COMPARISON BETWEEN AUDITORY WORKING MEMORY AND SPEECH PERCEPTION IN NOISE IN CHILDREN WITH AND WITHOUT CHESS TRAINING

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This Dissertation is submitted as part fulfillment

for the Degree of Master of Science in Audiology

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CERTIFICATE

This is to certify that this dissertation entitled ***"Comparison Between Auditory Working Memory And Speech Perception In Noise In Children with and without Chess Training"*** is a bonafide work submitted in part fulfillment for degree of Master of Science (Audiology) of the student Registration Number: 18AUD023. 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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July,2020

I dedicate

my first ever scientific work

to

my late godmother,

grandfathers

and

my best science teacher

(late Jaikumar Sir)

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“Ennudayone Ni Enne Kan Mani Pol Kaatheedaname, Nin Chirakaale Marachu Parikshayil Ninnenne Kaakkaname”

(Lord guard me as thy beloved one, and hide me in the shadow of your wings, save me from the trials of my life)

– Mor Ephrem’s Memra (Repentance)

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Abstract

The presence of competitive noise impairs listening in many communicative situations. Since one of the variables influencing speech perceptions in noise is the working memory and as the working memory improves with chess training (Burgoyne et al., 2016; Chase & Simon, 1973), chess training thereby should affect speech perception. However, the role of chess training on speech understanding in noise and its relationship with auditory working memory (WM) has not been explored. Hence, the current study was taken up to compare the auditory WM and speech perception in noise in children with and without chess training.

Thirty normal-hearing children who were native listeners of Kannada, of which 15 children with chess training who passed beginner's level and 15 children without chess training between the age range of 9- 11 years were recruited for the study. The working memory was measured using auditory forward digit span and auditory backward digit span tests. Speech in noise test in Kannada (Vaidyanath & Yathiraj, 2012) was used to measure the speech perception in noise test.

Results showed a significant difference in SPIN-K scores and digit span backward recall among the two groups. In contrast, no significant difference was observed for digit span forward recall. Further, the Spearman rank correlation test showed that there exists no significant correlation between SPIN-K scores with working memory measures (forward and backward digit span) in children with and without chess training.

By practicing chess, children generally improve WM, fluid intelligence, and concentration capacity (Bart, 2014). Working memory is said to be associated with improvement in speech perception in noise. Thus, children with chess training performed well in working memory and speech perception in noise tests. The study highlighted the positive effects of chess training and

helped understand the relationship between working memory capacity and speech perception in noise in children with chess training.

Chapter 1

Introduction

"A grandmaster needs to retain thousands of games in his head, for games are to him what the words of their mother tongue are to ordinary people or notes or scores to musicians."

- (Kasparov, as cited in Wooster, 2015)

Chess creates immense potential for the mind which can be used throughout one's life. Chess skill correlates positively with four major cognitive abilities i.e. fluid intelligence, understanding-knowledge, processing speed and short-term memory. These abilities are stronger in children than in adults (Burgoyne et al., 2016).

It improves and develops cognitive skills which especially in children would help in creating an ability to analyze and solve their problems correctly as chess enhances perception, creativity and reasoning to analyze and practice and perform different chess positions. Once children encounter complex and subtle matters they will follow the sophistication and subtlety of chess play, they will try to link or relate both these elements and try to find the logic. Chess play improves thinking and intellectual thought. It creates a feeling or the sort of thinking in the children to do their utmost to optimistically or persistently solve the issue (Kazemi et al., 2012). Skilled chess players have superior memory and recalling as they have to memorize a lot of chess-specific patterns that can result in suitable moves (Chase & Simon, 1973).

The capacity limited scheme which is responsible for encoding, storing, processing, and rehearsing information is known as working memory (WM) (Baddeley, 2012). Its span is measured by their capacity to store and process information simultaneously. Importantly, the ability to understand language, i.e., to store and process information relatively concurrently, is essential.

Auditory WM is positively linked with development and perception of language and speech, comprehension of reading and academic achievement (Vuontela, 2003;Gathercole et al.,2006; Alloway et al., 2009; Gillam, 2018). It is found to be a concomitant deficit in kids with a developmental language disorder, dyslexia and other developmental disorders like Attention-Deficit/Hyperactivity Disorder and Asperger syndrome (Alloway et al., 2009;Gray et al., 2019). Hence, auditory working memory can be considered as a good predictor for communication success.

