocalists Vs Non-Musicians	|Z|	p - value
4 Hz	7.77	0.01
8 Hz	7.56	0.01
16 Hz	9.26	0.01
32 Hz	9.45	0.01
64 Hz	9.46	0.01
128 Hz	9.45	0.01

Table 4.11

Results of Post Hoc Mann Whitney U test for SAM test between Violinists and Vocalists.

Violinists Vs Vocalists	$\lvert Z \rvert$	p value
4 Hz	0.37	0.70
8 Hz	0.53	0.59
16 Hz	0.13	0.89
32 Hz	0.27	0.78
64 Hz	0.18	0.85
128 Hz	0.33	0.73

4.2 Results of speech perception in noise test among violinists, vocalists and non-musicians

As shown in table 4.12, descriptive statistics for the speech perception in noise test, the mean scores were noticeably low (-4.88) for the non-musicians group when compared to the violinists (-7.11) and vocalists (-7.50) as shown in the Figure 4.5.

Table 4.12.

Descriptive statistics for Speech Perception in Noise test.

Groups	Mean	Median	SD
Violinists	-7.11	-6.85	1.24
Vocalists	-7.50	-7.50	1.26
Non-Musicians	-4.88	-4.50	0.95

Note: SD =Standard Deviation

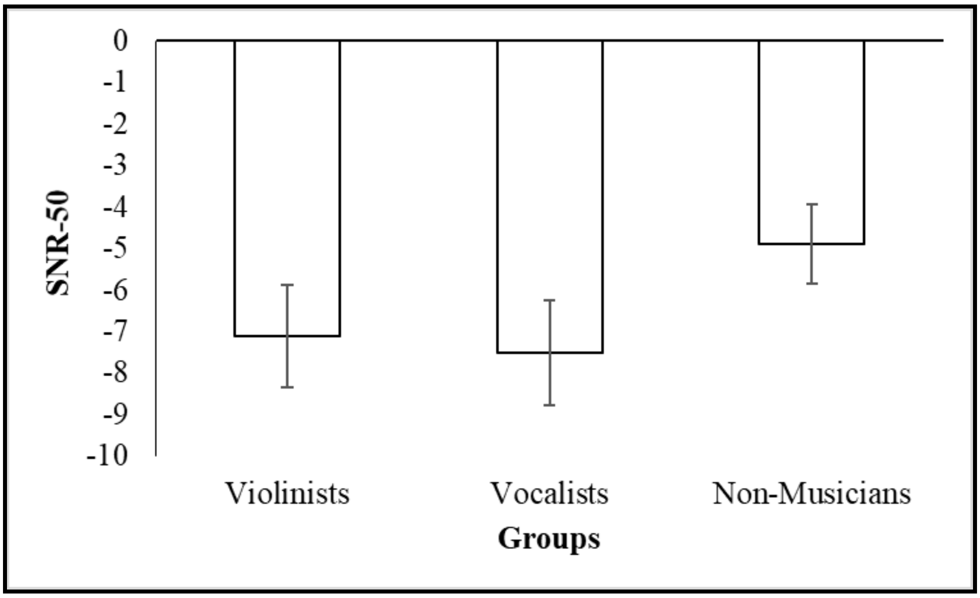

Figure 4.5. Mean and standard deviation of speech perception in noise among violinists, vocalists and non-musicians

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 111.33$, p+0.001<0.016). As shown in the Table 4.13, the results of non-parametric Post Hoc Mann Whitney U test revealed that there was a significant difference between violinists and non-musicians in their Speech Perception in Noise test scores ($|Z| = 8.02$, $p = .001 < .016$). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians in their Speech Perception in Noise test scores ($|Z| = 8.68$, $p = .001 < .016$). But the results have shown that there was no significant difference between violinists and vocalists in their Speech Perception in Noise test scores ($|Z| = 1.59$, $p = 0.11 > 0.016$).

Table 4.13.

Results of Post Hoc Mann Whitney U test of Speech Perception in Noise test scores across three groups- Violinists, Vocalists and Non-musicians

Subgroups	Mean Rank	|Z|	*p*-value
Violinists	65.43	1.59	.111
Vocalists	55.58		
Vocalists	33.75	8.68	.001
Non-musicians	87.65		
Violinists	35.48	8.02	.001
Non-musicians	85.52		

4.3 Results of auditory working memory tests among violinists, vocalists, and non-musicians

a) Forward Digit Span Test

As shown in table 4.14, descriptive statistics for the forward digit span test of auditory working memory reveals that the mean scores were noticeably low for the non-musicians (5.13) group when compared to the violinists (6.72) and vocalists (6.67) as shown in the Figure 4.6.

Table 4.14.

Descriptive statistics (Mean, Median and Standard Deviation) for Forward Digit span Test of Auditory Working Memory.

Groups	Mean	Median	SD
Violinists	6.72	7.00	.76
Vocalists	6.67	7.00	.72
Non-Musicians	5.13	5.00	.85

Note: SD = Standard deviation

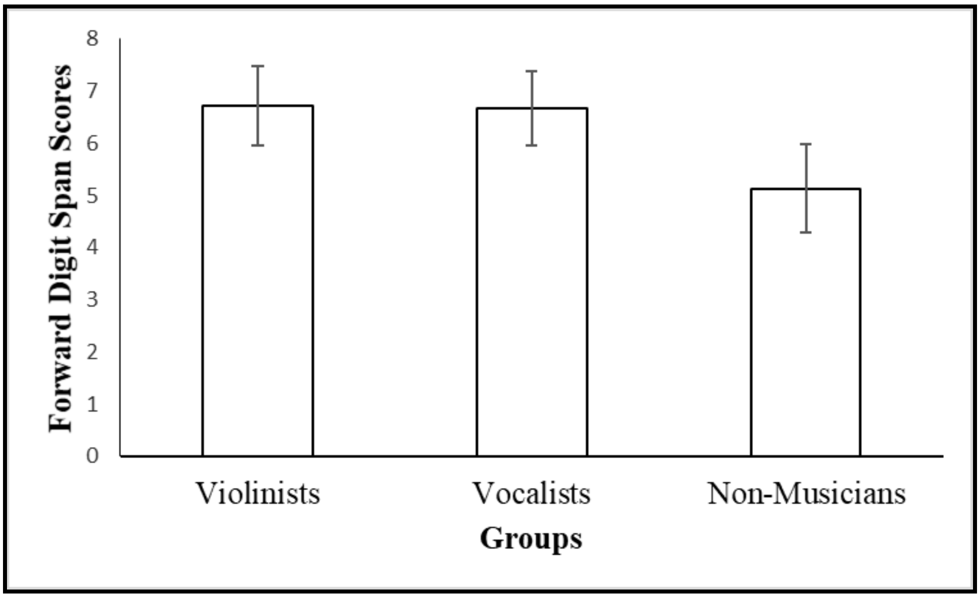

Figure 4.6. Mean and standard deviation of forward digit span test among violinists, vocalists and non-musicians.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 92.37$, $p=0.001<0.016$). As shown in the table 4.15, the results of the non parametric post hoc Mann Whitney U test revealed that there was a significant difference between violinists and non-musicians ($|Z|= 8.29$, $p= .001<.016$). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians ($|Z|= 8.25$, $p= .001<.016$). But the results have shown that there was no significant difference between violinists and vocalists in their Forward Digit Span test processing ($|Z|= 0.32$, $p= 0.74>0.016$).

Table 4.15.

Results of Post Hoc Mann Whitney U test in Forward Digit Span Test scores across three groups of Violinists, Vocalists and Non-musicians

Subgroups	Mean Rank	|Z|	*p* value
Violinists	61.44	. 323	.747
Vocalists	59.56		
Vocalists	85.43	8.256	.001
Non-musicians	35.58		
Violinists	85.60	8.293	.001
Non-musicians	35.40		

b) Backward Digit Span Test

As shown in table 4.16, descriptive statistics for the backward digit span test reveals that the mean scores were noticeably low for the non-musicians (4.02) group when compared to the violinists (5.77) and vocalists (5.68). The results of the three groups are presented below in the Figure 4.7.

Table 4.16.

Descriptive statistics (Mean, Median and Standard Deviation) for Backward Digit Span Test of Auditory Working Memory.

Groups	Mean	Median	SD
Violinists	5.77	6.00	.83
Vocalists	5.68	5.50	.77
Non-Musicians	4.02	4.00	1.01

Note: SD- Standard Deviation

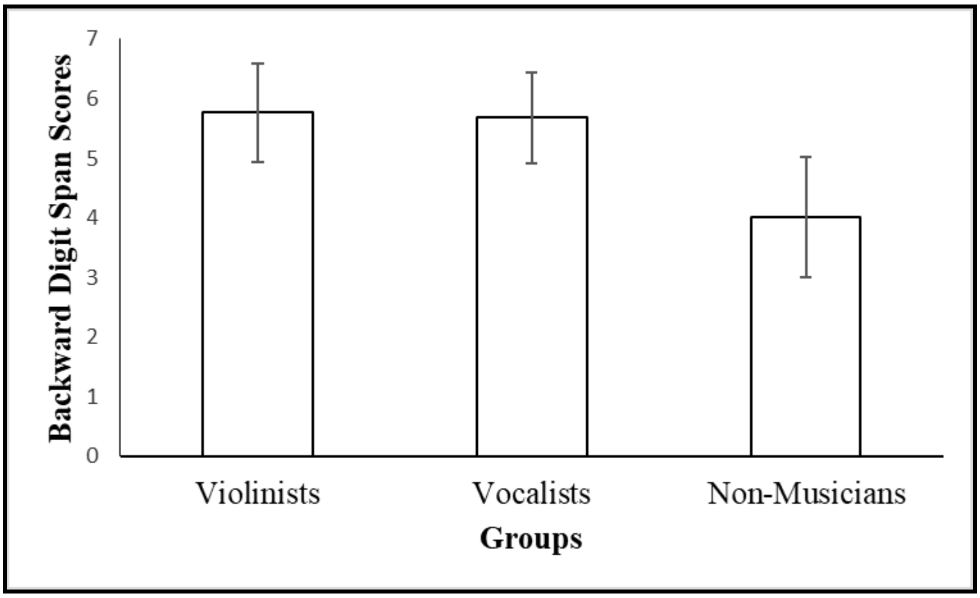

Figure 4.7: Mean and Standard Deviation of Backward Digit Span test scores among Violinists, Vocalists, and Non-musicians

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 76.51$, $p=0.001<0.01$). As shown in the table 4.17, the results of non parametric Post Hoc Mann Whitney U test revealed that there was a significant difference between violinists and non-musicians ($|Z|= 7.53$, $p= .001<.016$). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians ($|Z|= 7.43$, $p= .001<.016$). But the results have shown that there was no significant difference between violinists and vocalists in the Backward Digit Span test ($|Z|= 0.48$, p= 0.63>0.016).

Table 4.17.

Results of Post Hoc Mann Whitney U test of Backward Digit Span test scores across three groups- Violinists, Vocalists and Non-musicians.

Subgroups	Mean Rank	|Z|	*p* value
Violinists	61.91	.482	.630
Vocalists	59.09		
Vocalists	83.39	7.434	.001
Non-musicians	37.61		
Violinists	83.77	7.537	.001
Non-musicians	37.23		

c) Verbal Retention for Meaningful Pairs test

As shown in table 4.18, descriptive statistics for the verbal retention for meaningful pairs of auditory working memory revealed that the mean scores were noticeably low for the non-musicians (3.82) group when compared to the violinists (6.13) and vocalists (6.17). The results of the three groups are presented below in the Figure 4.8.

Table 4.18

Descriptive statistics (Mean, Median and Standard Deviation) of Verbal Retention for Meaningful Pairs Test among Violinists, Vocalists and Non-musicians.

Groups	**Mean**	**Median**	**SD**
Violinists	6.13	6.00	.72
Vocalists	6.17	6.00	.74
Non-Musicians	3.82	4.00	.70

Note: SD- Standard Deviation

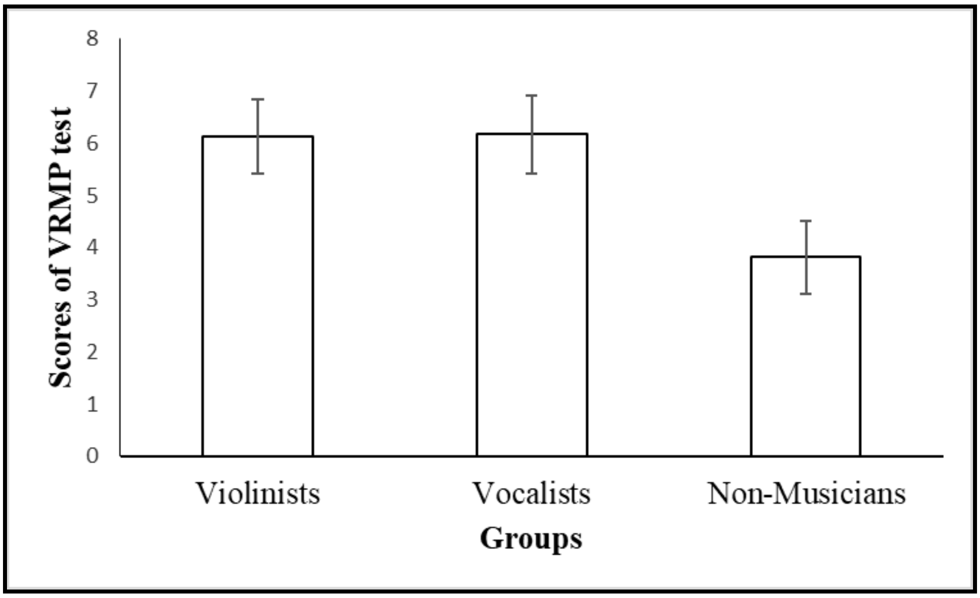

Figure 4.8: Mean and standard deviation of verbal retention for meaningful pairs test of auditory working memory among violinists, vocalists and non-musicians.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 117.68$, $p = 0.001 < 0.016$). As shown in Table 4.19, the results of non parametric Post Hoc Mann Whitney U test revealed that there was a significant difference between violinists and non-musicians in their Verbal Retention for Meaningful Pairs test ($|Z| = 9.33$, $p = .001 < .016$). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians in their Verbal Retention for Meaningful Pairs test ($|Z| = 9.33$, $p = .001 < .016$). But the results have shown that there was no significant difference between violinists and vocalists in their Verbal Retention for Meaningful Pairs test ($|Z| = 0.27$, $p = 0.78 > 0.016$).

