ASSOCIATION BETWEEN SPEECH PERCEPTION AND WORKING MEMORY WITH COMPETING MESSAGE IN MUSICIANS AND NON-MUSICIANS

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September, 2023

CERTIFICATE

This is to certify that this dissertation entitled **'Association between Speech Perception and Working Memory with Competing Message in Musicians and Non-musicians'** is a bonafide work submitted in part fulfilment for degree of Master of Science (Audiology) of the student Registration Number: **P01II21S0071**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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This is to certify that this dissertation entitled **'Association between Speech Perception and Working Memory with Competing Message in Musicians and Non-musicians'** has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **'Association between Speech Perception and Working Memory with Competing Message in Musicians and Non-musicians'** is the result of my own study under the guidance of a faculty at All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
September, 2023

Registration No. P01II21S0071

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Abstract

Aim: The study investigates the association between speech perception in noise (SPIN) and auditory working memory (AWM) in the presence of competing messages in musicians and non-musicians.

Objectives: To evaluate the association between speech perception in noise at -5 dB, 0 dB,+5 dB SNRs and auditory working memory in the presence of a competing message at +3 dB,+5 dB & +7 dB SNR in musicians and non-musicians.

Design: Based on the formal training in Carnatic music that each individual had received (greater than 5 years for M group) and the results of a questionnaire regarding musical perception ability (greater than or equal to 17 for M group), 40 individuals with normal hearing and hearing sensitivity were divided into two groups as musicians (M 20) and non-musicians (NM 20). Through the use of pure tone audiometry, tympanometry & reflexometry, and otoacoustic emissions; the normal hearing acuity of both groups was assessed. For the purpose of evaluating and comparing the relationship between speech perception in noise and auditory working memory when a competing message is present, speech perception in noise using Kannada PB words as signal and four talker babble as noise was obtained for +5 dB, 0 dB, and -5 dB SNRs. Working memory scores were also obtained while presenting talker babble as competing message for +3 dB, 5 dB, and +7 dB SNRs.

Results: The results showed a significant difference between the two groups' SPIN scores, but not a significant difference between their AWM values. On both the forward and backward span tests, the correlation between spin and AWM was non-significant for SPIN +5 dB, SPIN 0 dB SNR, and SPIN -5 dB SNR.

Discussion: The results demonstrated that there is no advantage of music for working memory tested in the presence of competing message, even though musical training aids in understanding speech in challenging listening situations like noise. Further research reveals that neither spin nor auditory working memory are correlated in musicians or non-musicians.

Conclusion: Training in music will improve the ability to hear speech in noisy environments, which we encounter every day. There is debate over the relationship between SPIN and AWM and the impact of musical training on AWM.

Chapter 1

Introduction

Speech perception is considered one of the most vital aspects of human auditory function, as it aids in efficient communication and contributes to proficient social interaction (Broersma & Scharenborg, 2010). Since spoken language comprehension ultimately depends on the sensory and perceptual analysis of the acoustic-phonetic input, understanding the perception of connected speech is an essential topic of research (Pisoni, 1985). Literature suggests that speech understanding is low demand task in quiet, whereas it is difficult in adverse conditions such as noise and reverberation (Shimizu et al., 2002). To successfully communicate in a noisy setting, an ability of a listener to hear a relevant voice is crucial (Hennessy et al., 2022). Hence, Listeners frequently struggle to understand speech in noisy environments, regardless of hearing sensitivity (Glyde et al., 2011). Although it is tough to recognize speech in noise for those people with hearing loss, even normal hearing individuals also experience challenges in noisy situations (Smoorenburg, 1992).

Evidence in the literature shows that musical training can benefit the auditory system over the long run by improving perception and raising cognitive abilities (Coffey et al., 2017). A few findings suggested that learning music enhances verbal memory (Chan et al., 1998), speech perception (Parbery-Clark et al., 2009), Intelligent Quotient (IQ) scores (Schellenberg, 2004), analytic listening abilities (Oxenham et al., 2003), and spatial abilities (Schellenberg, 2005). Numerous studies have revealed that musicians perform better on some auditory tasks than non-musicians. On speech-in-noise (SPIN) tasks, it has been observed that musicians perform better than non-musicians (Parbery-Clark et al., 2009). There are disparities between musicians and non-musicians in terms of SPIN performance, according to several cross-sectional studies (Parbery-Clark et al., 2011; Zendel et al., 2015), while others have observed no differences (Boebinger et al., 2015; Madsen et al., 2017). Additionally, the study demonstrated that in musicians, the brains go through a variety of structural modifications, including functional adjustments in sensory regions (Schlaug, 2001; Gaser & Schlaug, 2003), auditory areas; (Schneider et al., 2002; Lappe et al., 2008), the brainstem (Wong et al., 2007), and other multimodal integration areas. However, there has been substantial debate over whether or not the effects of musical training are limited to just the field of music. Some authors claim that this training is domain-specific; the music faculty is not a binary entity one has or does not have. It is made up of a collection of neurally isolable processing components, each of which has the potential to be specialized for music (Peretz & Coltheart, 2003).

According to the overlap, precision, emotion, repetition, and attention (OPERA) theory, music training may have a major impact on speech processing since it calls on shared cognitive or sensory functions, involves repetition and attentional focus, and is emotionally fulfilling. Music training may encourage neural plasticity because it places a greater demand on the brain networks that perceive music and speech than does regular communication (Patel, 2011). The auditory working memory (AWM) of musicians is superior to non-musicians for both musical and non-musical stimuli, according to Cohen et al. (2011). They used well-known music, spoken English, and visual objects to test musicians' and non-musicians' auditory and visual recall. In both groups, memory for audio stimuli was worse than memory for visual objects. The ability to recall sounds does not therefore improve to the levels found with visual stimuli, despite the fact that substantial musical training is connected to enhanced musical and non-musical auditory memory.

According to evidence, cognition is necessary for improved speech perception, in which auditory impulses are converted into representations to determine language structure (Pisoni, 1985). Cognition involves a broad range of processes like imagination, intelligence, judgment, and evaluation, and AWM is one of the key components. AWM enables the short-term storage of pertinent data and its task-specific modification. It is an essential aspect of many higher cognitive processes, making it a part of the brain. AWM enables the short-term storage of pertinent data and its task-specific modification. It is an essential aspect of many higher cognitive processes, making it a part of the brain (Pisoni, 1985). It is crucial in many daily tasks like solving problems, learning, and following instructions (Lei et al., 2022).

Evidence suggests that in an unfavourable listening environment, a negative impact is observed in cognitive tasks for human participants (Cassidy & MacDonald, 2007). Thus, AWM capacity is reduced when background noise is added, resulting in the decreased ability to record the target speaker's attention span (Parbery-Clark et al., 2011). However, there are contradictory findings that AWM tasks performed much better in noise than in silence; it is possible that individuals used their enhanced AWM capacity to their advantage when responding to inference questions in noise (Nagaraj, 2021). The AWM can be assessed through tasks including forward, backward, ascending, and descending digit span tasks, operation span, math span, reading span, listening span, etc.