Ease of language understanding (ELU) (Rönnberg et al., 2013), reports WM as a factor that connects the language input with the phonological representations in semantic long-term memory (LTM). It is presumed that if the incoming signal matches with the phonological presentations in LTM, the implicit/automatic processing of language comprehension is achieved. However, if the incoming signal is distorted or missing information due to negative listening environments, there is a discrepancy between the phonological input and the LTM representation. This discrepancy can happen due to different causes like internal disturbances (i.e., related to the linguistic, cognitive, and auditory integrity) and external disturbances like surrounding noise which can cause energetic or informational masking.

Background noise such as speech babble, leads to deficit in processing of the WM system. In the presence of irrelevant auditory stimuli, Salamé and Baddeley (1982) defined impaired recall as the “irrelevant speech effect”. When a discrepancy happens, processing becomes effortful and slow, and cognitive skills, such as WM, inhibition, and attention, are required to understand speech. The ELU model indicates that people with higher working memory ability have greater understanding of speech in noise compared to people with reduced working memory capability.

In quiet and noise, Sullivan et al., (2015) administered listening comprehension and WM tasks to 20 normal hearing children between the age range of 8- to 10-years. Listening comprehension tasks had listening to short passages which were two to seven sentences long. They had to answer questions about the main idea, understanding, vocabulary, details, and reasoning. WM efficiency was considerably lower in terms of noise compared to quiet. This has been attributed to increased recruitment of cognitive skills in noise. Overall, the finding showed greater correlations between WM and listening comprehension in noise relative to the quiet. This was interpreted as representing greater demands of the WM for noise listening.

Hence, from the above studies, we understood that the memory affects speech perception and as skill training like playing chess improves one’s cognitive ability especially memory. The present study is taken up to determine how speech perception in noise and WM is related in children with and without chess training.

Need for the study

The presence of competitive noise impairs listening in many communicative situations. During the school-age years, children face different situations (i.e., classrooms) each day which are not favorable for communicating and learning as the noise and reverberation times for schools are mostly exceeded(Gillam, 2018; Osman & Sullivan, 2014).Working memory improve chess training (Burgoyne et al., 2016; Chase & Simon, 1973), which in turn have an impact on speech perception. Hence, in the present study the role of chess training in understanding speech under challenging listening conditions was assessed in children with and without chess training.

Aim of the study

To investigate the relationship between auditory working memory (WM) and speech perception in noise in children with and without chess coaching.

Objectives of the study

- To measure the WM ability using the digit span test in children with and without chess coaching.
- To measure speech perception in noise in children with and without chess coaching.
- To find out the relationship between WM, speech in noise in children with and without chess coaching.

Chapter 2

Review of Literature

Children learn in environments where there is always background noise. Juan and Tilano (2019) conducted a study to check the classroom acoustics, i.e., reverberation time and noise level in 26 classrooms. The average classroom noise pressure level and reverberation time was about 64.6 dB (A) and 1.51s, which were well above the international standards. A similar observation has been made by Saravanan et al. (2019) in the study done in the Indian scenario. The classroom noise not only causes distraction and annoyance but can also affect speech perception resulting in poor academic performance. In typically developing children, the competence to get through with the speech in noise depends on the individual’s age, cognitive and language skills(MacCutcheon et al., 2019) and also on the environmental factors like the spectral, temporal and spatial characteristics of the background noise and reverberation (McCreery et al., 2017; MacCutcheon et al., 2019).

2.1. Effect of Noise on Speech Perception

Cocktail party effect is the ability of the listener to focus on particular stimuli while passing over a range of various other stimuli like the noisy background. It is an extremely important auditory skill required by children on a daily basis. Children face various difficult listening situations daily, for example, listening to a teacher's voice when there are reverberation and background noise (fan sound, classmate's voices, etc.). Psychoacoustic studies have reported that compared to adults, children’s speech perception is more impaired by unfavorable listening conditions. Leibold and Buss (2013) compared the consonant identification of children between the age range of 5 to13 years and adults in the presence of a 2-talker masker or continuous speech shaped noise .Speech-shaped noise masks certain identification signals through energetic masking while the two talker masker produces both informational and energetic masking. Results showed that in the presence of speech-shaped noise performance were poorer for children who under the age of ten when compared adults, but by the age of 11 to 13 years the performance became adult-like. Similar variation in the results (child-adult differences) was observed in scores even for older children in the midst of a 2-talker masker. Authors reason out the significant child-adult differences seen while comparing 2 talkers with noise masker to the children's immaturity to correctly separate and pay attention to the target signals in the fluctuating two-talker masker whereas adults have the better ability to separate the sound correctly. Also, in the fluctuating speech masker, adults can aid more from slight improvements in the SNR at the "dips" than children.