Table 4.19

Results of post hoc Mann Whitney U test in verbal retention for meaningful pairs test scores across three groups of violinists, vocalists and non-musicians

Subgroups	Mean Rank	|Z|	*p* value
Violinists	59.70	.272	.786
Vocalists	61.30		
Vocalists	89.50	9.330	.001
Non-musicians	31.50		
Violinists	89.50	9.335	.001
Non-musicians	31.50		

d) Verbal Retention for Non-Meaningful Pairs Test

As shown in table 4.20, descriptive statistics for the verbal retention for non-meaningful pairs test revealed that the mean scores were noticeably low for the non-musicians (2.75) group when compared to the violinists (4.75) and vocalists (4.70). The results of the three groups are presented below in the Figure 4.9.

Table 4.20.

Descriptive statistics (Mean, Median and Standard Deviation) for Verbal Retention for Non-Meaningful Pairs Test among Violinists, Vocalists and Non-musicians

Groups	Mean	Median	Standard Deviation
Violinists	4.75	5.00	.72
Vocalists	4.70	5.00	.67
Non-Musicians	2.75	3.00	.60

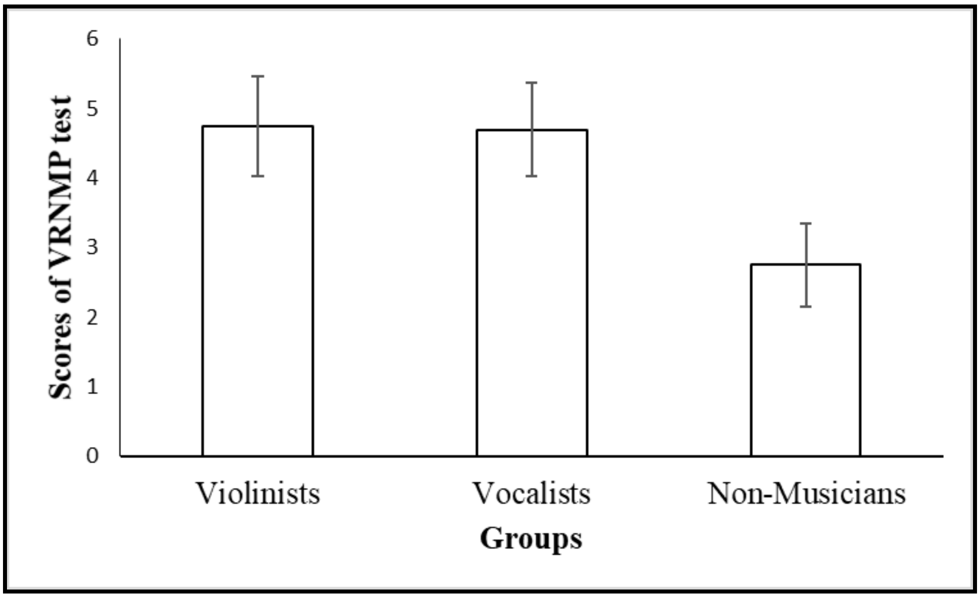

Figure 4.9: Mean and Standard Deviation of Verbal Retention for Non-Meaningful Pairs Test among Violinists, Vocalists and Non-musicians

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Violinists, Vocalists and Non-Musicians). The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 118.78$, $p=0.001<0.01$). As shown in the Table 4.21, the results of non parametric Post Hoc Mann Whitney U test revealed that there was a significant difference between violinists and non-musicians in their Verbal Retention for Non Meaningful Pairs test scores ($|Z|= 9.37$, $p= .001<.016$). The Post Hoc results also found that there was a significant difference between vocalists and non-musicians in their Verbal Retention for Non Meaningful Pairs test scores ($|Z|= 9.39$, $p= .001<.016$). But the results have shown that there was no significant difference between violinists and vocalists in their Verbal Retention for Non Meaningful Pairs test scores ($|Z|= 0.30$, $p= 0.76>0.016$).

Table 4.21.

Results of Post Hoc Mann Whitney U test in Verbal Retention for Non-Meaningful Pairs Test across three groups of Violinists, Vocalists and Non-musicians

Subgroups	Mean Rank	Z	*p* value
Violinists	61.38	.301	.764
Vocalists	59.63		
Vocalists	89.46	9.396	.001
Non-musicians	31.54		
Violinists	89.46	9.379	.001
Non-musicians	31.54		

Years of experience and its effect on vocalists and violinists.

This part of results reveal the influence of years of musical experience on temporal processing, speech perception in noise and auditory working memory among three different sub groups of violinists and vocalists: junior proficiency, senior proficiency and vidwath proficiency (10 subjects or 20 ears in each group).

The data of the total 60 ears' of all the tests was subjected to Shapiro-Wilk's test for normality with respect to the three groups. The results revealed that the data was not normally distributed (i.e., $p<0.05$).

Hence, the non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three subgroups (i.e., junior, senior and vidwath groups). The test results revealed that there was no significant difference between all the three sub groups of violinists and vocalists except in GDT and DDT tests in violinists. Hence, to see the pair wise significant difference among the groups, a Mann-Whitney U test was carried out.

Since multiple pair wise comparison was carried out, the significance level is considered Bonferroni-Alpha corrected, i.e., p value is compared with level of significance (Alpha corrected) 0.016 is observed. (Therefore, here if p</= 0.016, there is a significant difference among the groups).

4.4 Results of tests for temporal processing in vocalists and violinists:

4.4.1 Results of tests for temporal processing in vocalists:

a) Gap Detection Test in vocalists:

As shown in table 4.22, descriptive statistics for the Gap Detection Test revealed the mean scores were noticeably better for the vidwath violinists (1.88 ms) group when compared to the junior violinists (1.94 ms) and to the senior violinists (1.98 ms). The results are presented in the Figure 4.10.

Table 4.22.

Descriptive statistics (Mean, Median and Standard Deviation) for Gap Detection Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Junior	1.94	1.95	0.388
Senior	1.98	1.75	0.319
Vidwaths	1.88	1.85	0.393

Note: SD- Standard Deviation

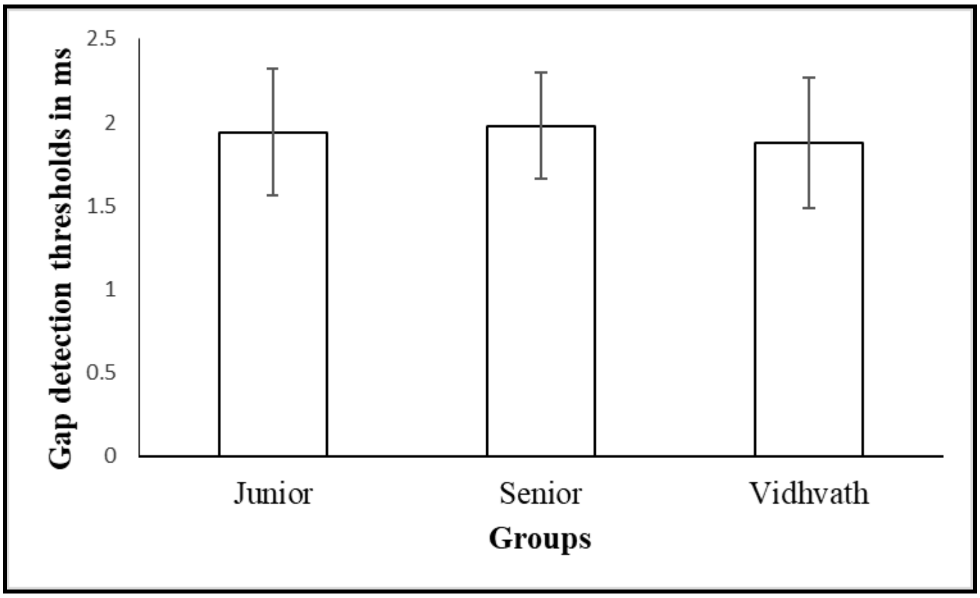

Figure 4.10: Mean and Standard Deviation of Gap Detection Test among Junior Vocalists, Senior Vocalists and Vidwath Vocalists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwaths in Vocalists) in their Gap detection test scores of temporal processing. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 0.315$, $p=0.854>0.05$).

b) Duration Discrimination Test in vocalists:

As shown in table 4.23, descriptive statistics for the Duration Discrimination Test of Temporal processing revealed that the mean scores were noticeably better for the senior vocalists (28.33 ms) group when compared to the vidwath vocalists (28.80 ms) and junior vocalists (31.63 ms). The results are presented in the Figure 4.11.

Table 4.23.

Descriptive statistics (Mean, Median and Standard Deviation) for Duration Discrimination Test of Temporal Processing in Vocalists.

Groups	Mean(ms)	Median	SD
Junior	31.63	29.75	7.002
Senior	28.33	28.00	2.903
Vidwaths	28.80	28.50	2.203

Note: SD- Standard Deviation.

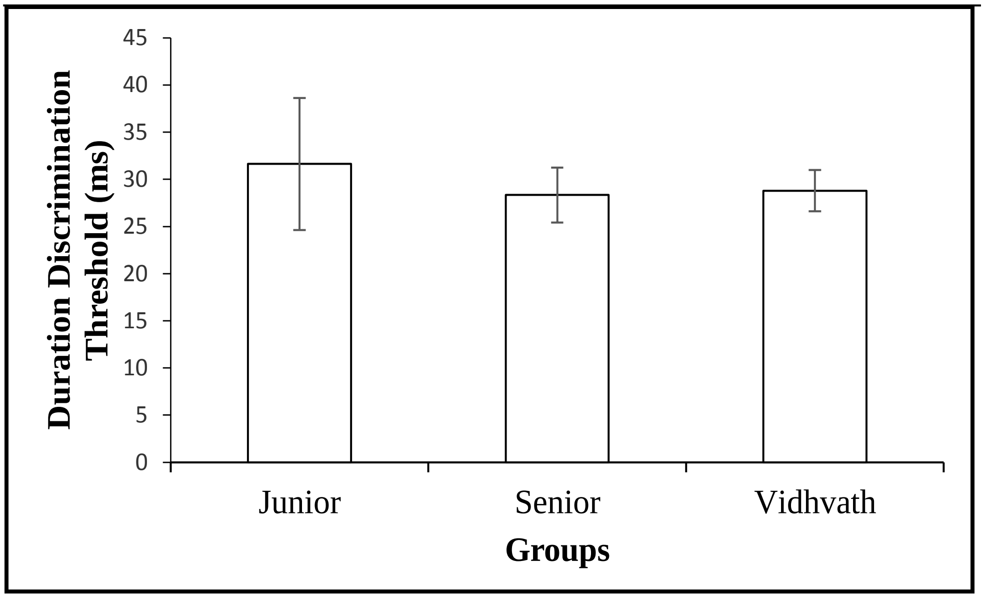

Figure 4.11: Mean and Standard Deviation of Duration Discrimination Test among Junior Vocalists, Senior Vocalists and Vidwath Vocalists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwath Vocalists) in their Duration Discrimination test scores of temporal processing. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 2.213$, p=0.331>0.05).

c) Duration Pattern Test in Vocalists

As shown in table 4.24, descriptive statistics for the Duration Pattern Test of Temporal processing revealed that the mean scores were better for the vidwath vocalists (29.90) group when compared to the senior vocalists and junior violinists (29.70). The results are presented in the Figure 4.12.

Table 4.24.

Descriptive statistics (Mean, Median and Standard Deviation) for Duration Pattern Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Junior	29.70	30.00	.470
Senior	29.70	30.00	.470
Vidwaths	29.90	30.00	.308

Note: SD- Standard Deviation

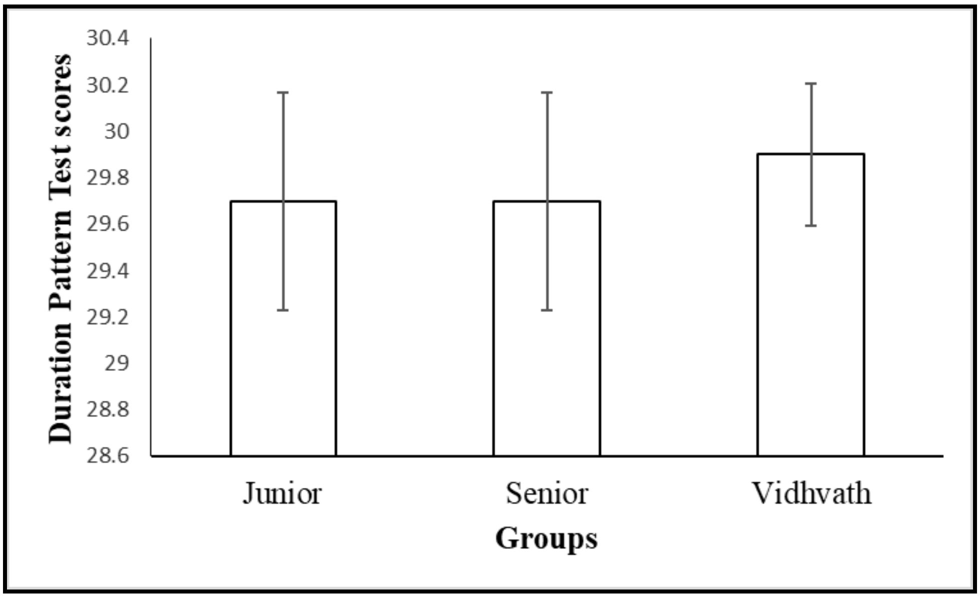

Figure 4.12: Mean and Standard Deviation of Duration Pattern Test among Junior Vocalists, Senior Vocalists and Vidwath Vocalists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwaths) in their Duration Pattern test scores of temporal processing. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 2.932$, $p = 0.231 > 0.05$).

d) Sinusoidally Amplitude Modulation Noise test in Vocalists.

This particular test was administered at 6 different frequencies. They were 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128Hz. As shown in table 4.25, descriptive statistics for the Sinusoidal Amplitude Modulation Noise test at 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128 Hz are presented. The results are presented in the Figure 4.13.

Table 4.25.

Descriptive statistics (Mean, Median and Standard Deviation) for Sinusoidally Amplitude Modulation Noise at 4Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz and 128 Hz.