A recent study by Escobar et al. (2020) found no significant difference between musicians and non-musicians for SPIN and no significant interaction between music training and AWM. This study showed that listeners with high AWM capacity can perform significantly better on SPIN tasks regardless of prior music training. However, AWM for tones is an explicit cognitive task that has been examined in several studies in which improved performance is shown in groups of musicians compared to non-musicians (Williamson et al., 2010; Talamini et al., 2022).

AWM and SPIN do not generally correlate with one another. People with normal hearing rely more on their auditory skills than their cognitive skills in loud surroundings, and AWM capacity is not a reliable indicator of SPIN (Fullgrabe & Rosen, 2016; Magimairaj et al., 2018). A study, however, refuted the findings presented above. They discovered that speech recognition substantially depends on AWM, particularly in older adults, and that people with hearing loss are especially vulnerable to this link (Millman & Mattys, 2017). Working memory exercises can help these people better hear speech over background noise (Wayne et al., 2016; Thunberg et al., 2016). A review conducted by Morteza and Abdollah (2019) concluded that working memory training may help listeners better perceive speech in noisy environments. In noise testing, people with a larger WM capacity better recognize speech than others. Therefore, the difficulty of SPIN could be lessened, especially in older people, if WM training could boost WM ability.

To successfully understand SPIN, linguistic analyses must be carried out with the proper allocation of cognitive resources, such as WM and attention (Rönnberg et al., 2013). The intermediate results of linguistic processing must be maintained active until the listener/reader can comprehend the information thoroughly. This makes WM essential for executing complicated activities like listening and reading comprehension (Just & Carpenter, 1992; Daneman & Merikle, 1996). The executive mechanism of the attention-mediated section of the AWM system is in charge of actively processing new speech input and preventing information deterioration. It is also thought that when doing complex cognitive tasks like reading or listening, people rapidly switch between processing and storing information (Barrouille et al., 2007; Barrouille et al., 2011; Jarrold et al., 2011).

1.1 Need for the study

During day-to-day life, we face different situations (i.e., market, railway station, classrooms, etc.) which may be unfavourable for communicating and learning as the noise and reverberation times for most of the environment exceed. Hence, a competitive message impairs listening in many communicative situations. Evidence from the literature showed an advantage of practicing music on the auditory and cognitive abilities such as SPIN and AWM (Parbery-Clark et al., 2011; Zendel et al., 2015). Musicians are excellent at sifting through complicated soundscapes for meaningful signals due to training that demands regular practice (Williamson et al., 2010). Such musical experience is thought to translate to the abilities necessary for successful SPIN. The effects of music on auditory processing, multisensory integration, and the apparent reciprocity between cognitive and sensory processes facilitate sensory learning (Kraus et al., 2009). However, many studies have reported better speech perception skills in noise comparing musicians to non-musicians (Parbery-Clark et al.,2009; Zendel et al.,2015).

The existing literature has shown that music training can improve AWM (Chan et al., 1998; Williamson et al., 2010); however, few studies denied this advantage (Strait et al., 2010; Hansen et al., 2013). However, most of the studies in the literature performed AWM tasks in quiet situations (without introducing any competing message), and only a few studies (Anoop & Kumar, 2021) have studied AWM in the presence of various competing messages. Since there is a mixed result regarding the music training in SPIN and AWM, it requires more research. On the other hand, for

AWM, in the presence of competing messages for musicians, no studies focus on the need for such experiments.

1.2 Aim of the study

The study investigates the association between speech perception and auditory working memory when competing messages are present in musicians and non-musicians.

1.3 Objectives of the Study

1. To assess the speech perception in noise (SPIN) scores in musicians and non-musicians at +5 dB, 0 dB & -5 dB signal-to-noise ratio (SNR).
2. To assess the auditory working memory (AWM) abilities in the presence of competing messages using digit span test (forward and backward) in musicians and non-musicians at +3dB, +5 dB & +7 dB SNR.
3. To evaluate the association between speech perception and auditory working memory in the presence of competing messages in musicians and non-musicians.

1.4 Null hypotheses

Based on the previous investigations on SPIN and AWM in musicians and non-musicians the following null hypotheses were formulated for the present study.

- There is no significant difference in SPIN among musicians and non-musicians.
- There is no significant difference in AWM abilities in the presence of competing message among musicians and non-musicians.
- There is no significant association between speech perception and auditory working memory in the presence of competing messages in musicians and non-musicians

Chapter 2

Review of Literature

It is accepted that both primary and secondary sensory areas play a significant role in creating music. Those who undergo extensive musical training over many years will have refined auditory skills. The literature shows that music improves language and cognition, brain structure and function, WM, and auditory processing tasks. The anatomical and functional aspects of the auditory system are most frequently changed by musical training. These alterations occur at various levels from the brainstem through the primary and secondary auditory cortices (Altenmüller & Gruhn, 2002). A description of a few of this research on musicians is provided in the following section.

2.1 Role of Neural Plasticity

Neuroplasticity refers to the structural and functional modifications that experience or adaptation to environmental demands caused in the central nervous system (at the cellular or system level). The term "plasticity" is used in the context of cognitive neuroscience to describe changes in the brain's structure and functions that are connected to learning or experience and have an impact on an individual's behaviour (Buonomano & Merzenich, 1998; Zatorre et al., 2012). The structural changes in individual brain cells and the reconfiguration of the neuronal networks that support intricate cognitive functions are all examples of neuroplasticity. Neural plasticity can be classified into two; functional neuroplasticity refers to changes in brain function, whereas structural neuroplasticity refers to large-scale structural changes in the brain, such as size, shape, density, and connectivity.

Numerous studies have discovered that musicians' brains exhibit structural and functional adaptation with long-term musical experience for sound processing (Pantev et al., 2001; Gaser & Schlaug, 2003; Peretz & Zatorre, 2005). Earlier research about the neurological effects of musical experience mainly focused on the neural plasticity of the cortex (Shahin et al., 2003; Trainor et al., 2003; Kuriki et al., 2006; Rosenkranz et al., 2003; Lappe et al., 2008), but recent studies have shown that neural plasticity also extends to the subcortical auditory system. According to Schlaug et al. (2009), musicians have larger anterior corpus callosum than non-musicians. This discovery demonstrates that early childhood is the time when musical training makes the corpus callosum flexible.