Neuman et al., 2010 studied the effect of the combination of reverberation and noise on speech recognition performance (SNR-50) in children and adults who are in normal hearing. For this study, a virtual test paradigm was used to vary the reverberation time between 0.3, 0.6, and 0.8sec and signal-to-noise ratios to obtain SNR 50. The authors observed that for 50 percent performance, children need positive SNRs on average, whereas for adults the thresholds were close to 0 dB SNR or < 0 dB SNR. Adults did not have an SNR loss in reverberant SNR-50 when compared to SNR-50 without reverberation. Children aged between 6 and 8 years and between 9 and 12 years showed moderate to mild SNR loss i.e., SNR- 50 values for children decreased with increasing age. Thus they concluded that for a higher the reverberant environment the better SNR is required to have a good speech understanding for younger children.

2.2. Effect of Cognition in Speech Perception in Noise

Unfavorable listening conditions not only affect the individual’s well being but also disturb their mental performance. As listening becomes more effortful, children have to use more cognitive capacity to decode the speech. Klatte et al. in 2007 studied the effects of moderate-intensity of background noise on short-term storage and verbal information processing in 6 to 8-year-old children. No significant difference was noted in the word identification performance between quiet, controlled condition and the presence of irrelevant speech while a considerable difference reported for train sound. The author's reason is that the train sound is continuous noise with more physical masking than speech noise. Short-term memory (STM) performance in the non-word task and performance on the execution of oral instructions were severely disrupted by the background speech but not with train sound. Phonological awareness is the ability to access and shape the sound units of language. It is one cognitive skill that is closely related to STM and the acquisition of written language. To perform this phonological awareness task, the child must encode and maintain phonological representations in STM. To see the impact of noise on phonological awareness tasks in children, the Klatte et al. in 2007 conducted another experiment in 7-8-years-old children where they had to decide which one of the three words differed from the other two for the initial or the final sound. They also assessed the effect in the serial recall of verbal items presented visually whereas sequence of digits drawn randomly and without repetition from the set of 1 to 9 with a presentation frequency of one digit per second. Children had to call back presented digits in the correct sequence, and the level increased from three to six digits. The noises such as background speech, unfiltered train sound, filtered train sound, and control sound embedded into the software controlling the digit recall task. The recalling ability was severely disrupted by background speech and decreased by 25 percent when compared with the control condition. But other sounds did not seem to affect the performance. Therefore, the authors concluded that moderate-intensity noise and background speech could disrupt children's cognitive performance, phonological storage, and language processing.

Zekveld et al. (2011) used pupillometry to study the effect of cognitive ability, age and hearing loss on the cognitive processing load while listening to speech presented in noise. Subjects included middle-aged normal, and hearing loss participants. Their SNRs required for 50%, 71%, and 84% of the sentence intelligibility i.e., SRT50%, SRT71%, and SRT84%, respectively was estimated. Pupil response, a test of processing speed Text Reception Threshold (TRT), and a word vocabulary test were done. The authors noted that with diminishing speech intelligibility, the pupil response systematically increased. In difficult listening conditions, age, and hearing loss factors included cognitive overload. Better TRTs and higher word vocabulary were corresponded with greater mental processing load along the speech intelligibility levels. Hence, previous literature supports that when speech understanding becomes difficult due to adverse listening condition and/or hearing loss, the dependence on effortful cognitive and linguistic processes rises.

MacCutcheon et al., 2019 explored how linguistic and cognitive capabilities are modulating the advantages of spatial separation between a target speaker and different types of noise sources. Thresholds for speech reception (SRT) assessed in simulated school listening environments in 39 children aged between 5–7 years. The SRT of the target sentences were inserted in speech -shaped white noise and single-talker contexts. The target and background noise was at 0°or was spatially separated with target at 0° and background noise at 90° to the right. Participant's expressive language and backward digit repetition were also assessed. Results showed that SRT was highest for informational maskers i.e., single talker context and in collocated condition where the target and background noise was at 0°, and individual differences in language ability and memory span were connected to advantages from spatial release from masking. In particular, the individual language differences and memory span were associated with the use of spatial cues in separate circumstances. Cognitive skills that are related to working memory capabilities, such as inhibition from the interfering sounds and executive attention control (Engle, 2002), provide advantages for the perception of spatial signals which aid in the auditory stream segregation of competing sounds.