		4 Hz	8 Hz	16 Hz	32 Hz	64 Hz	128 Hz
Junior	Mean	-23.00	-20.09	-22.75	-21.75	-21.03	-20.02
	SD	2.32	11.07	2.46	1.81	1.50	1.70
	Median	-21.90	-23.05	-23.20	-21.75	-21.20	-20.55
Senior	Mean	-22.15	-22.07	-21.90	-21.88	-20.86	-20.45
	SD	2.46	2.19	1.74	1.60	1.56	1.60
	Median	-22.85	-22.20	-22.35	-22.05	-21.00	-20.65
Vidwath	Mean	-22.85	-22.62	-21.97	-21.94	-20.79	-20.60
	SD	2.30	2.35	1.87	1.57	1.45	1.35
	Median	-23.75	-23.35	-22.35	-22.05	-20.90	-20.65

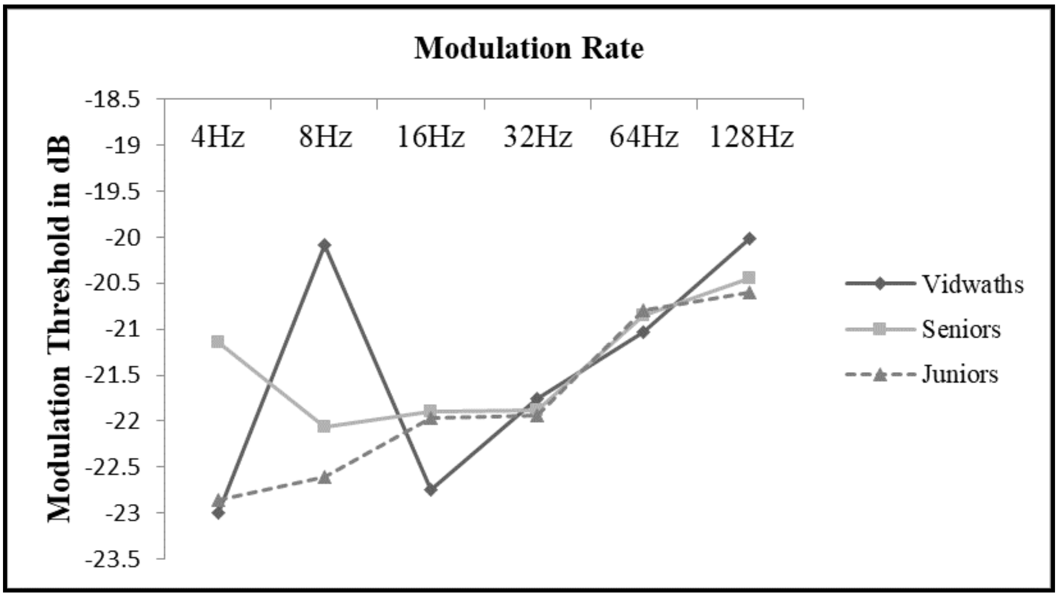

Figure 4.13: Mean of Sinusoidally Amplitude Modulation Noise test results for Junior, Senior, and Vidwath Vocalists.

Table 4.26 shows the results of the non-parametric Kruskal-Wallis (H) which was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwaths in vocal music). The test results revealed that there was no significant difference between the three groups.

Table 4.26

Results of Kruskal-Wallis test and its significance across three groups.

Frequency	χ^2	*p* value
4 Hz	1.647	.439
8 Hz	1.183	.553
16 Hz	2.141	.343
32 Hz	.396	.820
64 Hz	.259	.878
128 Hz	.892	.640

4.4.2 Results of tests for temporal processing in violinists:

a) Gap Detection Test in violinists.

As shown in table 4.27, descriptive statistics for the Gap Detection Test revealed that the mean scores were noticeably better for the vidwath violinists (1.81 ms) group when compared to the junior violinists (1.92ms) and to the senior violinists (2.26ms). The results of the three groups are presented below in the Figure 4.14.

Table 4.27.

Descriptive statistics (Mean, Median and Standard Deviation) for Gap Detection Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Junior	1.92	1.85	0.402
Senior	2.26	2.25	0.608
Vidwath	1.81	1.82	0.352

Note: SD- Standard Deviation.

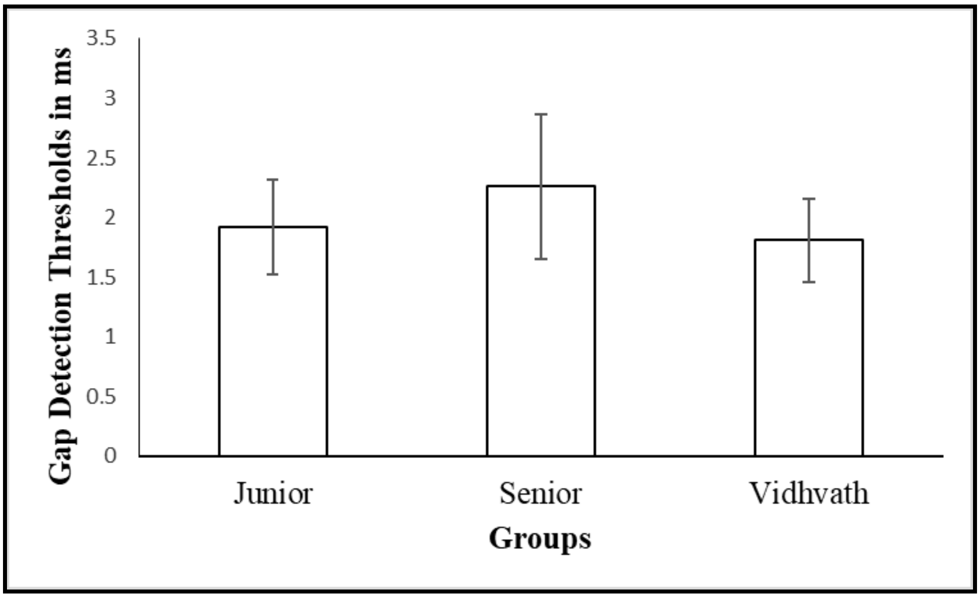

Figure 4.14: Mean and Standard Deviation of Gap Detection Test among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwaths in Violin) in their Gap detection test scores of temporal processing. The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 6.572$, p=0.037<0.05). Table 4.28 shows the results of non-parametric Post Hoc Mann Whitney U test which revealed that there was a significant difference between junior violinists and senior violinists in their Gap Detection test scores of temporal processing (|Z|= 1.938, p= .053</=.05). The Post Hoc test results also found that there was no significant difference between junior violinists and vidwaths in their Gap Detection test scores of temporal processing (|Z|= .479, p= . 632>.05). The Post Hoc test results found that there was a significant difference between senior violinists and vidwaths in their Gap Detection test scores of temporal processing (|Z|= 2.410, p= . 016<.05).

Table 4.28.

Results of Post Hoc Mann Whitney U test in Gap detection test scores across three groups of Violinists - juniors, seniors and Vidwaths.

Subgroups	Mean Rank	|Z|	*p* value
Junior Violinists	16.95	1.938	.053
Senior Violists	24.05		
Junior Violists	21.38	.479	.632
Vidwaths	19.63		
Senior Violinists	24.90	2.410	.016
Vidwaths	16.10		

b) Duration Discrimination Test in violinists:

As shown in table 4.29, descriptive statistics for the Duration Discrimination Test of temporal processing revealed that the mean scores were noticeably better for the senior violinists (26.85ms) group when compared to the vidwath violinists (29.33 ms) and to the junior violinists (34.65ms). The results are presented in the Figure 4.15.

Table 4.29.

Descriptive statistics (Mean, Median and Standard Deviation) for Duration Discrimination Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Junior	34.65	30.75	11.87
Senior	26.85	27.50	3.445
Vidwaths	29.33	29.00	3.643

Note: SD- Standard Deviation.

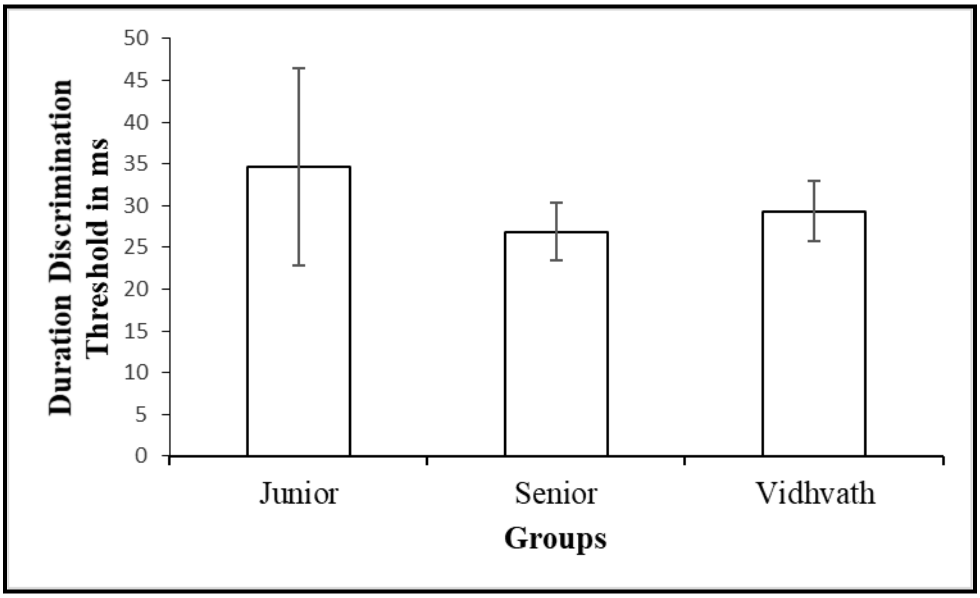

Figure 4.15: Mean and Standard Deviation of Duration Discrimination Test among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwaths in Violin) in their Duration Discrimination test scores of temporal processing. The test results revealed that there was a significant difference between the three groups (i.e., $\chi^2 = 8.116$, p=0.017<0.05). Table 4.30 shows the results of non-parametric Post Hoc Mann Whitney U test which reveals that there is a significant difference between junior violinists and senior violinists in their Duration Discrimination test scores of temporal processing (|Z|= 2.553, p= .011<.05). The Post Hoc test results found that there was no significant difference between junior violinists and vidwaths (|Z|= 1.220, p=. 223>.05). The Post Hoc test results also found that there was a significant difference between senior violinists and vidwaths in their duration discrimination test scores of temporal processing (|Z|= 2.068, p = . 039<.05).

Table 4.30.

Results of Post Hoc Mann Whitney U test in Duration Discrimination test scores across three groups

Subgroups	Mean Rank	|Z|	*p* value
Junior Violinists	25.20	2.553	.011
Senior Violists	15.80		
Junior Violists	22.75	1.220	.223
Vidwaths	18.25		
Senior Violinists	16.70	2.068	.039
Vidwaths	24.30		

c) Duration Pattern Test in Violinists.

As shown in table 4.31, descriptive statistics for the Duration Pattern Test of Temporal processing revealed that the mean scores were noticeably better for the junior violinists (29.85) group when compared to the vidwath violinists (29.75) and to the senior violinists (29.65). The results of the three groups are presented below in the Figure 4.16.

Table 4.31.

Descriptive statistics (Mean, Median and Standard Deviation) for Duration Pattern Test of Temporal Processing.

Groups	Mean(ms)	Median	SD
Junior	29.85	30.00	.366
Senior	29.65	30.00	.489
Vidwaths	29.75	30.00	.444

Note: SD- Standard Deviation.

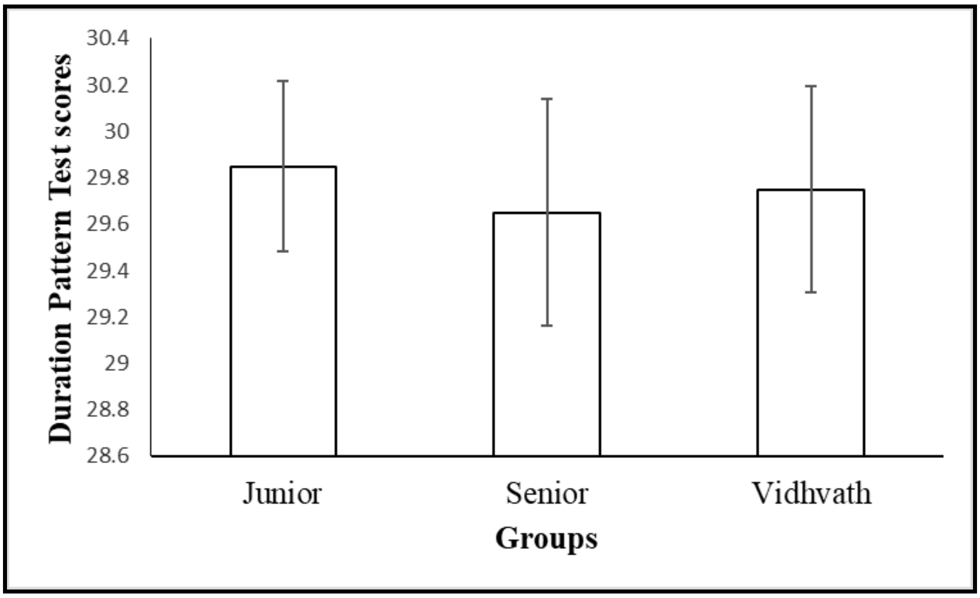

Figure 4.16: Mean and Standard Deviation of Duration Pattern Test among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwaths) in their Duration Pattern test scores of temporal processing. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 2.098$, $p=0.350>0.05$).

d) Sinusoidally Amplitude Modulation Noise test in Violinists:

This particular test was administered at 6 different frequencies. They are 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128Hz. Table 4.32 shows the descriptive statistics for the Sinusoidal Amplitude Modulation Noise test at 4Hz, 8Hz, 16Hz, 32Hz, 64Hz and 128 Hz of the three sub groups of violinists. The results of the three groups are presented below in the Figure 4.17.

Table 4.32.

Descriptive statistics (Mean, Median and Standard Deviation) for Sinusoidally Amplitude Modulation Noise at 4Hz, 8 Hz, 16 Hz, 32 Hz, 64 Hz and 128 Hz.

		4 Hz	8 Hz	16 Hz	32 Hz	64 Hz	128 Hz
Junior	Mean	-22,58	-20.01	-22.57	-21.57	-21.33	-20.29
	SD	2.46	11.08	2.34	1.85	1.33	1.65
	Median	-22.85	-22.80	-22.60	-20.95	-21.50	-20.65
Senior	Mean	-21.84	-19.94	-21.98	-21.85	-20.74	-20.45
	SD	2.40	10.98	2.12	1.34	1.47	1.54
	Median	-21.75	-23.20	-22.60	-22.05	-20.75	-20.65
Vidwath	Mean	-23.08	-21.96	-22.22	-21.88	-20.81	-20.53
	SD	2.18	2.49	1.60	1.81	1.52	1.45
	Median	-23.75	-23.20	-22.85	-22.15	-21.05	-20.65

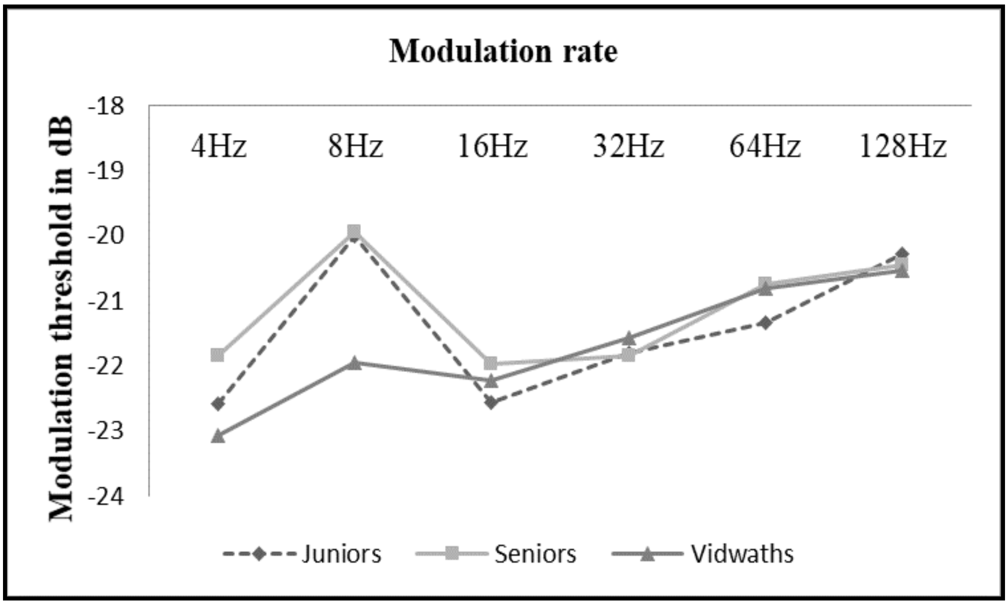

Figure 4.17: Mean of Sinusoidally Amplitude Modulation Noise test among Junior, Senior and Vidwath Violinists.