2.2 Enhanced perception of signal in noise as a function of musical training

It takes skill to distinguish the crucial aspects of a signal while suppressing the irrelevant information, and it also requires the capacity to use linguistic context to "fill in" elements obscured by background noise (Brandt & Rosen, 1980). One of the facets of musicianship is the capacity to separate voices or instruments that are presented simultaneously. As a result, musicians with musical training have improved auditory perception, supported by anatomical and functional changes in the cortical and subcortical areas of the brain related to processing sound, notably speech in noisy environments. It was reported that musicians could distinguish melodies from ambiance harmonics (Levin & Edgerton, 1999) which is comparable to hearing speech in noisy environments. This ability to perceive speech in noise is strong in musicians but lacking in children with learning problems. As a result, the "usefulness of music training could be used as a global intervention strategy in individuals with noise exclusion deficits. Noise-exclusion deficit is a deficit in which children with language-based learning disorders show impaired processing of speech in challenging listening environments (Sperling et al., 2006)

Numerous studies have shown that musicians' brainstem representations of the timing and harmonic structure of speech are superior to those of non-musicians'. According to Musacchia et al. (2007) and Parbery-Clark et al. (2009), these characteristics are crucial for distinguishing speech sounds from background noise. The auditory pathways from the brainstem to the main and secondary cortices undergo structural and plastic changes as a result of extensive musical training, which also improves brain structure and function in the areas responsible for cognition, language, and auditory processing.

2.3 Working memory in musicians

Parbery-Clark. (2009) investigated the effect of musical training on WM and frequency discrimination threshold. Sixteen individuals with ten years of musical training and age-matched non-musicians participated in the study. The results showed that a smaller frequency discrimination threshold and greater WM capacity were obtained in musician groups. Musicians performed significantly better in WM and frequency discrimination tasks than non-musicians.

Similar comparisons between musicians and non-musicians' WM were made by Talamini et al. (2016). Each participant in the study finished a digit span exercise that was presented visually, audibly, or through audio-visuals. To examine the role of rehearsal strategies and to alter task difficulty, the task was performed either with or without a contemporaneous task (articulatory suppression). Finally, each participant's musical ability was assessed using the PROMS test, which measures music perception skills. Musicians' attention spans were longer than non-musicians' regardless of the sensory modality or the accompanying task. The auditory and audio-visual spans (but not the visual) were linked with one PROMS test subscale in addition. Results point to a general advantage for musicians in verbal WM tasks over non-musicians, potentially affecting sensory modality and task complexity.

Bailey and Penhune (2010) assessed early- and late-trained musicians on an auditory rhythm synchronization task, matching them based on years of musical training, hours of current practice, and experience. Six woodblock rhythms with varied degrees of metric difficulty made up the assignment. Additionally, cognitive subtests testing vocabulary, WM, and pattern recognition were administered to the subjects. The two groups of musicians performed the rhythm task differently, with the early-trained musicians doing the task more accurately regarding the temporal structure of the rhythms. On the cognitive tests, there were no differences between the groups. Interestingly, individual task performance in both groups was connected with years of formal training and AWM skills. These findings are consistent with the notion that musical instruction can help children improve their sensory-motor synchronization skills during a critical period in early life.

Event-related potentials and a standardised WM test were utilised in a study by George and Coch (2011) to look at the neurological and behavioural elements of WM in college-aged musicians and non-musicians. On standardised executive, phonological, and visual memory tests, musicians performed better than non-musicians in terms of conduct. According to electrophysiological findings, musicians updated their working memory (WM) more quickly and with less effort in the visual domain (shorter latency P300s). Additionally, musicians showed greater sensitivity to the auditory standard/deviant difference by allocating more brain resources to auditory stimuli (higher amplitude P300). These findings suggest that sustained music training improves working memory (WM) in the auditory and visual domains as well as in behavioural and ERP assessments.

2.4 Auditory Working Memory and Speech Perception in Noise

Two hypotheses have been presented in the literature about the relationship between WM and speech perception: The first is Just's capacity hypothesis (1992), which suggests that, across all cognitive processes, WM performs limited activity. Memory loss happens when processing requires a lot of effort or takes a long period. The complexity of the processing increases as the system operates more slowly. When WM capability is maximised, access to other cognitive resources is constrained. The diminished functionality of the hearing aids causes increased auditory fatigue, which lowers the rate of cognitive processing. To assign the retrieval and storage of resources to new tasks, the workload of WM should be reduced (Stenback et al., 2016).

The second paradigm is the ease of language understanding (ELU) model, which claims that any discrepancy between speech input and phonological representation stored in long-term memory impairs automatic vocabulary retrieval and compels busy processing processes like WM. This mismatch can be brought on by both internal and external distortions, such as issues with the hearing apparatus and cognitive function (Rönnberg et al., 2010). According to the ELU model, which contends that the degree of cognitive function interference in speech recognition depends on the hearing conditions (Füllgrabe et al., 2015), the individual's cognitive aptitude can predict the degree of speech recognition in challenging hearing situations. AWM and SPIN do not typically correlate with one another (Fullegre, 2016; Magimairaj et al., 2018; Fullegre & Rosen, 2018).

Some literature studied the connection between AWM, linguistic proficiency, and SPIN in children between the ages of 7 and 11 years with normal hearing and non-verbal IQ scores. Both language and AWM were assessed. They discovered none of the other measurements and SPIN had a meaningful correlation. Their findings refuted the notion that children's AWM capability and SPIN are related, and they recommended employing numerous SPIN instead of one. In research that used the Reading-Span in conjunction with a test of SPIN identification (Magimairaj et al., 2018).

Fullgrabe and Rosen (2016) reviewed published and unpublished investigations discussing the relationship between AWM and SPIN. Little to no evidence of a connection between AWM and SPIN performance was found in the survey. To determine whether there is a correlation between Reading-Span scores and the ability to identify matrix phrases in noise, they also examined fresh data from 132 participants who had normal hearing and were drawn from a range of adult ages (18 to 91 years). Age-related declines in performance on both tasks were evident, and correlations remained modest even after age and audibility effects were taken into account. Separate studies for other age groups showed that the correlation did not apply to persons under 40 and was only significant for older and middle-aged groups.

Similar to this, Millman and Mattys (2017) investigated the relationship between speech perception in modulated maskers and components of AWM across a range of SNRs. On 30 adults, SPIN, non-word repetition, forward and backward digit tests were conducted. They discovered that only in the least advantageous SNR did speech perception in modulated maskers correlate with individual differences in the phonological component of AWM (as evaluated by non-word repetition). There was still no correlation after adjusting for factors including age, gender, and hearing sensitivity. According to the study's findings, listeners who have stronger phonological AWM are better able to detect sentences in modulated noise situations.

McCreery et al. (2017) examined how cognitive and linguistic abilities that impact voice recognition in noise in normal-hearing children. Ninety-six kids between the ages of 5 and 12 with normal hearing participated in the study. Monosyllabic words, syntactically correct sentences with semantic anomalies, and semantically and syntactically anomalous word sequences were used to measure SPIN. Individual variations in SPIN were predicted using vocabulary, syntax, and AWM tests. Although there was no association for the perception of one-syllable words, the study found a substantial relationship between AWM and SPIN.