2.3. Effect of Working Memory Capacity in Speech Perception

Working memory (WM) in simple terms refers to a human memory system that temporarily stores and manipulates information while the execution of compound cognitive tasks, which mainly involves comprehension, learning and problem-solving. It is usually considered an executive function (EF), where the individual uses his/her cognitive skills to manage and organize his or her mental abilities to achieve a goal. Other EF includes planning, organizing, updating, attention control, fluid reasoning, inhibition, and self-monitoring (Gillam 2018). This plays a significant part in children's ability to learn new vocabulary, understand complex sentences, and follow a variety of grammatical patterns, which helps in speaking and writing.

Osman and Sullivan (2014) conducted a study to analyze the auditory WM in degraded conditions in school-age children with typical hearing. The authors also checked whether the differences in performance in noise were contributed by the amount of cognitive effort required by the task. Twenty children between the age range of 8-10 years were the participants of the study. Testing was done using four auditory WM tasks (Backward and Forward Digit Recall, Listening Recall Primary, and Secondary).Each of the tasks was performed in 4-talker babble noise at 0 dB and –5 dB SNRs and also in quiet. Results showed that the midst of multi-talker babble noise negatively impacted auditory working memory performance. No matter how complicated the task was, the noise had a similar impact on the efficiency. They concluded that the auditory WM process for children at their school-age was inhibited with addition of noise.

McCreery et al. (2017) assessed effect of linguistic and cognitive skills affect speech recognition in noise for typically developing children with normal hearing. Ninety-six children between the age range of 5 to 12 years were incorporated for the study. Testing was done with speech recognition in noise for syntactically correct but semantically anomalous sentences, semantically and syntactically anomalous word sequences and monosyllabic words. Four subtests of the Automated Working Memory Assessment were used to document the verbal WM and visuospatial ability. For each sensory modality, both simple and complex span tasks were used. Production error, receptive vocabulary and receptive syntactic knowledge were also checked. These measures were used to anticipate individual variation in speech recognition in noise. Results indicate an association between greater WM and better speech recognition in noise irrespective of the noise type. Higher vocabulary skills for sentences and word sequences were linked with greater recognition in noise. Thereby it was inferred that children's speech recognition in noise was influenced by both WM and language ability.

On the contrary, Magimairaj et al. in 2018 assessed the relation between speech perception in noise (SPIN), WM capacity and abilities of language in eighty-three children. All the subjects were between the age of 7 to 11 years. They completed the Speech-in-Noise (SIN) Test, multiple measures of language and a selective auditory attention task, and WM. WM test included short term memory digit span task, auditory WM task where the child had to recall the words and numbers presented to him in the correct order. The stimulus presentation in digit WM task was computer paced (time-controlled). A single-digit number was presented on the monitor for 1secsucceeded by an inter-stimulus interval of 1 sec. In the neighboring screen two red squares for 2 secs (i.e., big–big; small–small; big–small or small–big) were displayed randomly. Initially, the child had to assess whether the two squares were identical / different then later had to respond by touching a box labeling them same or different. Even by controlling the age, there was no significant correlation between children's performance on SIN with any of the memory, language, and attention measures. However, there was a significant positive relationship among memory, language, and attention measures. Hence, the outcome did not promote the relationship between WM capacity and SPIN in children.

2.4. Effect of WM training on Cognition

Individual's WM can be enhanced by intensive training of working memory (Verhaeghen et al., 2004; Westerberg et al., 2007; Klingberg, 2010).Morrison and Chein (2011) examined whether training related to an increase in WM capacity can bring about advancement in a series of essential cognitive skills. The training for complex WM (CWM) span consisted of both spatial and verbal versions of the task. Subjects who completed four weeks of WM training showed significant difference in temporary memory measures (verbal-spatial CWM and STM). These benefits promoted significant increase in comprehension of reading and were generalized to performance on the Stroop task also. The result showed that domain-general attention control mechanisms were affected by WM training and hence can elicit far-reaching cognitive benefits. This implies that WM training can be thereby used as a popular measure for improving essential cognitive abilities.