Table 4.33 shows the non-parametric Kruskal-Wallis (H) test that was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwath violinists). The test results revealed that there was no significant difference between the three groups.

Table 4.33.

Results of Kruskal-Wallis (H) test and its significance across three groups.

Frequency	χ^2	*p* value
4 Hz	2.668	.263
8 Hz	.024	.988
16 Hz	.328	.849
32 Hz	.827	.661
64 Hz	1.890	.389
128 Hz	.070	.966

4.5Results of speech perception in noise in vocalists and violinists.

a) Speech perception in noise test in vocalists.

As shown in table 4.34, descriptive statistics for the Speech perception in noise test revealed that the vidwath vocalists (-7.95) have performed noticeably better than the junior (-7.45) and the senior vocalists (-7.1). The results of the three groups are presented below in the Figure 4.18.

Table 4.34.

Descriptive statistics (Mean, Median and Standard Deviation) for Speech Perception in Noise Test.

Groups	Mean(ms)	Median	S D
Junior	-7.45	1.19	-7.5
Senior	-7.1	1.35	-7.0
Vidwaths	-7.95	1.14	-7.5

Note: SD- Standard Deviation.

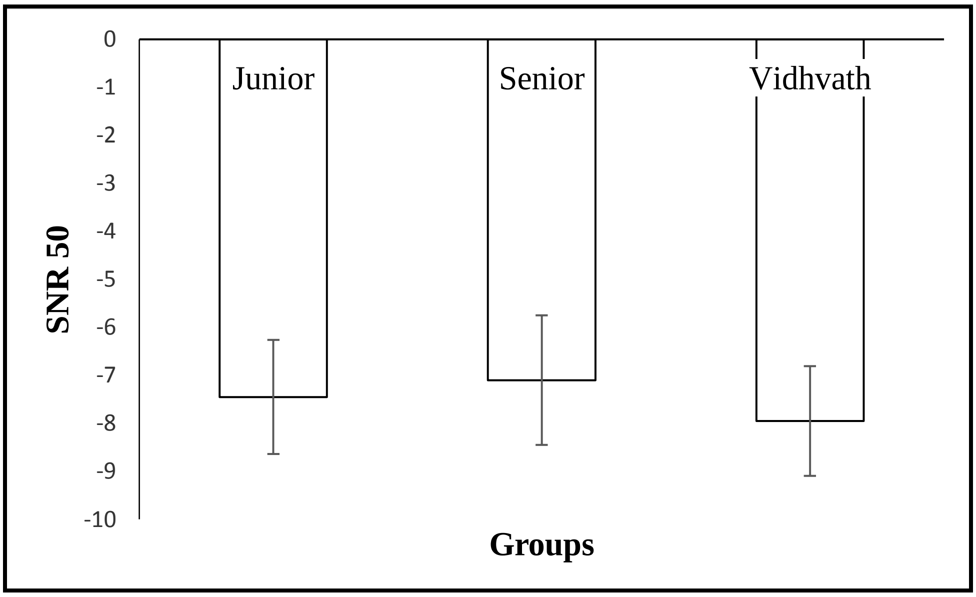

Figure 4.18: Mean and Standard Deviation of Speech Perception in Noise Test among Junior Vocalists, Senior Vocalists and Vidwath Vocalists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwaths in vocalists) in their speech perception in noise. The test results revealed that there is no significant difference between the three groups (i.e., χ^2 = 4.63, p=0.09>0.05).

b) Speech perception in noise test in Violinists.

As shown in table 4.35, descriptive statistics for the Speech perception in noise test reveals that the senior violinists (-7.45) have performed noticeably better than the junior (-7.08) and the vidwath violinists (-6.81). The results of the three groups are presented below in the Figure 4.19.

Table 4.35.

Descriptive statistics (Mean, Median and Standard Deviation) for Speech Perception in Noise Test:

Groups	Mean	Median	SD
Junior	-7.08	-7.35	1.27
Senior	-7.45	-7.50	1.39
Vidwaths	-6.81	-6.50	1.03

Note: SD- Standard Deviation.

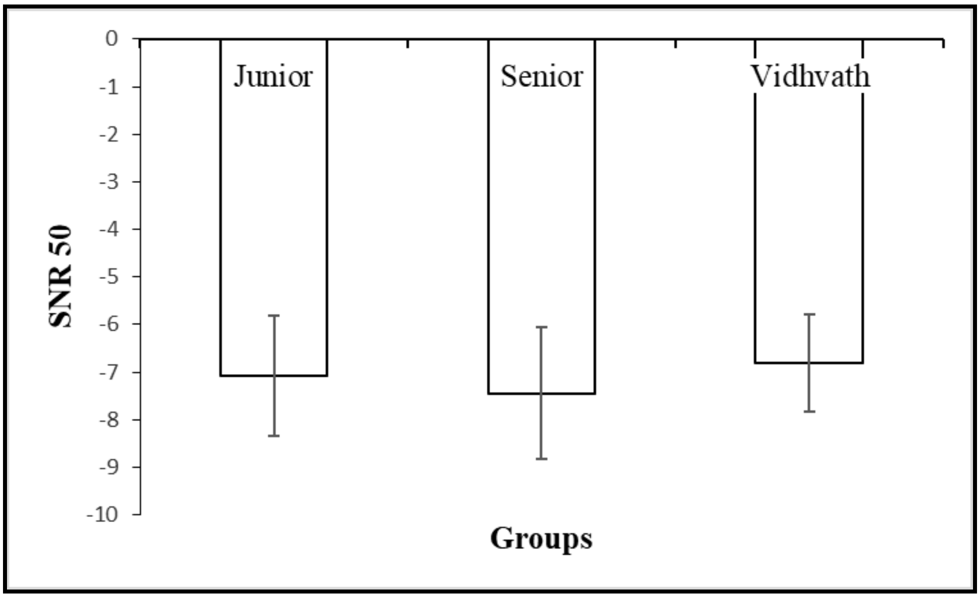

Figure 4.19: Mean and Standard Deviation of Speech Perception in Noise Test among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwaths in Violin) in their speech perception in noise test. The test results revealed that there is no significant difference between the three groups (i.e. $\chi^2 = 2.21$, $p=0.331>0.05$).

4.6 Results of auditory working memory in vocalists and violinists:

4.6.1 Auditory working memory tests in vocalists:

a) Forward Digit Span Test in vocalists.

As shown in table 4.36, descriptive statistics of the Forward Digit span test revealed that the seniors (6.80) have performed noticeably better than the vidwaths (6.65) and the junior vocalists (6.55). The results of the three groups are presented below in the Figure 4.20.

Table 4.36.

Descriptive statistics (Mean, Median and Standard Deviation) for Forward Digit span Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	6.55	6.00	.686
Senior	6.80	7.00	.768
Vidwaths	6.65	6.50	.745

Note: SD- Standard Deviation.

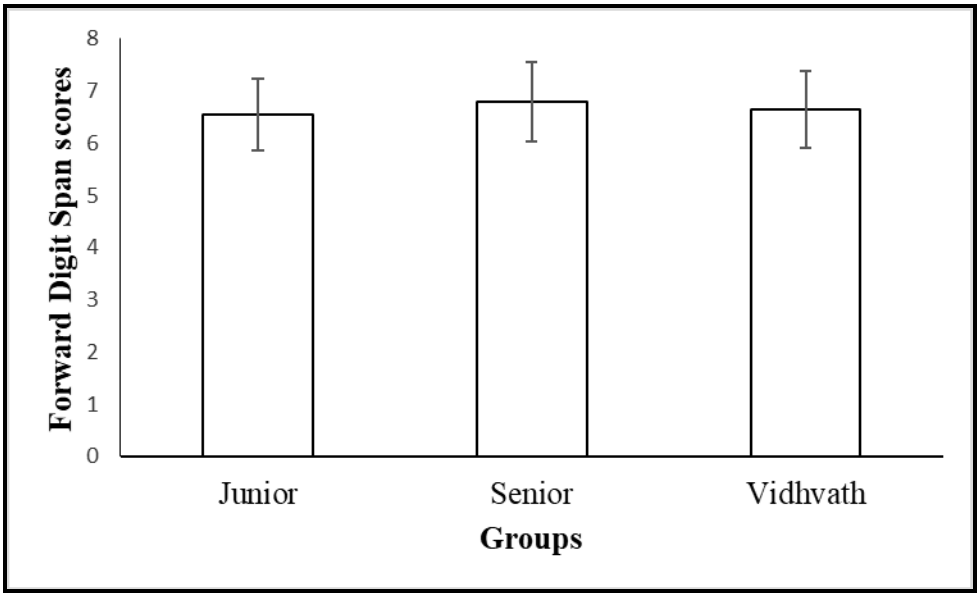

Figure 4.20: Mean and Standard Deviation of Forward Digit Span test of Auditory Working Memory among Junior Vocalists, Senior Vocalists and Vidwath Vocalists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwath Vocalists) in their digit span forward test of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 1.156$, p=.561>0.05)

b) Backward Digit Span Test in vocalists.

As shown in table 4.37, descriptive statistics for the backward digit span test of auditory working memory revealed that the mean scores were noticeably high for the junior and vidwath vocalists (5.70) group when compared to the senior vocalists (5.65). The results of the three groups are presented below in the Figure 4.21.

Table 4.37.

Descriptive statistics (Mean, Median and Standard Deviation) for Backward Digit span Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	5.70	5.50	.745
Senior	5.65	5.50	.801
Vidwaths	5.70	5.50	.801

Note: SD- Standard Deviation.

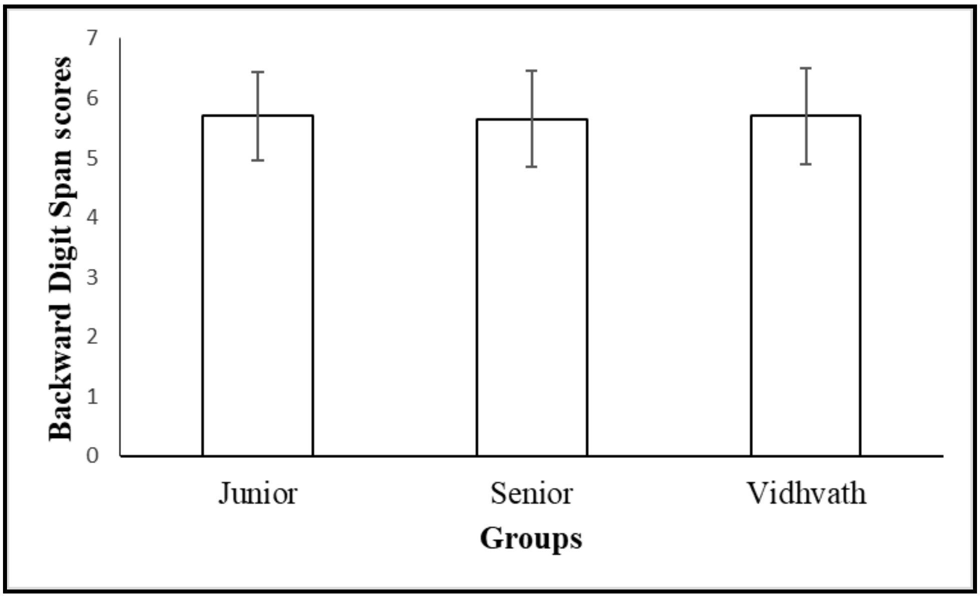

Figure 4.21: Mean and Standard Deviation of BackwardDigit Span test of Auditory Working Memory among Junior Vocalists, Senior Vocalists and Vidwath Vocalists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwath Vocalists) in their backward digit span test of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = .029$, $p=.985>0.05$)

c) Verbal Retention for Meaningful Pairs test in vocalists.

As shown in table 4.38, descriptive statistics for the verbal retention for meaningful pairs of auditory working memory revealed that the juniors (6.25) performed noticeably better than the vidwaths (6.15) and the senior vocalists (6.10). The results of the three groups are presented below in the Figure 4.22.

Table 4.38.

Descriptive statistics (Mean, Median and Standard Deviation) for Verbal Retention for Meaningful Pairs Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	6.25	6.00	.786
Senior	6.10	6.00	.718
Vidwaths	6.15	6.00	.745

Note: SD- Standard Deviation.

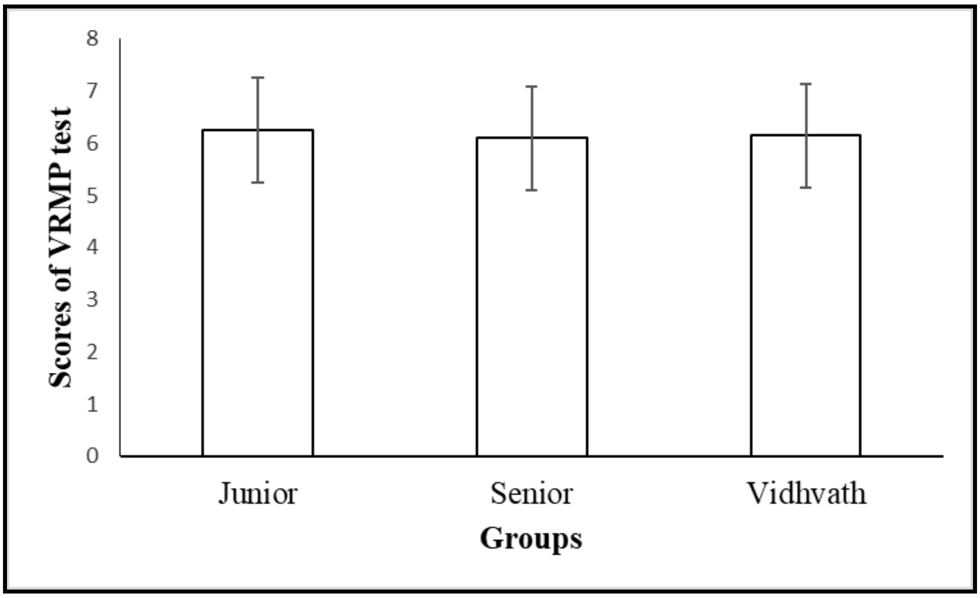

Figure 4.22: Mean and Standard Deviation of Verbal Retention for Meaningful Pairs Test of Auditory Working Memory among Junior Vocalists, Senior Vocalists and Vidwath Vocalists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwath Vocalists) in their verbal retention for meaningful pairs of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 0.511$, $p=.744>0.05$).

d) Verbal Retention for Non-Meaningful Pairs Test in vocalists.