Children's performance on voice recognition and AWM tasks with two noise source configurations back and side was compared by Sullivan et al. (2015). WM and SPIN were administered counterbalanced across listening conditions to children with normal hearing between the ages of 8 and 10. They discovered that SPIN was much worse when presented at 180 degrees azimuth than 90 degrees azimuth. The configuration of the noise source had no impact on how well AWM performed. However, AWM performance in noise was much worse than in quiet, independent of posture. When noise was provided at a 90° azimuth, there was no correlation between SPIN and WM. Children use perceptual cues and cognitive resources in light of the task's challenge and the signal's audibility. Cognitive resources are primarily used when listening conditions worsen, and tasks are more challenging. AWM training may improve SPIN environments (Ingvalson et al., 2015). Further, they had given ten days of reversed digit span training in native Mandarin Chinese and native English speakers. Both reading span and SPIN improved significantly after training, whereas untrained controls showed no improvement. These findings imply that AWM training can be utilized to enhance speech perception in noisy environments.

Gordon and Cole (2016) evaluated younger and older listeners with normal hearing who had varying AWM spans SPIN scores. The SNR corresponding to 50% correct performance was calculated using words and sentences in noise. As cognitive tests, the Listening Span Test and Reading Span tests were used. They discovered that listeners with normal hearing and low AWM capacity are less able to respond in the presence of noise. The contribution of AWM to SPIN was evaluated by Morteza and Abdollah in 2019 concluded that speech recognition relies heavily on AWM. Older people who have hearing loss showed this relationship significantly. AWM exercises can help these people better hear speech over background noise. AWM ability is another factor that affects the performance of hearing-impaired individuals fitted with hearing aids. Using a novel paradigm, Lad et al. (2020) tested AWM for non-speech sounds that vary in frequency and amplitude modulation rate. They discovered that, in individuals with normal audiometric thresholds at standard clinical frequencies, the precision of AWM for frequency is significantly related to SPIN performance but not for amplitude.

Chapter 3

Methods

The purpose of the present study is to better understand SPIN, AWM in the presence of competing messages, and the relationship between SPIN and AWM in the presence of competing messages in musicians and non-musicians. To fulfil the aim and objectives, a standard group comparison research design was used, and the participants were selected using a purposive sampling technique.

3.1 Participants

For the study, 40 participants in the age range of 18 to 25 years were recruited. They were grouped into two groups; Group I consisted of 20 musicians with five years of formal training, whereas Group II consisted of 20 participants without no formal musical training. Before the testing, informed consent was obtained from all the participants, which expressed their readiness to participate in the study.

3.1.1 Participants selection for Group I (Musicians)

- Twenty participants between the ages of 18 and 25 years,
- All the participants had Kannada as their native language,
- All the participants were vocalists and academically trained in Carnatic music (south Indian classical) for at least five years,
- All the participants had hearing sensitivity within normal ranges (Pure tone average (PTA) between 25 dB HL for 500 - 4000 Hz) (Clark, 1981),
- All the participants had Speech recognition thresholds (SRT) within +12 dB of PTA,
- All the participants had speech identification scores (SIS) at 40 dB SL at least 80% (ref SRT),

- They had a Bilateral 'A' or ‘As’ type of tympanogram at 226 probe tone frequency and acoustic reflex (ipsilateral and contralateral) present at 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz,
- All the participants had the presence of Transient Evoked Oto Acoustic Emissions (TEOAEs) at 80 dB peSPL and SNR of +6 dB at least for three consecutive frequencies,
- No H/o any neurological or psychological dysfunction,
- No C/o tinnitus or hyperacusis,
- No H/o noise exposure, ototoxic medicine.

3.1.2 Participant Selection for Group II

- Twenty participants between the ages of 18 and 25 years,
- All the participants had Kannada as their native language,
- No formal experience in Carnatic music (south Indian classical),
- The hearing sensitivity within normal ranges (PTA between 25 dB HL for 500 to 4000 Hz) (Clark, 1981),
- All the participants had SRT within +12 dB of PTA,
- All the participants had SIS at 40 dB SL at least 80% (ref SRT),
- They had a Bilateral 'A' or ‘As’ type of tympanogram at 226 probe tone frequency and acoustic reflex (ipsilateral and contralateral) present at 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz,
- All the participants had presence of TEOAEs at 80 dB peSPL and SNR of +6 dB for at least three consecutive frequencies,
- No H/o any neurological or psychological dysfunction,
- No C/o tinnitus or hyperacusis,

- No H/o noise exposure, ototoxic medicine.

3.2 Instrumentation, Software, and Materials

- PTA, SRT, and SIS were obtained using a calibrated GSI Audiostar Pro (Grason-Stadler Incorporation, USA) coupled with telephonic TDH 39 supra-aural headphones and Radio ear B-71 bone vibrator.
- A calibrated GSI-tympstar (Grason-Stadler Incorporation, USA) clinical immittance meter, calibrated as per ANSI 1987, was employed for checking auditory reflexes and doing tympanometry.
- TEOAEs were measured using the ILO 292 DP Echo port system (Otodynamics Inc., UK).
- A personal computer loaded with Smriti-Shravan software version 3.0 (Kumar & Maruthy, 2013) was used for AWM tasks.
- A personal computer loaded with custom MATLAB function was used for mixing babbles and Phonemically Balanced Kannada PB words (Gnanateja, 2017).
- Calibrated headphone (Sony MDR-ZX310AP) to deliver stimulus for testing.
- A sound level meter and appropriate couplers were used for calibration.
- Questionnaire on musical perception ability to select participants for Group I.

3.3 Test environment

All the testing and experiments were conducted in a soundproofed, air-conditioned rooms with allowed ambient noise levels (ANSI S3.1-1999, R2013).

3.4 Procedure

3.4.1 Preliminary evaluations

Detailed case history. All the participants were asked to provide a thorough case history to rule out any pathological abnormalities of the auditory system and to gather details regarding their work environment and prior employment.

Otoscopic examination. The otoscopic evaluation was performed on all participants to examine tympanic membrane status and the presence of earwax. Participants with excessive cerumen or ear canal abnormalities were referred to an otorhinolaryngologist.

Pure tone audiometry. The diagnostic dual-channel audiometer GSI Audiostar Pro (Grason-Stadler Incorporation, USA) was used to evaluate pure tone thresholds in a sound-treated environment. For frequencies spanning from 250 to 8000 Hz for air conduction (AC) with TDH 39 headphones and from 250 to 4000 Hz for bone conduction (BC) with B 71 bone vibrator, thresholds were established using the modified Hughson and Westlake technique (Carhart & Jerger, 1959). To rule out the possibility of peripheral hearing loss in the participants, the criteria of 25 dB HL and pure tone average of 500 Hz, 1000 Hz, 2000 Hz, and 4000 Hz were taken into consideration (Clark, 1981).

Speech audiometry. SRT was obtained using Spondee words in Kannada, developed by Rajshekar (1978). A Phonemically Balanced Kannada PB word list (Yathiraj & Vijayalakshmi, 2005) was used to get SIS. The stimulus was delivered using a GSI Audiostar Pro diagnostic audiometer (Grason-Stadler Incorporation, USA) coupled with TDH 39 headphones.

Immittance evaluation. An immittance evaluation was carried out to rule out any middle ear problems. Tympanometry using a 226 Hz probing tone and acoustic reflex testing with a calibrated GSI Tympstar Pro immittance meter were both part of the procedure.

Transient Evoked Oto Acoustic Emissions (TEOAEs). TEOAEs testing was carried out using a calibrated ILO 292 DP Echo port system (Otodynamics Inc., UK) at 80 dB peSPL. The presence of OAE response was confirmed by the criteria of +6dB SNR at three consecutive frequencies.

Participants who met the above selection criteria were considered for the additional evaluation.

3.4.2 Questionnaire on Music Perception Ability

The ability to perceive music was verified for Group I (musicians) using a questionnaire developed by Neelamegarajan et al. (2017) provided in appendix 1. The questionnaire contains 28 items that can be answered in binary (yes or no) and took 10 to 15 minutes to complete. The tests covered pitch discrimination, melody recognition, timbre identification, pitch awareness, and rhythm perception. Pitch awareness has seven questions, pitch discrimination and identification have six questions, timbre perception has three questions, melody recognition has six questions, and rhythm perception has six questions. The response of “Yes” was given a score of one, and response of “No” was taken as zero out of 28 questions. Only those who received a score of at least 17 was considered in the musician group, and others are excluded.

3.4.3 Generation of babble and stimulus

The Kannada speech babbles were produced using a standard Kannada passage of 300 words created by Savithri and Jayaram (2004) and uttered by four native female speakers. The speaker was told to read portions while the microphone was positioned 20 cm in front of their mouth for recording purposes. Using a recorder (MOTU microbook II, Cambridge, Massachusetts) and Adobe Audition 3.0 software (Adobe Systems, USA), the sentences were digitally captured in a sound-treated room. As the target stimuli for SPIN, a list of phonemically balanced Kannada PB words created by Yathiraj & Vijayalakshmi (2005) was employed. A personal computer loaded with a custom MATLAB function was used to mix babbles and Phonemically Balanced Kannada PB words (Gnanateja, 2017) at -5 dB, 0 dB, and +5 dB SNRs. Each word mixed with speech babble chunked together to make a list for each SNRs, which contains 25 PB words.

3.4.4 Speech in Noise (SPIN)

The SPIN test was conducted using a Kannada PB word list (Yathiraj & Vijayalakshmi, 2005) mixed with four-talker Kannada babble. The SPIN scores were obtained for three conditions such as +5 dB, 0 dB & -5 dB SNRs using calibrated headphones (Sony MDR-ZX310AP). The participant was instructed as follows:

> “You are going to hear several words through the headphones. Each word will be presented with a noise playing in the background. You must ignore the background, focus on the words, and repeat them. In some cases, the background can be quite loud, making it difficult to understand the word completely; if you do not understand it completely, you are allowed to guess. Even if you understand partially, you need to repeat it.”

3.4.5 Auditory Working memory (AWM) measures

The Smriti-Shravan software version 3.0 was used for all working memory tasks (Kumar & Maruthy, 2013). Eight Kannada digits between zero and eight, with the exception of two, were chosen for the studies in the digit span tasks (forward and backward). The letters "ondu," "mooru," and "elu" were used for the digits one, three, and seven, respectively. All of the chosen digits were bisyllabic. Given that the word is trisyllabic (/eradu/), the number two is not used. At 70 dB SPL, the stimuli were delivered binaurally with calibrated headphones (Sony MDR-ZX310AP). The stimuli were four talkers babbling in Kannada at +3 dB, +5 dB, and +7 dB SNR with a one-second inter-stimulus period while four random numbers were presented. The participant received the following guidance:

> “You are going to hear several sequences of digits. You need to listen to the series carefully. You must ignore the background, focus on the words, and repeat them; you can guess if you do not understand them completely. Even if you know partially, you need to repeat it. Once the last digit is presented, you must type the digit in the same order as given for the forward digit span and in reverse order for the backward digit span. For example, if the stimulus was the sequence of one, two, three, and four, you must type in one, two, three, and four for forward digit span and four, three, two and one for backward digit span”.

At a time, only one SNR was tested and was given a break of a minimum of 24 hours between each SNR to avoid the practice effect. Also, the SNRs and digit tasks were selected randomly to avoid the order effect.

3.5 Statistical Analysis

Shapiro Wilk's test of normality was carried out to check the normality of the entire data. The choice of parametric test will be made in case of normal distribution ($p>0.05$), or else the choice of non-parametric test will be made ($p<0.05$) to compare the SPIN, AWM & correlation of AWM and SPIN between the two groups. An Independent t-test or Mann-Whitney U test will be administered to check the difference between Musician and Non-musician groups. Karl Pearson or Spearman correlation will be administered accordingly to study the association between SPIN and AWM scores of both groups.

To ascertain if all of the data was normally distributed, the Shapiro-Wilk test of normality was employed. Choosing a parametric test ($p > 0.05$) for a normal distribution or a non-parametric test ($p > 0.05$) for a non-normal distribution to compare SPIN, AWM, and the correlation of AWM and SPIN between the two groups. SPIN scores were compared between two groups using the Mann- Whitney U test because they had a non-normal distribution. In the forward digit span (FS) task, +3 dB SNR, +5 dB SNR, and +7 dB SNR were normally distributed, therefore an independent t-test was employed. In the backward digit span (BS) test, +3 dB SNR was non-normally distributed, so a Mann-Whitney U test was used. To examine the relationship between the SPIN and AWM scores of the two groups, Spearman correlation was used.

Chapter 4

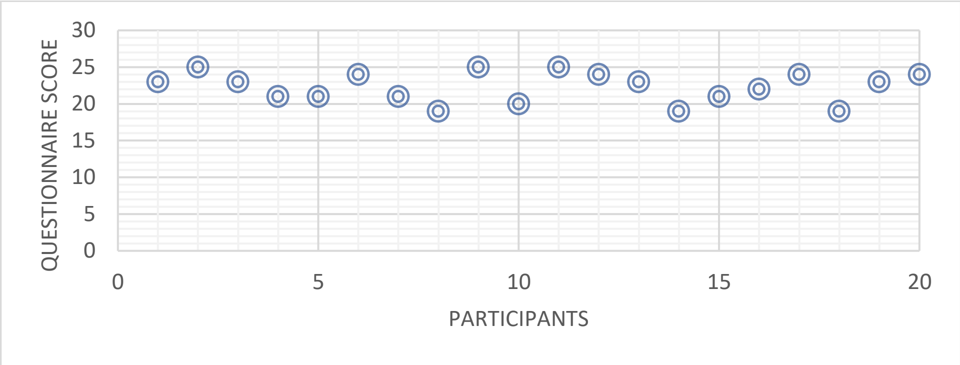
Results

The study compared SPIN, AWM in the presence of competing messages and the association between SPIN and AWM in the presence of competing messages across musicians and non-musicians. A total of 40 participants were recruited for the study and were equally grouped. Statistical analysis of the raw data was done using Statistical Package of Social Science Software (SPSS) software version 26.0. The normality check of the obtained data was done using Shapiro-Wilk's test of normality. It was found that a few parameters were normally distributed however, a few others were not. Hence for data that did not follow a normal distribution ($p < 0.05$), a comparison of groups was made by using the Mann-Whitney U test and for data that followed a normal distribution ($p < 0.05$), the across-group comparison was done using independent t-test. Correlation analysis was done using Spearman's correlation coefficient between the SPIN scores and AWM in the presence of competing messages for both groups.