As shown in table 4.39, descriptive statistics for the verbal retention for non-meaningful pairs of auditory working memory revealed that the juniors (4.75) performed noticeably better than the vidwaths (4.70) and the senior vocalists (4.65). The results are presented in the Figure 4.23.

Table 4.39.

Descriptive statistics (Mean, Median and Standard Deviation) for Verbal Retention for Non-Meaningful Pairs Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	4.75	5.00	.639
Senior	4.65	4.50	.745
Vidwaths	4.70	5.00	. 657

Note: SD- Standard Deviation.

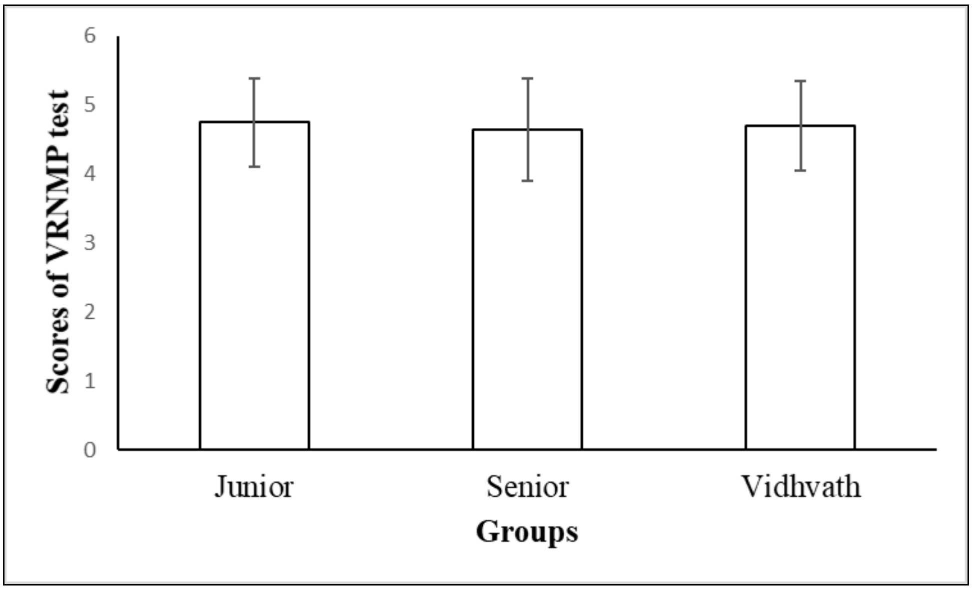

Figure 4.23: Mean and Standard Deviation of Verbal Retention for Non-Meaningful Pairs Test of Auditory Working Memory among Junior Vocalists, Senior Vocalists and Vidwath Vocalists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Vocalists, Senior Vocalists and Vidwath Vocalists) in their verbal retention for non-meaningful pairs of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 0.385$, $p=.825>0.05$).

4.6.2 Results of auditory working memory in violinists.

a) Forward Digit Span Test in Violinists.

As shown in table 4.40, descriptive statistics for the Forward Digit span test revealed that the vidwaths (6.80) have performed noticeably better than the senior (6.70) and the junior violinists (6.65). The results of the three groups are presented below in the Figure 4.24.

Table 4.40.

Descriptive statistics (Mean, Median and Standard Deviation) for forward Digit span test:

Groups	Mean	Median	SD
Junior	6.65	6.50	.745
Senior	6.70	7.00	.733
Vidwaths	6.80	7.00	.834

Note: SD- Standard Deviation.

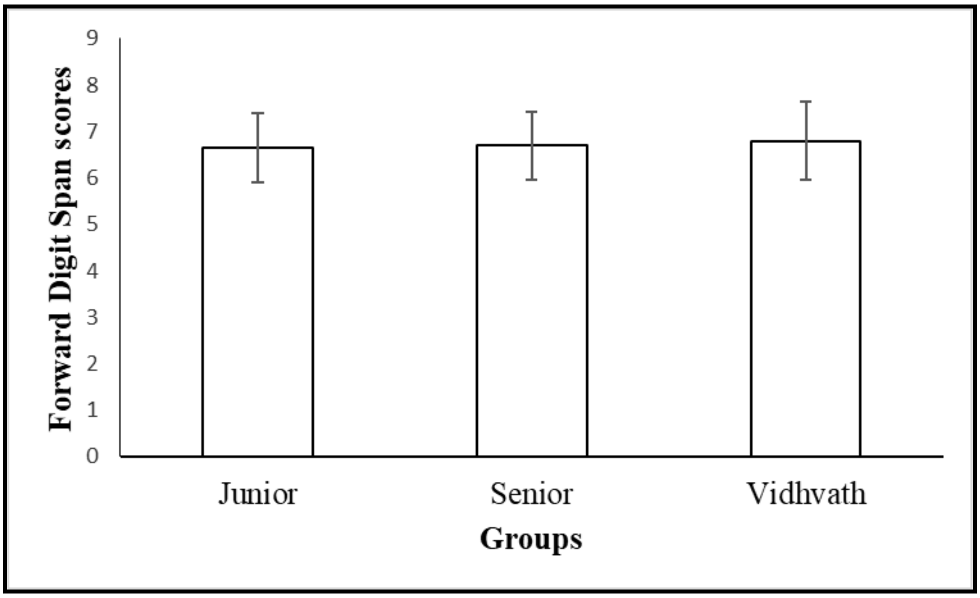

Figure 4.24: Mean and Standard Deviation of Forward Digit Span test scores among Junior Violinists, Senior Violinists and Vidwath Violinists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwath Violinists) in their forward digit span test of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = .310$, $p=.857>0.05$).

b) Backward Digit Span Test in violinists.

As shown in table 4.41, descriptive statistics for the Backward Digit span test revealed that the seniors (5.85) have performed noticeably better than the vidwaths (5.75) and the junior violinists (5.70). The results of the three groups are presented below in the Figure 4.25.

Table 4.41.

Descriptive statistics (Mean, Median and Standard Deviation) for Backward Digit span Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	5.70	5.00	.865
Senior	5.85	6.00	.875
Vidwaths	5.75	6.00	.786

Note: SD- Standard Deviation.

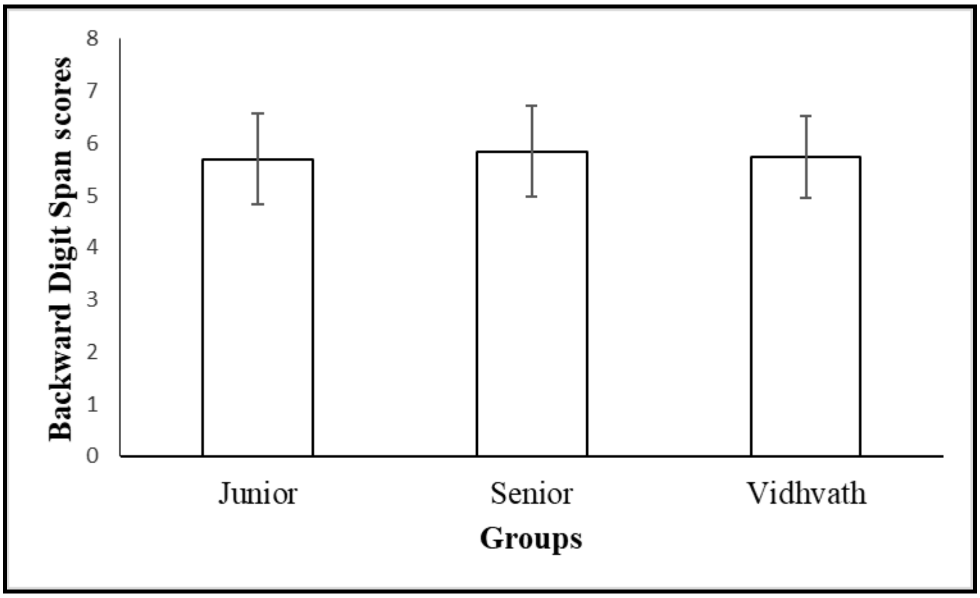

Figure 4.25: Mean and Standard Deviation of Backward Digit Span test of Auditory Working Memory among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwath Violinists) in their backward digit span test of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = .352$, $p=.839>0.05$).

c) Verbal Retention for Meaningful Pairs test in violinists.

As shown in table 4.42, descriptive statistics for the verbal retention for meaningful pairs test scores revealed that the seniors (6.40) performed noticeably better than the juniors (6.05) and the vidwaths (5.95). The results of the three groups are presented below in the Figure 4.26.

Table 4.42.

Descriptive statistics (Mean, Median and Standard Deviation) for Verbal Retention for Meaningful Pairs Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	6.05	6.00	.759
Senior	6.40	6.00	.598
Vidwaths	5.95	6.00	.786

Note: SD- Standard Deviation.

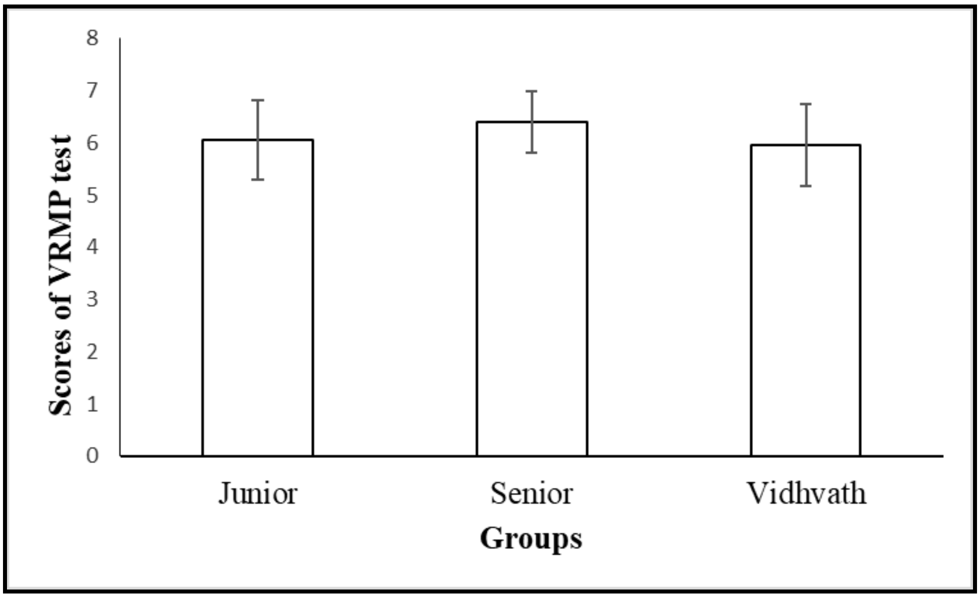

Figure 4.26: Mean and Standard Deviation of Verbal Retention for Meaningful Pairs Test of Auditory Working Memory among Junior Violinists, Senior Violinists and Vidwath Violinists

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwath Violinists) in their verbal retention for meaningful pairs of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 4.062$, p=.131>0.05)

d) Verbal Retention for Non-Meaningful Pairs Test in violinists.

As shown in table 4.43, descriptive statistics for the verbal retention for non-meaningful pairs of for meaningful pairs test scores revealed that the juniors (4.90) performed noticeably better than the seniors (4.75) and the vidwath violinists (4.60). The results of the three groups are presented below in the Figure 4.27.

Table 4.43.

Descriptive statistics (Mean, Median and Standard Deviation) for Verbal Retention for Non-Meaningful Pairs Test of Auditory Working Memory.

Groups	Mean	Median	SD
Junior	4.90	5.00	.718
Senior	4.75	5.00	.786
Vidwaths	4.60	4.50	.681

Note: SD- Standard Deviation.

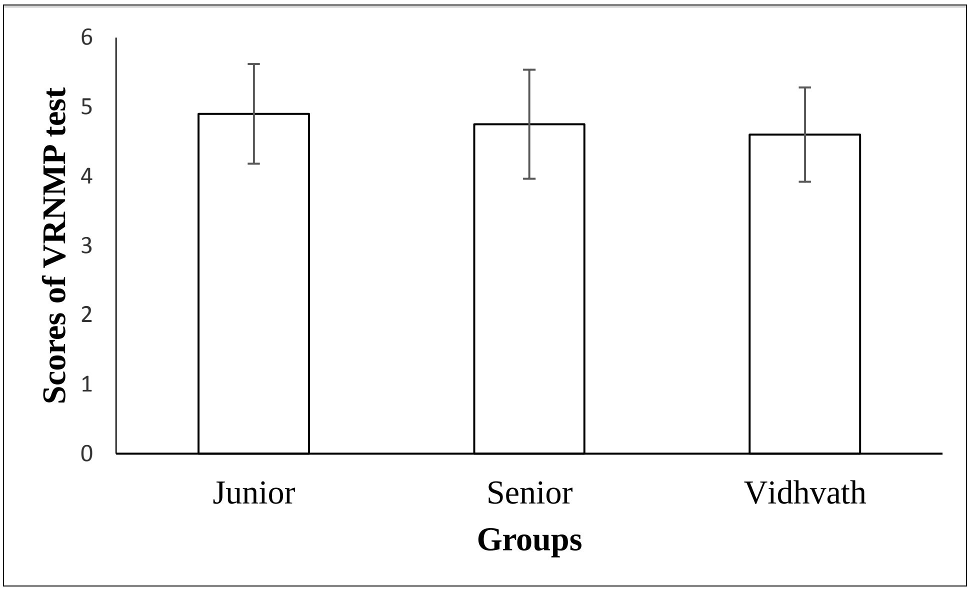

Figure 4.27: Mean and Standard Deviation of Verbal Retention for Non-Meaningful Pairs Test of Auditory Working Memory among Junior, Senior and Vidwath Violinists.

The non-parametric Kruskal-Wallis (H) test was carried out to see the significant difference across the three groups (i.e., Junior Violinists, Senior Violinists and Vidwath Violinists) in their verbal retention for non-meaningful pairs of auditory working memory. The test results revealed that there was no significant difference between the three groups (i.e., $\chi^2 = 1.763$, $p=.414>0.05$).