The questionnaire on music perception abilities developed by Neelamegarajan et al. (2017) was administered to those participants who satisfied the criteria to be in Group I of musicians. The musicians who scored equal to or greater than 17 on the test were considered Group I (musicians). The scores obtained by each of the musicians in Group I in the questionnaire are shown in Figure 4.1.

Figure 4.1

Scores obtained by Musicians on the questionnaire (Neelamegarajan et al., 2017) on musical perception ability.



4.1 SPIN scores in musicians and non-musicians at +5 dB, 0 dB & -5 dB SNR

Descriptive statistics were applied to determine the median, minimum, and maximum SPIN scores at +5 dB, 0 dB, and -5 dB SNR in musicians and non-musicians. This is represented in table 4.1. The graph illustrates the median SPIN scores at different SNRs below (Figure 4.2).

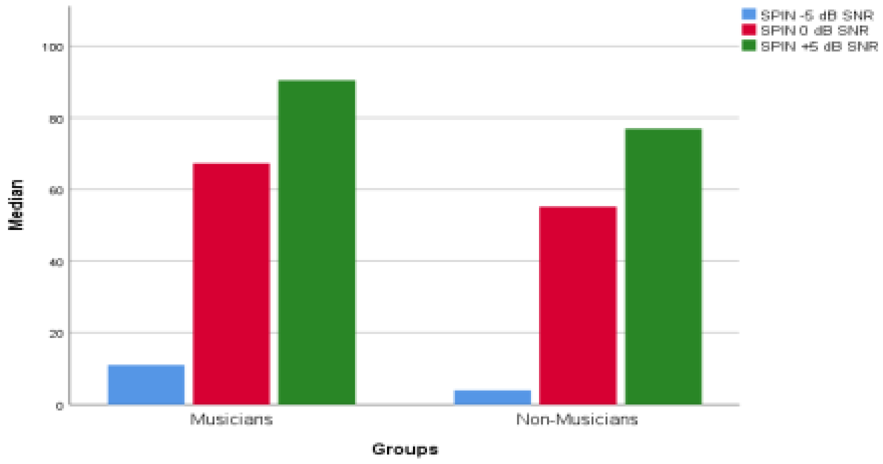
Table 4.1

The median, minimum, and maximum SPIN scores at +5dB, 0 dB, and -5 dB SNR in musicians and non-musicians

	Musician			**Non- musician**		
	Median	Min	Max	Median	Min	Max
-5 dB SNR	12	4	20	4	0	14
0 dB SNR	68	48	80	60	24	76
+5 dB SNR	92	84	96	78	64	88

Figure 4.2

The median of SPIN scores at different SNR



The normality check was done using Shapiro-Wilk's normality test, which revealed a non-normal distribution of the obtained data. Hence, the SPIN scores obtained at different SNRs were compared between two groups using the Mann-Whitney U test (table 4.2). There was a significant difference ($p < 0.05$) obtained between musicians and non-musicians at all SNR tested (-5 dB, 0 dB & +5 dB SNR).

Table 4.2

Mann- Whitney U test results of SPIN scores at +5dB, 0 dB, and -5 dB SNR in musicians and non-musicians

	U	**/Z/**	**P**
-5 dB SNR	55	3.98	*0.00
0 dB SNR	97	2.80	*0.01
+5 dB SNR	15	5.11	*0.00

* $p < 0.05$ (Significant difference)

4.2. AWM abilities in the presence of competing messages in musicians and non-musicians at +3 dB, +5 dB & +7 dB SNR

Descriptive statistics were carried out on obtained data to find out mean, median, and standard deviation of AWM abilities in the presence of competing messages of +3 dB, +5 dB & +7 dB SNR. The findings are represented in table 4.3.

Table 4.3

Mean, median and standard deviation for forward and backward span tests in the presence of competing messages in musicians and non-musicians

Groups	**Musicians**			**Non- musicians**		
Measures	**Mean**	**Median**	**S D**	**Mean**	**Median**	**S D**
FS +3 dB SNR	6.17	6.45	1.20	5.84	5.60	1.05
FS +5 dB SNR	6.52	6.45	1.09	5.89	6.10	0.92
FS +7 dB SNR	6.56	6.70	1.25	5.56	5.60	0.85
BS +3 dB SNR	5.69	5.85	1.22	5.34	5.40	1.13
BS +5 dB SNR	5.76	5.85	1.16	5.25	5.15	1.18
BS +7 dB SNR	5.82	5.80	1.19	4.91	4.65	0.94

For normally distributed data revealed by Shapiro-Wilk's normality test, the independent t-test was carried out; for non-normally distributed data, the Mann-Whitney U test was applied. It was found that the obtained data of +3 dB SNR, +5 dB SNR & +7 dB SNR in the forward digit span (FS) task and +5 dB SNR & +7 dB SNR in the backward span digit (BS) task were normally distributed. Hence, the results of the independent t-test showed that there was no significant difference ($p > 0.05$) between musicians and non-musicians in the forward digit span (FS) task at three different SNRs (+3 dB SNR, +5 dB SNR & +7 dB SNR) and backward span digit (BS) task at two SNRs (+5 dB SNR & +7 dB SNR). The results are depicted in Table 4.4. Similarly, the Mann-Whitney U test was carried out for non-normally distributed data of +3 dB SNR in the BS task. It was found that there was no significant difference ($p > 0.05$) in +3 dB SNR of BS task between musicians and non-musicians. This is shown in Table 4.5.