CHAPTER - V

DISCUSSION

Based on the gaps identified in the literature, the current study probed to compare the performance difference in musicians and non musicians with respect to temporal processing, speech perception in noise and auditory working memory, more so the primary objective was to compare the same between violinists and vocalists. The study also investigated the effect of years of experience within the group of violinists and vocalists by dividing each group into three subgroups based on the proficiency of examinations conducted by the Karnataka Secondary board (i.e., junior, senior and vidwath). Overall the results revealed a significant difference between the musicians and non musicians but no significant difference was found between the violinists and vocalists in any of the tests. The analysis also revealed that there was no significant difference in the performance between the three sub groups of musicians (except for the GDT and DDT in violinists). The findings obtained are elaborately discussed under the following broad sections:

5.1 Temporal processing among vocalists, violinists and non musicians.

5.2 Speech perception in noise among vocalists, violinists and non musicians.

5.3 Auditory working memory among vocalists, violinists and non musicians.

5.4 Temporal processing, Speech perception in noise and Auditory working memory among the subgroups of vocalists and violinists.

5.1 Temporal processing among vocalists, violinists and non musicians:

The present study reveals no significant difference between violinists and vocalists in their temporal processing abilities. However, a significant difference was noted between musicians (violinists and vocalists) and non-musicians. The results are in consonance with results of past studies (Ramseyer & Altenmuller (2006); Mohmadkhani et al (2010); Sangamanatha et al (2012); Ishii et al (2006); Mishra et al (2014); Donai & Jennings (2016); Zubin & Rajalakshmi, 2012) which report that temporal processing abilities are better or superior in musicians compared to non-musicians. Musicians' superior performance on perceptual temporal tasks, that do not require reference memory processes, suggests that extensive music training may exert a positive effect on timing performance. A few studies (Monterio et al, 2010; Fujisaki & Kashino, 2002 ;) have reported no significant difference between musicians and non-musicians. It can be observed that in these studies the mean age of music initiation is high and this may be one of factors leading to such results.

Further, since no statistically significant difference in temporal processing was noted between violinists and vocalists, one need to be a little circumspect in directly comparing the present results with those obtained previously. There are three reasons. First, the tests previously used by various researchers to compare auditory processing within musicians have gauged different aspects of auditory processing – such as the smallest detectable frequency difference as assessed by Nikjeh et al (2008) using difference limens for frequency (DLFs) – whereas in the present study we have focused only on temporal processing. Second, the categories of musicians used by other researchers span a broad range; since each musical instrument has its own distinctive features; one instrument cannot be directly compared with another. Third, to the best of our knowledge, until now no studies have been conducted between violinists and vocalists using psychoacoustic tests like GDT, DDT, DPT, and modulation detection thresholds for SAM noise. Nevertheless, putting aside the above three reasons, an attempt can be made to broadly compare our findings with similar studies. Our findings are in partial agreement with Nikjeh (2006) who used DLFs and reported slightly better, though not significant, pitch production in vocal musicians than instrumental musicians (brass, wind, or strings); overall, however, there was no significant difference in pitch perception and pitch production accuracy between musicians. In a different category of musicians, Kishon-Rabin et al. (1999) reported a significant difference in frequency discrimination thresholds (using DLFs) between classical musicians and contemporary musicians. Seppanen et al. (2006) also reported a significant difference in mismatch negativity (MMN), which assesses pre-attentive acoustic discrimination, between musicians who prefer aural strategies to practice and those who use other strategies. Halwani et al. (2011) have reported that singers have a larger tract volume in the left dorsal and ventral arcuate fasciculus compared to instrumentalists, although there is no significant difference between the two. They further conclude that musicians, especially singers, can be used as a model to demonstrate structural as well as functional adaptations of the auditory – motor system by showing structural differences between the brains of those engaged in specific types of music training (vocal versus instrumental).

From the present study, it can be inferred that both vocal and violin training each probably enhances certain temporal processing abilities. Unfortunately, the results do not give a clear pointer as to which form of musical training (vocal or instrumental) might be used as a potential therapy for those who have poor temporal processing skills. On a positive note, it can be reported that any genre of music training (vocal or instrumental) can be used as a potential therapy program for those who have poor temporal processing skills.

Further studies are needed to investigate whether particular type of musical training could be called upon to improve specific temporal processing abilities. The above results of temporal processing indicate that there is a significant difference between musicians (Violinists and Vocalists) and non-musicians. *Hence, the results of the present study reject the null hypothesis 1, which states that 'there will be no significant difference in the temporal processing abilities among vocalists, violinists and non-musicians'*.

5.2Speech perception in Noise among vocalists, violinists and non musicians:

According to the finding of this study, musicians (vocalists, violinists**)** outperform non-musicians in extracting speech from the noisy background. Many of the earlier study resultswho have used behavioural tests to study speech perception in noise are in congruence with this finding (Saha & Rajalakshmi, 2013; Thomas & Rajalakshmi, 2011; Parbery-Clark, Skoe, Lam et al., 2009; Slater et al, 2015; Bascent & Gaudrian, 2016; Clayton et al, 2016; Swaminathan et al, 2015; Parbery –Clark et al, 2011a; Parbery –Clark et al, 2011b; Zendel et al, 2015; Du & Zatorre, 2016; Parbery –Clark et al, 2009b; Bidelmann & Weiss, 2014; Varnet et al, 2015; Fuller et al, 2014;). A few studies (Ruggles et al, 2014; Boebinger at al 2015 ;) are not in congruence with the finding of this study.

These findings suggest that musical experience confers an advantage resulting in more precise neural synchrony in the auditory system. According to Anderson and Kraus (2010), musicians probably due to music induced brain plasticity have more robust temporal and spectral encoding of the eliciting speech stimulus, which possibly offsets the deleterious effects of background noise. This is one of the well accepted biological explanations postulated for musicians' perceptual enhancement for speech-in-noise.

Musicians, as a result of training which requires consistent practice, online manipulation, and monitoring of their instrument, are experts in extracting relevant signals from the complex sound scape (e.g., the sound of their own instrument in an orchestra). The effect of such musical experience is believed to be transferred on the skills that sub serve successful perception of speech in noise.

No difference was observed in the speech in noise performance between vocalists and violinists. This finding is again in congruence with the Slater and Kraus (2016) study which compared speech perception in noise between percussionists, non musicians and vocalists, Hence, it might be correct to speculate that probable changes in the underlying neural circuitry that occur following extensive musical experience is not influenced by the type of music (vocal vs. instrumental). However, before any conclusion is drawn in this regard, support from many more related studies might be essential.

The above findings of the study indicate that musicians have shown better performance than non-musicians. *Hence, the results of the study reject the null hypothesis, which states that 'There will be no significant difference in speech perception in noise among vocalists, violinists and non-musicians.'*

5.3Auditory Working Memory among vocalists, violinists and non-musicians.

The purpose of the current study was to evaluate and add to the understanding of how music experience may play a role in changing cognitive abilities related to auditory memory. Out of four memory tests, results of all the tests have shown music induced enhancement of auditory memory in musicians (both violinists and vocalists) compared to non musicians. This result is in congruence with the evidence from earlier behavioural studies reporting general enhancement of memory in musicians. (Zubin & Rajalakshmi , 2012; Ho YC et al, 2003; Williamson et al, 2010; Jacobson et al, 2008; Parbery Clark et al, 2009; Franklin et al, 2008; Bergman et al, 2014; Hanna & Gajewski, 2012; Vasuki et al, 2016; Parbery – Clark et al, 2011; Clayton et al, 2016; Bidelman et al, 2013; Pallexn et al, 2010; Williamson et al, 2010; Schluze et al, 2012; Schluze et al, 2011; Suarez et al, 2015; Anaya et al, 2016; George & Coch, 2011; Lee et al, 2007; Ramachandra et al, 2012; Talamini et al, 2016; Weiss et al, 2014; Tierney et al, 2008; Roden et al, 2014).But within the musician group, i.e., the vocalists and the violinists, no significant difference was found in the performance of all the four tests. More studies are needed to conclude that the type of the stimuli used for practicing music has no effect on the types of memory enhanced.

The results of the present study have revealed that both violinists and vocalists have shown greater performance in both digit span test (Forward and Backward) and verbal retention (Meaningful Pairs and Non-meaningful Pairs) than non-musicians. Hence, the null hypothesis '*There will be no significant difference in auditory working memory among vocalists, violinists and non-musicians*" has been rejected.

5.4Temporal processing, Speech perception in noise and Auditory working memory among the subgroups of vocalists and violinists

The present study also focused on studying the effect of years of experience on temporal processing, speech perception in noise and auditory working memory of Violinists and Vocalists. The following section reveals the discussion of all the variables of the study and verifying the hypotheses. To study the effect of years of musical experience on the scores of the tests for temporal processing, speech perception in noise and auditory working memory in the musician group (violinists and vocalists), the groups were sub grouped based on the proficiency level that is – Junior (10 subjects, 20 ears each in the violinist and the vocalist group), senior and Vidwath and the analysis was carried out. The results revealed no significant difference among the subgroups (both in vocalists and violinists) for any of the tests administered except for Gap detection test and Duration Discrimination test in violinists. In these two tests also, there is no positive relationship between the years of experience and the test scores. Mishra (2014) reported that the GDT thresholds significantly correlated with the years of musical experience. Later, he reports that if two potential outliers were removed out of the 16 musicians GDT scores, then the correlation was not significant. Hence, we can say that the findings of this study are in congruence with the above mentioned study (Mishra, 2014).

Though there is a significant difference noted in the above two tests there is no clear pattern observed here, or in the results of any other tests among both violinists and vocalists. Though we can expect a generalized trend that the processing skills get better as the years of experience increase, such a trend has not been observed here. May be one reason is that, the junior and the senior candidates were a comparatively younger lot when compared to the vidwath group who were mostly the well-established performing musicians or music teachers. While the younger lot was eager and enthusiastic about the tests going on and their scores in each test and the entire research as such, the vidwath group were relatively more laid back and not so enthusiastic about the tests or their scores. This might be one of the contributing factors for the expected trend not to be seen in this study. It has been reported that there is a systematic age related decline in temporal processing (Kumar & Sangamanatha, 2011), speech perception in noise (Wong et al., 2009, Anderson, Parbery-Clark, White-Schwoch, & Kraus, 2012; Bidelman et al. 2014) and working memory (Fandakova, Sander, Werkle-Bergner & Shing, 2014) and hence the younger adult group performance will always be better when compared to the other age groups. Again this finding is not consistently observed in all the tests of the present study. The relationship between the age and musical expertise is directly proportional. Hence, more studies need to be conducted to exactly understand this complex relationship on the processing skills. A few studies (Parbery Clark et al, 2012; Barberry – Clark et al, 2009) have reported that musical training postpones the age related decline in musicians when compared to non musicians. Coffey et al,(2016) reported that Hearing In Noise Test scores correlated significantly with the age of onset of music initiation but not with the total practice hours. Parbery-Clark et al. (2009) found a distinct speech in noise advantage for musicians as measured by Quick Speech Perception in Noise (QuickSIN) test. They found that years of consistent practice with a musical instrument correlated strongly with performance on speech in noise perception along with auditory working memory and frequency discrimination. But these findings have not been observed in this study.

But, to the best of our knowledge no study has directly compared musicians with varying degrees of musical experience with each other with respect to their auditory processing skills. The results of the current study reveal that a person need not undergo very long periods of musical training to achieve the benefits of musicianship on processing skills. These results are in congruence with studies who have studied the effects of short term music training on speech perception in noise (Jain et al, 2015). But on the contrary, these findings were not replicated when temporal processing was assessed using psycho acoustical tests (Jain et al, 2014) after short term music training. Hence more empirical research in this area is required to clearly understand the complex relationship between the years of musical experience and its effect on the auditory processing skills.

The above results of temporal processing have revealed that years of experience do not have an impact on the temporal processing ability among violinists and vocalists. Hence the null hypothesis of the study has been accepted, which states that 'There will be no significant effect of years of musical experience on temporal processing in both the groups (violinists and vocalists). The above results have also shown that years of experience in violin music or vocal music doesn't have any impact on the ability to perceive speech in noise and auditory working memory among violinists and vocalists. Hence, the null hypothesis of the study has been accepted which states that 'There will be no significant effect of years of musical experience on speech perception in noise in both the groups (violinists and vocal musicians)'and 'There will be no significant effect of years of musical experience on auditory working memory in both the groups (violinists and vocal musicians)'.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The primary aim of the present study was to compare temporal processing, auditory working memory and speech perception in noise among vocalists, violinists and non-musicians. The secondary aim of this study was to find out the effect of years of musical experience on these auditory processing skills.

A total 90 participants in the age range of 18-45 years and native speakers of Kannada were considered for this study. A structured questionnaire was administered to find out about the musical background and general health of the subjects. For the first 3 objectives, a total of 90 participants in the age range of 18 to 45 years were included who were again divided into three groups consisting of 30 members each. Group 1 and group 2 included 30 Carnatic vocalists and 30 Carnatic violinists who must have passed at least the junior music proficiency exam (though this group included those musicians who have passed senior or vidwath proficiency, the inclusion criteria was that they must have passed the minimum junior exam). Group 3 included 30 age matched non musicians who had no formal training in music. For the last 3 objectives, the group 1 and group 2 were again regrouped as junior (n=10), senior (n=10) and the vidwath (n=10) group based on their proficiency level in each group. 4 temporal processing tests – Gap Detection Threshold Test (GDT), Duration discrimination Test (DDT), Duration Pattern Test (DPT) and Modulation detection threshold for sinusoidally amplitude modulated noise (SAM) ; 1 speech perception in noise test - Speech in noise test (using Kannada sentences) (Avinash, Meti & Kumar, 2009) and 4 Auditory Memory tests – 2 for auditory working memory - Forward Digit Span Test (FDS) and Backward Digit Span Test (BDS) and 2 auditory memory tests -

Verbal retention for Meaningful pairs Test (VRMP) Verbal retention for Non-Meaningful pairs Test (VRNMP) were administered on all the 90 subjects.

Results revealed a significant difference between the musicians (vocalists & violinists) and non-musicians in all the tests (tests assessing temporal processing, auditory working memory & speech perception in noise). The musicians outperformed the non musicians. But there was no significant difference observed between the vocalists and the violinists. Similarly, no significant difference was observed between the three subgroups (junior, senior & the vidwath groups) in any of the tests in the vocalists. Whereas, in Violinists, the junior group performed significantly better than the senior group and the vidwaths performed significantly between than the senior group in the GDT test. Again, in the DDT test, senior group performed significantly better than the junior and the vidwath group. However, no clear relationship between the proficiency and the performance has been observed in both the tests. There was no significant difference between the three sub groups of violinists in any of the remaining tests.

Considering the existing literature reports and findings of this study, it can be said that musicians clearly have an advantage over non-musicians in many auditory processing performances including temporal processing, auditory memory and speech in noise perception. Most importantly the findings of this study lead to a conclusion that type of music (vocal versus instrumental) does not have a strong influence on music induced auditory processing enhancements. In other words, both vocal and instrumental musicians perform similar and are equally better than non-musicians in auditory memory and speech perception in noise skills. This finding has a unique implication that the person can choose the genre of music he/ she wants according to his preferences during rehabilitation. Another major finding of this study is that there is no direct relationship between the proficiency level of the subject and their performance in any of the tests. It can be inferred that the person need not complete all the proficiency levels in music to get the musician benefits. He can achieve those benefits even by practicing / learning music at the basic proficiency level. Further research in this area using electro physiological tests is needed to clearly understand the complete picture.

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ANNEXURE -1

QUESTIONNAIRE

I. Basic information

Name:	Age/Sex:	Date:
Education:	Occupation:	DOB:
Mother tongue:	Contact no:	

II. Musical history

- *Musical training and proficiency:*
  - ➢ Are you trained in any form of formal musical training? Yes/No

    If yes, which form of musical training? Vocal/Instrumental

    If instrumental, which instrument?
  - ➢ Onset (age) of musical training:
  - ➢ Since how long (no. of years) have you been practicing music?
  - ➢ How often do you practice music? (no. of hours / week) :
  - ➢ Musical proficiency:
  - ➢ Do you have any professional qualifications in music? Yes/No

    If yes, please describe:

III. Medical history

- *Hearing health:*
  - ➢ Do you have hearing loss/ difficulty? Yes/No

    Ears: Right/Left/Both

    If yes, age of onset of hearing loss/difficulty:

    Nature of hearing difficulty: Progressive/ Fluctuating

    Specify difficult to listen situations if any:

If you know, please specify what caused your hearing loss:

- H/o ear discharge/ ear pain/ ear infections: Yes/No

  If yes, details of the same:

- H/o ear surgery: Yes/No

  If yes, details of the same:

- Do you have buzzing or ringing sensation (tinnitus) in either ear?

  Yes/No

  If yes, is it Constant or Intermittent?

  If constant, for how long will it last?

- Do you have any difficulty tolerating sounds (Hyperacusis)? Yes/No

  If yes, describe:

- H/o Dizziness/ Vertigo: Yes/No

  If yes, describe:

- Does anyone have history of hearing loss in your family?

- Have you undergone any hearing evaluation in the past? If yes, please describe the results and recommendation:

- *General health:*

  - Do you have Diabetes or H/o any other systemic diseases (like mumps, measles)? Yes/No

    If yes, describe regarding the same:

  - Any other medical problems/illness:

IV. Life-style:

- Do you smoke/ chew paan? – Yes/No

  If yes, how often?

- Do you consume large amounts of aspirin/ caffeine? Yes/No

If yes, how often?

- Do you consume alcohol? – Yes/No

  If yes, how often?

- Do you indulge in any other music exposure (ex: walkman usage, loud car stereo etc)? – Yes/No

  If yes, specify

- Do (Did) you work in a noisy environment? - Yes/No
- If indulged in noisy jobs, since how many years have you been working there?
- Do (did) you wear any ear protective devices (ear muffs/ ear plugs)?
- Were you exposed to any impulse noise (cracker burst etc.)?
- Do you indulge in any other noisy leisure time activities (listening to personal music system)? if yes, specify.
- When you were last exposed to noise/music?
- Do you take special care about your voice and vocal hygiene?

V. Self-assessment of hearing status.

- Do you hear people speaking, but have difficulty understanding the words?
- Do you notice you are favoring one ear over the other?
- Do you find yourself asking others to repeat themselves?
- Do people seem to mumble more often, making it hard for you to understand them?
- Do you have problems clearly understanding certain women's or children's voices?
- Do you have difficulty following conversations in noisy background?
- At what volume do you hear music or TV programs? Low/ Moderate/ High/ Very High.
- Do you have any problem in understanding or conversing over telephone?
- If you attend other musical programs, where do you prefer to sit?

Do you have any other concerns to share?

ANNEXURE -2

MEANINGFUL WORD PAIRS – LIST 1

Level – 1		
1	ಬಳೆ – ಗಾಜು	ba̤le – ga:ʤu
2	ಮನೆ – ಗೋಡೆ	mane – go: d̤e
3	ಗೂಡು – ಮರಿ	gu:d̤u – mari

Level – 2		
1	ಕಲ್ಲು – ಶಿಲ್ಪಿ	kallu - ʃilpi
2	ಕೋಲು – ಏಟು	ko:lu – e:t̤u
3	ಗುಡಿ – ಘಂಟೆ	gud̤i - ghan̤t̤e
4	ಹಣ್ಣು – ಬಾಳೆ	han̤n̤u – ba:l̤e
5	ಪೆನ್ನು – ಶಾಯಿ	pennu - ʃa:ji
6	ತಾಯಿ – ಮಗು	ta:ji – magu

Level – 3		
1	ಊರು – ಮನೆ	u:ru – mane
2	ಕಾಡು – ಮರ	ka:d̤u – mara
3	ಬಾವಿ – ನೀರು	ba:vi – ni:ru
4	ಹಕ್ಕಿ – ಕಾಗೆ	hakki – ka:ge
5	ಹೂವು – ಜಾಜಿ	hu:vu - ʤaʤi
6	ಬಣ್ಣ – ಬಿಳಿ	ban̤n̤a - bil̤i
7	ನೆಲ – ಮಣ್ಣು	nela - man̤n̤u
8	ಬಳ್ಳಿ – ಕಾಯಿ	bal̤l̤i – ka:ji
9	ಕೇಕೆ – ನಗು	ke:ke - nagu

Level – 4		
1	ದು:ಖ – ಅಳು	d̪uhka - al̥u
2	ತಾಯಿ – ಕಂದ	taːji - kand̪a
3	ಮಂಚ – ರೋಗಿ	mañtʃ - roːgi
4	ಮೇಕೆ - ಕುರಿ	meːke – kuri
5	ಕಾಲು – ಗೆಜ್ಜೆ	kaːlu - geʤʤe
6	ಕಣ್ಣು - ಕಪ್ಪು	kan̥n̥u – kappu
7	ಬಾನು – ಮಳೆ	bhaːnu - mal̥e
8	ಡಬ್ಬಿ – ತಿಂಡಿ	d̥abbi - tin̥d̥i
9	ದೇಹ – ಮೂಳೆ	deːha – muːl̥e
10	ಸಂತೆ – ಜನ	sante - ʤana
11	ಕೆನ್ನೆ – ಗುಳಿ	kenne - gul̥i
12	ಬಾಯಿ – ಹಲ್ಲು	baːji – hallu

Level – 5		
1	ಅಂಗ – ತಲೆ	aŋga - t̪ale
2	ಹಾಳೆ – ಗೆರೆ	haːl̥e – gere
3	ತಟ್ಟೆ – ಊಟ	tat̥t̥e – uːt̥a
4	ಸೀರೆ – ನೂಲು	siːre – nuːlu
5	ಪಕ್ಷಿ – ರೆಕ್ಕೆ	paks̥i – rekke
6	ಸೇಬು – ಬೀಜ	seːbu – biːʤa
7	ರೈಲು – ಕಂಬಿ	railu – kambi
8	ಸೊಪ್ಪು – ದಂಟು	soppu - dan̥t̥u
9	ಬಸ್ಸು – ಚಕ್ರ	bassu - ʧakra
10	ರಸ್ತೆ – ಟಾರು	raste - t̥aːru
11	ಚಾಕು – ಚೂಪು	ʧaːku - ʧuːpu
12	ಮರ – ಗರಿ	mara - gari
13	ಆಸ್ತಿ – ಹಣ	ast̪i - han̥a
14	ಆನೆ – ದಂತ	aːne - dant̪a
15	ಹೆಣ್ಣು - ಕೇಶ	hen̥n̥u – keːʃa

Level – 6		
1.	ಹಸು – ಹಾಲು	hasu – ha:lu
2.	ಮೊಟ್ಟೆ – ಕೋಳಿ	moṭṭe - koḷi
3.	ಮುಖ – ಮೂಗು	mukha – mu:gu
4.	ಭೂಮಿ – ನೆಲ	bhu:mi – nela
5.	ರಾಜ್ಯ – ಜಿಲ್ಲೆ	ra:ʤja - ʤille
6.	ಗಂಟು – ಬಟ್ಟೆ	gaṇṭu - baṭṭe
7.	ಬೆಂಕಿ – ಬಿಸಿ	beŋki – bisi
8.	ಸರ – ಮುತ್ತು	sara - muṯṯu
9.	ವಾರ – ದಿನ	va:ra - dina
10.	ಮಂಜು – ಚಳಿ	mañʤu - ʧaḷi
11.	ಬಾಲೆ – ಬಿಂಕ	ba:le – biŋka
12.	ಓಲೆ – ಕಿವಿ	o:le – kivi
13.	ಬೊಟ್ಟು – ಹಣೆ	boṭṭu - haṇe
14.	ಹಸ್ತ – ರೇಖೆ	hasta – re:khe
15.	ಶೀಶೆ – ಗಾಜು	ʃi:ʃe – ga:ʤu
16.	ಸೌದೆ – ಕಡ್ಡಿ	soude - kaḍḍi
17.	ಗಂಡು – ಮೀಸೆ	gaṇḍu – mi:se
18.	ವನ – ಗಿಡ	vana - giḍa

Level – 7		
1.	ಕಪ್ಪೆ – ಜಿಗಿ	kappe - ʤigi
2.	ನಾಯಿ – ಮೂಳೆ	na:ji – mu:ḷe
3.	ನರಿ – ದ್ರಾಕ್ಷಿ	nari – dra:kṣi
4.	ಹಬ್ಬ – ಸಿಹಿ	habba - sihi
5.	ತೆಂಗು – ಎಣ್ಣೆ	teŋgu - eṇṇe
6.	ಮಂಗ – ಮರ	maŋga – mara
7.	ಸೂರ್ಯ – ಶಾಖ	su:rja - ʃa:kha
8.	ತಲೆ – ಟೋಪಿ	t̪ale - ṭo:pi
9.	ಬಸ್ಸು – ಕೆಂಪು	bassu – kempu
10.	ಬೆನ್ನು – ಬಾಗು	bennu – ba:gu
11.	ಕೀಟ – ರೋಗ	ki:ṭa – ro:ga
12.	ಮೇಷ್ಟ್ರು – ದೊಣ್ಣೆ	me:ṣṭru - d̪oṇṇe
13.	ಹೂವು – ಪೂಜೆ	hu:vu – pu:ʤe
14.	ಚಿನ್ನ – ಬಳೆ	ʧinna - baḷe
15.	ಆಮೆ – ಮೊಲ	a:me – mola
16.	ನದಿ – ದೋಣಿ	nad̪i – do:ṇi
17.	ನೀರು – ದಾಹ	ni:ru – da:ha
18.	ಹುಲಿ – ಬೇಟೆ	huli – be:ṭe
19.	ಬಂಡಿ – ಎತ್ತು	baṇḍi - et̪t̪u
20.	ಅಂಗಿ – ಗುಂಡಿ	aŋgi - guṇḍi
21.	ಮಿಂಚು - ಮಳೆ	minʧu - maḷe

MEANINGFUL WORD PAIRS – LIST 2

Level 1		
1	ಯುದ್ಧ– ಬಾಣ	jud̪d̪ha – ba:n̥a
2	ಕಾಳು– ಬೇಳೆ	ka:l̥u – be:l̥e
3	ಕೆಂಡ– ಬೆಂಕಿ	ken̥d̥a – beŋki

Level 2		
1	ಉದ್ದು– ವಡೆ	ud̪d̪u - vad̥e
2	ಹೂಜಿ– ನೀರು	hu:ʤi – ni:ru
3	ಕೋಟೆ– ಕಿಂಡಿ	ko:t̥e - kin̥d̥i
4	ಗಾಡಿ– ಎತ್ತು	ga:d̥i - et̪t̪u
5	ನೊಣ– ಕೀಟ	non̥a – ki:t̥a
6	ಸೊಳ್ಳೆ– ಕಚ್ಚು	sol̥l̥e - kaʧʧu

Level 3		
1	ವೀಣೆ– ತಂತಿ	vi:n̥e - t̪ant̪i
2	ಹಲ್ಲು– ಬಿಳಿ	hallu - bil̥i
3	ತಂದೆ– ದುಡಿ	t̪and̪e - d̪ud̥i
4	ರಕ್ತ– ಕೆಂಪು	rakta – kempu
5	ರಾತ್ರಿ– ಚಂದ್ರ	ra:tri - ʧand̪ra
6	ದಪ್ಪ– ಹೊಟ್ಟೆ	d̪appa - hot̥t̥e
7	ದೋಣಿ– ಹುಟ್ಟು	do:n̥i - hut̥t̥u
8	ದ್ರಾಕ್ಷಿ– ಹುಳಿ	dra:ks̥i - hul̥i
9	ಬೇರು - ಕಂಡ	be:ru - kan̥d̥a

Level 4		
1	ಇಡ್ಲಿ– ಚಟ್ನಿ	id̪li - ʧat̪ni
2	ಬಲೆ– ಮೀನು	bale – miːnu
3	ಪಲ್ಯ– ಸೊಪ್ಪು	palja – soppu
4	ವೃಕ್ಷ– ತೆಂಗು	vrukʂa – teŋgu
5	ನೊರೆ– ಸೋಪು	nore – soːpu
6	ಕಲೆ– ನೃತ್ಯ	kale – nrutja
7	ಹಾವು– ವಿಷ	haːvu - viʂa
8	ಗಂಧ– ಘಮ	gand̪ha – ghama
9	ಅಕ್ಕಿ– ರೊಟ್ಟಿ	akki - rot̪t̪i
10	ಪೂಜೆ– ಭಕ್ತಿ	puːʤe - bhakt̪i
11	ಮುಳ್ಳು– ಚುಚ್ಚು	mul̪l̪u - ʧuʧʧu