Table 4.4

Independent t-test results of forward and backward digit span task at different SNRs in musicians and non-musicians

	T	**df**	**Sig. (2-tailed)**
FS +3 dB SNR	0.90	38	0.37
FS +5 dB SNR	1.96	38	0.57
FS +7 dB SNR	2.93	38	0.01
BS +5 dB SNR	1.38	38	0.17
BS +7 dB SNR	2.66	38	0.11

Table 4.5

Mann- Whitney U test results of backward digit span task at +3 dB SNR in musicians and non-musicians

	U	**/Z/**	**P**
BS +3 dB SNR	155	1.20	0.23

4.3. Correlation between SPIN & AWM in the presence of competing messages in musicians and non-musicians.

Spearman's co-efficient established a correlation between SPIN & AWM in musicians and non-musicians. Results revealed that there was no significant correlation ($p > 0.05$) between AWM & SPIN in all tested SNRs in non-musicians. That is, AWM tasks (FS +3 dB SNR, FS +5 dB SNR, FS +7 dB SNR, BS +3 dB SNR, BS +5 dB SNR & BS +7 dB SNRs) with SPIN (-5 dB SNR, 0 dB SNR &+5 dB SNRs) showed no significant correlation ($p > 0.05$). Results are displayed in Table 4.6 & Table 4.7

Table 4.6

Results of Spearman's correlation value of SPIN scores with all AWM in Musicians

SPIN	Correlation value	FS +3 dB SNR	FS +5 dB SNR	FS +7 dB SNR	BS +3 dB SNR	BS +5 dB SNR	BS +7 dB SNR
-5 dB SNR	SC	0.43	0.11	0.34	-0.12	-0.13	0.09
	p-value	0.60	0.66	0.12	0.60	0.56	0.69
0 dB SNR	SC	0.19	0.18	0.15	0.03	0.02	0.14
	p-value	0.42	0.44	0.51	0.87	0.91	0.53
+5 dB SNR	SC	0.10	0.09	0.42	0.05	0.12	0.28
	p-value	0.65	0.10	0.07	0.81	0.58	0.22

SC= Spearman's Correlation Coefficient, P= Significance (2 tailed)

Table 4.7

Results of Spearman's correlation value of SPIN scores with all AWM in Non-musicians

SPIN	Correlation value	FS +3 dB SNR	FS +5 dB SNR	FS +7 dB SNR	BS +3 dB SNR	BS +5 dB SNR	BS +7 dB SNR
-5 dB SNR	SC	0.23	0.34	0.19	0.36	0.30	0.32
	p-value	0.33	0.14	0.41	0.11	0.19	0.15
0 dB SNR	SC	-0.18	-0.05	-0.41	-0.20	-0.19	-0.33
	p-value	0.45	0.83	0.30	0.38	0.40	0.14
+5 dB SNR	SC	0.50	0.41	-0.15	0.25	0.35	0.35
	p-value	0.84	0.06	0.52	0.27	0.12	0.15

SC= Spearman's Correlation Coefficient, P= Significance (2 tailed)

Overall, the test results revealed a significant difference in SPIN scores between musicians and non-musicians. It was also found that there was no significant difference in AWM scores in the presence of a competing message between musicians and non-musicians. Further the correlation analysis between SPIN and AWM in competing messages between both groups was found to be non-significant for all variables tested.

Chapter 5

Discussion

The main aim of the present study was to compare the association between speech perception and auditory working memory when competing messages are present in musicians and non-musicians. The objectives of this study were to measure and compare the speech perception in noise (SPIN) scores in musicians and non-musicians at +5 dB, 0 dB & -5 dB signal-to-noise ratio (SNR), assess and compare the auditory working memory (AWM) abilities in the presence of competing messages using digit span test (forward and backward) in musicians and non-musicians at +3 dB, +5 dB & +7 dB SNR & evaluate the association between speech perception and auditory working memory in the presence of competing messages in musicians and Non- musicians.

Literature suggests that extracting a speaker's voice from background masking noise is challenging, even for young adults with normal hearing (Assmann & Summerfield, 2004). Some findings showed a better performance in highly trained musicians on two measures of speech perception in noise, the Hearing-in-Noise Test (HINT) and the QuickSIN (Parbery-Clark et al., 2009), compared to non-musicians. However, there were no studies in the literature in which AWM was assessed in the presence of competing messages, even though AWM score in quite showed a musical advantage (Kraus et al. (2012).

5.1. SPIN scores in musicians and non-musicians at +5 dB, 0 dB & -5 dB SNR

The findings revealed that there was a significant difference in SPIN scores in musicians in all the SNRs tested, i.e., -5 dB, 0 dB & -5 dB SNR when compared to non-musicians. The results of the present study are in congruence with the literature stating that musicians have an advantage in speech perception in noisy situations (Parbery-

Clark et al., 2009). These findings indicate that musical training limits the disturbing effects of background noise on musicians. The advantage of musical training could be discussed with an increase in MOCB activity which is correlated with good speech in noise performance (De Boer & Thorton, 2008). The musician's use of fine-grained acoustic information and lifelong experience with parsing simultaneously occurring melodic lines may refine the neural code top-down so that relevant acoustic features are enhanced early in the sensory system. This top-down modulation has indeed been noted to be prominent in musicians (Trainor et al., 2009), and an increase in top-down modulation was reported in children following a year of musical training (Shahin et al., 2008), thus indicating the role of musical training in the sharpening of the brainstem responses in noise. Therefore, it can be concluded that musical training positively affects the perception of speech in noisy environments. Hence, the present study findings agree with the previously reported studies.

5.2 AWM abilities in the presence of competing messages in musicians and non-musicians at +3dB, +5 dB & +7 dB SNR

The results revealed that there was no significant difference in AWM scores at all tested SNRs, i.e., +3dB, +5 dB & +7 dB SNR between musicians and non-musicians. Similar findings were obtained in the study conducted by Escobar et al. (2020). In their research, based on performance on the backward digit span test, musicians and non-musicians were classified as having high or low WM. When WM capacity was matched, music training had no effect or interaction between music training and WM. These results are also in line with the findings of Boebinger et al. (2015) that musicians and non-musicians did not differ on digit span tests. This experiment's results suggest no significant difference between the cognitive abilities of musicians and non-musicians. They found that IQ is the factor that can predict AWM scores, not musical training. These results contrast the study by Ruggles et al. (2014), which found a significant difference in the full-scale IQs of musicians and non-musicians, but no significant relationship between IQ and AWM. This inconsistency further proves that the relationship between musical training and general cognitive abilities is complex and controversial (Schellenberg & Peretz, 2008).

However, there are a couple of study outcomes that are contradictory to the present study. Research works done using electrophysiological tests demonstrated that musicians have faster updating of WM (shorter latency P300s) in both the auditory and visual domains. It was also found that musicians allocated more neural resources to auditory stimuli (larger amplitude P300), indicating increased sensitivity to the auditory standard/ deviant difference and less effortful updating of AWM. Hence, these findings concluded that long-term music training improves WM in auditory and visual domains and behavioral and ERP assessments (George & Coch, 2011). Similarly, the findings of Kraus et al. (2012) highlight that AWM is an essential part of sound processing in the brain and suggest music training as a contributing source of these abilities. However, none of the literature discussed above performed AWM tasks in the presence of a competing message.

The selection criteria used to choose the musicians may be the reason for the present study's lack of agreement with the other studies. It could be explained by the starting age of musical training and the number of hours of practice. Another possibility is that even though it was scheduled on various days, the fact that participants had to perform it three times (at three different SNRS) made them feel unmotivated and weak, or otherwise, musical training did not improve AWM as demonstrated by SPIN.