Level 5		
1	ಶಬ್ದ– ಕಿವಿ	ʃabd̪a – kivi
2	ಹಳ್ಳ– ರಸ್ತೆ	hal̪l̪a – raste
3	ಗುಬ್ಬಿ– ಹಾರು	gubbi - haːru
4	ಜಾತ್ರೆ– ಹಬ್ಬ	ʤaːt̪re - habba
5	ದೊಣ್ಣೆ– ಪೆಟ್ಟು	d̪on̪n̪e - pet̪t̪u
6	ನಿದ್ರೆ– ಮಂಚ	nid̪re - mañʧa
7	ರಾತ್ರಿ– ಭೂತ	raːt̪ri – bhuːt̪a
8	ಚಾಕು– ಕೊಲೆ	ʧaːku – kole
9	ಪಾಚಿ– ಜಾರು	paːʧi - ʤːru
10	ಕೊಳ– ಮೀನು	kol̪a – miːnu
11	ಉದ್ದ– ಕೋಲು	ud̪d̪a – koːlu
12	ಕೋಳಿ– ಕೂಗು	koːl̪i – kuːgu
13	ಮರ– ತಂಪು	mara – tampu
14	ದಿಂಬು– ಹತ್ತಿ	dimbu - hat̪t̪i
15	ಮಂಡಿ– ಕಾಲು	man̪d̪i – kaːlu

Level – 6		
1	ಶಾಲೆ– ಗುರು	ʃaːle – guru
2	ಮಗು– ಅಳು	magu - al̥u
3	ದೇಶ– ಸೇವೆ	d̪eːʃa – seːve
4	ಮಾಲೆ– ಹಾರ	maːle – haːra
5	ಕಾರು– ಲಾರಿ	kaːru – laːri
6	ಗಿಳಿ– ಮೈನ	gil̥i – maina
7	ಸೂರ್ಯ– ಬಿಂಬ	suːrja – bimba
8	ಓದು– ಪುಟ	oːd̪u - put̥a
9	ಕೇರಿ– ಬೀದಿ	keːri – biːd̪i
10	ಉಂಡೆ– ಲಾಡು	un̥d̥e – laːd̥u
11	ಮಳೆ– ಒದ್ದೆ	mal̥e - od̪d̪e
12	ಕಬ್ಬು– ಬೆಲ್ಲ	kabbu – bella
13	ತೋಟ– ತೆಂಗು	toːt̥a – teŋgu
14	ಕುಣಿ– ಹಾಡು	kun̥i – haːd̥u
15	ಜ್ವರ– ಬಿಸಿ	ʤvara – bisi
16	ವಜ್ರ– ಗಟ್ಟಿ	vaʤra - gat̥t̥i
17	ರಾಗಿ– ಗೋಧಿ	raːgi – goːd̪i
18	ಸಿಹಿ– ಜೇನು	sihi - ʤeːn̪u

Level – 7		
1	ರೈತ– ಉಳು	rait̪a - ul̥u
2	ಹಾವು– ಹುತ್ತ	haːvu - hut̪t̪a
3	ಜೇಬು– ಕಾಸು	ʤeːbu – kaːsu
4	ಛತ್ರಿ– ಮಳೆ	ʧatri - mal̥e
5	ಬೆಕ್ಕು– ಇಲಿ	bekku – ili
6	ಬಾನು– ಚುಕ್ಕಿ	baːnu - ʧukki
7	ಬಾಲ– ಕೋತಿ	baːla – koːt̪i
8	ಚಕ್ರ– ವೃತ್ತ	ʧakra - vrut̪t̪a
9	ಓದು– ಕಣ್ಣು	oːd̪u - kan̥n̥u
10	ಬತ್ತ– ಅಕ್ಕಿ	bat̪t̪a – akki
11	ಕದ– ಬೀಗ	kad̪a - biːga
12	ತೊಡೆ– ತೋಳು	t̪od̥e - t̪oːl̥u
13	ಕಪ್ಪೆ– ಮೀನು	kappe – miːnu
14	ಘಂಟೆ– ಕಾಲ	ghan̥t̥e- kaːla
15	ತಪ್ಪು– ಏಟು	tappu – eːt̥u
16	ಜಡೆ - ನೀಳ	ʤad̥e – niːl̥a
17	ದಾನ– ಭಿಕ್ಷೆ	d̪aːna - bhiks̥e
18	ನೀಲಿ– ಬಣ್ಣ	niːli - ban̥n̥a
19	ದಾರ– ಹೊಲಿ	daːra – holi
20	ಮಳೆ– ಶೀತ	mal̥e - ʃiːt̪a
21	ಆಟ - ಚೆಂಡು	aːt̥a - ʧen̥d̥u

NON MEANINGFUL WORD PAIRS- LIST 1

Level – 1		
1	ತಾನು – ವನ್ಯ	ta:nu – vanja
2	ಗಂಡ – ಕೊಳ	gan̥d̥a - kol̥a

Level – 2		
1	ಮಣ್ಣು – ಜಾವ	man̥n̥u - ʤa:va
2	ಸುರಿ – ದೇವ	suri - d̪e:va
3	ಸಾಲು – ದ್ವಾರ	pa:lu - d̪va:ra

Level – 3		
1	ರಕ್ತ – ವೇಗ	rakt̪a – ve:ga
2	ಗಾಳಿ – ವಾಸ	ga:l̥i – va:sa
3	ದರ – ಗಣ್ಯ	d̪ara - gan̥ja
4	ರೋಗ – ಮಾಯೆ	ro:ga – ma:je

Level – 4		
1	ಮೌನ – ಮಾರ್ಗ	mauna – ma:rga
2	ದೇವಿ – ಕಸ	d̪e:vi – kasa
3	ಬೆಲ್ಲ – ವೇದ	bella – ve:d̪a
4	ಕಾರ್ಯ – ಗುಪ್ತ	ka:rja - gupt̪a
5	ನುಗ್ಗು – ಚೀಟಿ	nuggu - ʧi:t̥i

Level – 5		
1	ಕಲೆ – ಕೊಡ	kale - kod̥a
2	ಕಾಳು – ಶೂಲ	kaːl̥u - ʃuːla
3	ಹೆಣ್ಣು – ಜೀವ	hen̥n̥u - ʤiːva
4	ರೆಂಬೆ – ಜನ್ಮ	rembe - ʤanma
5	ಸೆಳೆ – ರೋಮ	sel̥e – roːma
6	ಯೋಗ – ಹಿಟ್ಟು	joːga - hit̥t̥u

Level – 6		
1	ದಣಿ – ದೂರ	dan̥i – duːra
2	ಸೈನ್ಯ – ತಾಗು	sainja – taːgu
3	ಸುತ್ತ – ಪುರಿ	sut̪t̪a – puri
4	ಬೀಜ – ನೆಲೆ	biːʤa – nele
5	ಸೊನ್ನೆ – ಜೋಳ	sonne - ʤoːl̥a
6	ನೀಚ – ಕೊಳೆ	niːʧa – kol̥e
7	ಚಳಿ – ಮಗ	ʧal̥i – maga

Level – 7		
1	ದತ್ತು – ರಾಗ	dat̪t̪u – raːga
2	ದಯ – ಶೋಕ	d̪aja - ʃoːka
3	ದೋಚು – ದಾರಿ	d̪oːʧu – daːri
4	ಗಾಯ – ರೈತ	gaːja - rait̪a
5	ಗುಣ – ಮರೆ	gun̥a – mare
6	ಶಿಲೆ – ಸೇನೆ	ʃile – seːne
7	ದಂಗು – ನವ	daŋgu – nava
8	ಸಾಗು – ದಾನ	saːgu - d̪aːna

Level – 8		
1	ಮಾಂಸ – ಮೌಲ್ಯ	ma:msa - maulja
2	ಗದ್ಯ – ನಾರಿ	gad̪ja – na:ri
3	ಚಕ್ರ – ಮಾಲೆ	ʧakra – ma:le
4	ಬಾಯಿ – ಲೀನ	ba:ji – li:na
5	ನವ್ಯ – ಸಜ್ಜು	navja - saʤʤu
6	ಜಾಲ – ಚೂರಿ	ʤa:la - ʧu:ri
7	ಜಗ – ಸಂಘ	ʤaga – saŋgha
8	ವೈದ್ಯ – ರಸ್ತೆ	paid̪ja - rast̪e
9	ಕೋಟೆ - ಬಂದ	ko:ʈe – banda

Level – 9		
1	ಚಟ – ಮಾಮ	ʧaʈa – ma:ma
2	ಧೂತ – ಮೀಸೆ	d̪hu:t̪a – mi:se
3	ನಾಶ – ಹಣೆ	na:ʃa - haɳe
4	ಮುದ್ದು – ಹಳಿ	mud̪d̪u - haɭi
5	ರೆಕ್ಕೆ – ನೌಕೆ	rekke – nauke
6	ದಯೆ – ಕರ	daje – kara
7	ಹಾಳು – ನಿದ್ರೆ	ha:ɭu - nid̪re
8	ದೂರು – ಲೋಪ	du:ru – lo:pa
9	ಪಾಲು – ಹಾಳೆ	pa:lu – ha:ɭe
10	ಕರು – ತೆಳು	karu - teɭu

Level – 10		
1	ಕುರ್ಚಿ – ಕಾಡು	kurʧi – ka:d̥u
2	ಸೋರು – ಗಡಿ	so:ru - gad̥i
3	ನಾರು – ತೆಂಗು	na:ru – teŋgu
4	ಬರ – ಲೀಲೆ	bara – li:le
5	ಸವಿ – ಮಂಗ	savi - maŋga
6	ರಾಶಿ – ಕಾಲ	ra:ʃi – ka:la
7	ಯುಕ್ತಿ – ಯುಗ	jukt̪i – juga
8	ಕಂದ – ಚಕ್ಕೆ	kand̪a - ʧakke
9	ತೇವೆ – ಹರ	te:ve – hara
10	ರೋಗ – ಮಸಿ	ro:ga – masi
11	ಬೇಗ – ನಾಮ	be:ga – na:ma

NON MEANINGFUL WORD PAIRS- LIST 2

Level – 1		
1	ಯಮ - ವಂಶ	jama - vamʃa
2	ಕೊಡೆ - ದಳ	koḓe - d̪al̥a

Level – 2		
1	ತಳ್ಳಿ - ಕವಿ	tal̥l̥i – kavi
2	ನಿದ್ದೆ - ಯಾನ	nid̪d̪e – jaːna
3	ಸಣ್ಣ - ದಡ	san̥n̥a - d̪aḓa

Level – 3		
1	ಗುಡ್ಡೆ - ಕನ್ಯೆ	guḓḓe – kanje
2	ಗಿರಿ - ಲತೆ	giri - lat̪e
3	ವಾದ್ಯ - ಸೀರೆ	vaːd̪ja – siːre
4	ವ್ರತ - ಹದ	vrat̪a - had̪a

Level – 4		
1	ಬೇರೆ - ಪಲ್ಯ	beːre – palja
2	ಗೂಳಿ - ದುಂಬಿ	guːl̥i - d̪umbi
3	ಕಾಳು - ಗತಿ	kaːl̥u - gat̪i
4	ಗಾದೆ - ಗವಿ	gaːd̪e – gavi
5	ತಂತಿ - ಪೂರ್ಣ	t̪ant̪i – puːrn̥a

Level – 5		
1	ಕದ - ವನ	kada – vana
2	ಕೂಸು - ಕೂಗು	ku:su – ku:gu
3	ಸೆರೆ - ವೇಳೆ	sere – ve:l̥e
4	ಶುಚಿ - ದಟ್ಟ	ʃutʃi - d̪at̥t̥a
5	ಸಾಕು - ಗರಿ	sa:ku – gari
6	ವನ - ವೈರಿ	vana - vairi

Level – 6		
1	ಲಯ - ಗಲ್ಲ	laja – galla
2	ನೋಟ - ದೊಣ್ಣೆ	no:t̥a - d̪on̥n̥e
3	ನುಂಗು - ನಟ	nuŋgu - nat̥a
4	ದೊನ್ನೆ - ರಾಗಿ	d̪onne – ra:gi
5	ಲಂಚ - ನಂಟು	lantʃa - nan̥t̥u
6	ಹಾಸು - ನೀಳ	ha:su – ni:l̥a
7	ತಳ - ತಿನ್ನು	t̪al̥a - t̪innu

Level – 7		
1	ಗುರಿ - ಹಾದಿ	guri – ha:d̪i
2	ನರ - ಸಸಿ	nara – sasi
3	ಸೇವೆ - ಕೈಗೆ	se:ve – kaige
4	ಮರ - ವಶ	mara - vaʃa
5	ಕುಳ್ಳ - ಮಣಿ	kul̥l̥a - man̩i
6	ತೇವ - ದಂಡ	t̪e:va - d̪an̥d̥a
7	ಸಿಂಹ - ಶ್ಲೋಕ	simha - ʃlo:ka
8	ರಜೆ - ಪೂಜೆ	radʒe – pu:dʒe

Level – 8		
1	ಮಚ್ಚೆ - ಲೆಕ್ಕ	maʧʧe – lekka
2	ವೈದ್ಯ - ತಂಪು	vaid̪ja - t̪ampu
3	ಹೆಡೆ - ಚಿತ್ತ	heḓe - ʧit̪t̪a
4	ಗಾಳ - ದುಡ್ಡು	ga:ḽa - d̪uḓḓu
5	ಸುಳಿ - ದರ್ಜೆ	suḽi - d̪arʤe
6	ಸರಿ - ಸೆರೆ	sari – sere
7	ಪದ್ಯ - ದಿನ	padja - d̪ina
8	ಶಂಕೆ - ಸತಿ	ʃaŋke - sat̪i
9	ನನ್ನ - ತಮ್ಮ	nanna – tamma

Level – 9		
1	ಹೊರ - ವಾರ	hora – va:ra
2	ಚೂಪು - ಯುವ	ʧu:pu – juva
3	ಕಸ - ಮೋಸ	kasa – mo:sa
4	ಲಾಲಿ - ಕಣ	la:li - kaṋa
5	ಮಾತು - ದುಡಿ	ma:t̪u - d̪uḓi
6	ತಿನ್ನು - ಮೋರೆ	t̪innu – mo:re
7	ತೆನೆ - ತೂಕ	t̪ene - t̪u:ka
8	ಪಾದ - ಕಲೆ	pa:d̪a – kale
9	ಸೊಳ್ಳೆ - ತೋಳ	soḽḽe – to:ḽa
10	ತಾರೆ - ಗಾನ	t̪a:re – ga:na

Level – 10		
1	ಹನಿ - ದಾಟು	hani - d̪a:t̥u
2	ಜಯ - ವಾದ	ʤaja – va:d̪a
3	ಶೂನ್ಯ - ಗಣಿ	ʃu:nja - gan̥i
4	ತಗ್ಗು - ಕೋಟೆ	t̪aggu – ko: t̥e
5	ನೆಲ - ವಾರ್ತೆ	nela – va:rt̪e
6	ದಿಟ - ತುದಿ	d̪it̥a - t̪ud̪i
7	ಬೇರು - ಬೆಲೆ	be:ru – bele
8	ಡಿಕ್ಕಿ - ಬೇರೆ	d̥ikki – be:re
9	ವೀರ - ಚಿನ್ನ	vi:ra - ʧinna
10	ರಸ್ತೆ - ಚಟ	rast̪e - ʧat̥a
11	ಕೂಸು - ನಾರು	ku:su – na:ru