5.3. Correlation between SPIN & AWM in musicians and non-musicians.

Correlation analysis reported that there was no significant correlation between AWM & SPIN in all tested SNRs in both musicians and non-musicians. A study by Boebinger et al. (2015) aligns with this result. They used the forward and backward Digit Span subtest of the Wechsler Adult Intelligence Scale (WAIS) (Wechsler, 1997) and Bamford-Kowal-Bench (BKB) lists (Bench et al., 1979) embedded with four different maskers (clear speech, spectrally rotated speech, speech-amplitude modulated noise, and speech-spectrum steady-state noise). They found that there was no significant interaction between masked speech and AWM abilities of musicians and non-musicians. Research work suggested that non-verbal IQ was a significant predictor of performance on masked speech tasks, not the AWM abilities across all participants.

However, the present study findings disagree with the study done by Escobar et al. (2020). They found a significant effect of AWM on SPIN ability on both the Quick Speech-In-Noise test (QuickSIN) and the Hearing in Noise Test (HINT) tests. Previous research has shown that greater WM capacity is linked to enhanced SIN perception (Parbery-Clark et al., 2009; Ingvalson et al., 2015; Gordon-Salant & Cole, 2016). Similarly, in a survey of 20 studies examining the relationship between SIN perception and forms of cognition, Akeroyd (2008) revealed similar conclusions. It was also reported that the listener is forced to rely more on acoustic cues and WM by increasing the semantic load and sentence length. Hence, when the listening situation becomes more complex, distinguishing between speech and noise depends on recruiting additional cognitive resources, such as WM (Parbery-Clark et al., 2009).

SIN perception has been incorporated into the Reverse Hierarchy Theory, which was first designed to explain visual processing (Nahum et al., 2008). According to this hypothesis, perception becomes more dependent on low-level auditory information as the SIN task grows more challenging. However, higher-order cognitive processes can only access this lower-level acoustic information via a backward (top-down) search, which hinders the simultaneous awareness of the ongoing auditory stream. Given how the Reverse Hierarchy Theory model interprets our findings, it is conceivable that improved WM capabilities could counteract disruptive backward search, leading to enhanced SIN performance. Alternatively, the necessity for backward searches is diminished if musicians have more unique acoustic representations, allowing them to concentrate on the higher-level representations connected to comprehension.

Evidence of literature in the past was done by correlating speech in adverse listening conditions with AWM in quiet. However, the present study performed the AWM task in the presence of a competing message. It could be a reason for getting poorer AWM scores than in quiet conditions and may lead to a lack of correlation between these two. Research reported that a person’s WM span is reduced in challenging listening situations compared to quiet conditions (Rabbitt, 1968; Pichora et al., 2003). Hence, the presence of background noise may also increase the attentional load, resulting in fewer resources being available for the rehearsal and recollection of target words (Heinrich et al. 2008).

Chapter 6

Summary and Conclusions

Perception of Speech in adverse listening conditions is essential for everyday communication. In most situations, the listener requires the ability to process complex auditory signals to understand the target speech or sound. Auditory working memory (AWM) is used to briefly store, manipulate, and integrate information with existing information in memory stores. Music training has been shown to enhance cognitive processing beyond general intelligence (Parbery-Clark et al., 2009). Previous research has shown that greater WM capacity in musicians is linked to enhanced SPIN perception (Parbery-Clark et al., 2009).

A total of 40 normal-hearing individuals aged between 18-25 years were involved in the study. The participants were grouped as Musicians (n=20) and non-musicians (n=20). Based on the musical training they received (> five years) and their performance in the questionnaire on musical perception abilities (score of >17), musicians were recruited. Both groups completed -5 dB SNR, 0 dB SNR, and +5 dB SNR SPIN tasks to assess and compare the impact of SPIN scores. The findings showed significant difference between the musician and non-musician groups in all tasks. However, in both the ascending and descending tasks at +3 dB SNR, +5 dB SNR, and +7 dB SNRs, there was no statistically significant difference in the AWM scores between the groups. Additionally, both groups' SPIN and AWM scores were correlated, but the correlation was not statistically significant.

This study shows musical training improves speech comprehension in challenging listening environments like noise. However, AWM does not benefit from music training, and the study also showed no link between SPIN and AWM.

6.1 Outcomes of the Study

- The study explains how music experience may play a role in SPIN and AWM.
- The study helps to understand the impact of long-standing musical training on complex auditory abilities.
- The gathered information from the study could throw light in counselling about the advantage of musical training and can be introduced in listening training units in the future.

6.2 Limitations and future directions

A significant limitation of the present study is the criteria used to select musicians; future studies should involve more strict criteria in which the years of musical experience should be increased and the starting age of musical training also considered.

Here only speech babble is used as a competing message, hence only informational masking is considered. Future studies can also extend to find the effect of energetic masking and the impact of speech-shaped noise.

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APPENDIX 1

Items in the "Questionnaire on Music Perception Ability" (Neelamegarajan et al., 2017)

'Questionnaire on Music Perception Ability (Neelamegarajan et al., 2017)
Note: The below questionnaire has questions related to different parameter of music like pitch awareness, pitch discrimi- nation & identification, timber identification, melody recognition, and rhythm perception. The responses are to be elicited in the form of Yes or No.

Pitch awareness:
1. Is your vocal (voice) range for speech and song the same?
2. Are songs sung in different pitches (shruthi/swarada matta)?
3. Are you aware that different songs have different ragas (tune/variation in swaras) and talas (beats)?
4. Do you feel that different singers sing in different pitches?
5. When we sing sa, ri, ga, ma, pa, ta, ni, sa, is there any change in pitch?
6. Have you heard of scales (swara shreni) in music?
7. Are you aware of sapthaswaras or seven notes in music?

Pitch discrimination and identification:
1. Can you discriminate the songs sung by male voice verses female voice?
2. Can you distinguish between high and low pitch (shruthi yalli vyathyasa) when you hear music?
3. Can you exactly find the note/scale (swara) of the music that is played?
4. Can you differentiate the “frequency modulations” (swara da erilitha) within the notes?
5. Can you differentiate as to whether the singer is still in pitch or has gone out of pitch?
6. Can you differentiate between singers from the song?

Timbre identification:
1. Can you identify the musical instrument (sangeetha vadya) played from a music that you hear?
2. If more than three musical instruments are played, can you identify and name all three instruments that are played?
3. When more than one instrument is played and one is out of pitch, can you make out the difference?

Melody recognition:
1. Can you exactly hum the song as you hear? (e.g., hnmmmm hmmn hn...)
2. Can you identify if there is a change in raga (tune) or modulation with emotion (bhava)?
3. Can you recognize different genres of music, like Carnatic, Hindustani, Western, jazz, rap, etc.?
4. Do certain parts of a song remind you of another song?
5. Can you recognize the song when someone hums it?
6. Can you identify the melodies of different emotions (raagada bhavane)?

Rhythm perception:
1. Can you differentiate if the music is slow/relaxing or fast/exciting?
2. Can you exactly count the number of beats (tala) in the song you hear?
3. Can you tap your feet/hand in the same rhythm along with the song's beats?