Morrison and Chein in 2011 tried to reason out whether WM training works and whether it yields generalized cognitive enhancement in their review article. They concluded that core training consist of repetition of demanding WM tasks designed to work on general discipline of WM mechanisms. It showed improvement in a range of areas of cognition (e.g., reading comprehension, cognitive control). It was consistent with studies of neuro imaging that involved changes in activation in zone linked with cognitive performance in the general domain. Therefore core WM training is a beneficial method to achieving general cognitive improvements.

Regarding this idea, Sala and Gobet (2017) conducted a meta-analytic study to find out the impact of WM training on academic and cognitive abilities (e.g., attention/inhibition, arithmetic, fluid intelligence, and literacy) in typically developing (TD) children of age range between 3 to 16 years. Results showed that WM training showed a significant impact on WM training-related cognitive abilities, but no obvious far-transfer effects were noted. So they concluded that WM training is ineffective at improving TD children's cognitive or academic abilities. These are modest when positive results are observed.

2.5. Role of Working Memory Training on Speech Perception

Ingvalson et al. (2015) probed to understand whether training in working memory could enhance understanding of speech in noise across languages. Twenty-three native

English speakers and twenty-five native Mandarin Chinese speakers were recruited for the study. They had completed 10 days of reversed span training on digits. After training in both the classes, speech comprehension in noise and reading span both improved significantly. Hence, they concluded that WM training was related with enhanced speech understanding in noise for both speakers.

2.6. Role of Skill Training on WM Capacity and Speech Perception

Ericsson and Kintsch (1995) suggested that long term skill and knowledge would greatly reflect on individual variations in WM ability. As a result to overcome the WM's capacity limitations, deep knowledge earned from the experience in a specific field can be made used. The connectionist approach by MacDonald and Christiansen (2002) describes how learning can augment processing capacity in skilled performance. From this observation it can be concluded that acquired domain-specific skills enhances both recall of domain-specific information and the measures of domain-related WM capacity.

Abacus includes recalling multiple numbers and calculations. The research conducted by Roy et al.(2019) examined the disparity in abacus trained children and children with no abacus training in the auditory working memory. They compared the reaction time and scores for digit backward, digit forward test, descending and ascending digit span test among these subjects (age of 9–13 years). The results revealed that the reaction time and scores of abacus trained children were significantly better than those without abacus training. In children with abacus training, therefore, they concluded higher auditory performance and improved auditory working memory. A similar observation was made by Chen et al. in 2011.

A study by Roden et al. (2014) revealed that 45 minutes of weekly training in music throughout a year in children aged 7 to 8 years notably improved their phonological short-term memory capacity. From a standardized and computerized working memory battery, seven subtests were used for the study; this was designed to evaluate phonological loop, visuospatial sketchpad and central executive, according to Baddeley's working memory model. The study suggested that children are benefiting from music training, especially in those features of cognitive functioning which are greatly associated to the processing of auditory information.

These studies agree with the study by Lee et al., 2007. The authors examined the outcomes of skill training, i.e., mental abacus and musical training, on WM. Subjects performed digit, non-word, and operation and simple and complex spatial span tasks. In all span tests the abacus and music learned kids performed better compared to the control group. They were showing improved working memory capacity with skill training.

Slater et al. (2015) conducted a longitudinal study of musically trained children aged between 6–9 years. They studied whether musical training over two years of up to 4 hours a week could enhance the perception of speech in noise relative to controls that did not undergo musical training. After one year of training, performance substantially did not vary for both the groups whereas a musician's benefit was noticed after two years of training. These findings therefore suggest that music training provides significant support for the development of basic auditory skills such as the ability to perceive speech in noise.

These results contradict the study done by MacCutcheon et al. in 2019, who investigated whether musical training can enhance the listener’s individual characteristics that have contributed to the perception of speech (e.g., linguistic, cognitive, and auditory skills) and improve the perception of speech in noise. They conducted the study in five to seven year old children who have received one year of musical training. The children's capacity to identify numbers and colored words in noise was assessed for several conditions, including different spatial combinations of target and masker (spatially separated and collocated) and under varying masker types (speech-shaped noise, single-talker background). Additionally, phonological STM was assessed using Number Repetition – Forward. Results indicate no significant interaction between the groups .i.e., musical training was not related with changes in a speech in noise (SiN) perception of phonological STM. The authors concluded that training in music improved neither phonological STM nor SiN perception in whichever listening conditions. The discrepancy between the findings can be attributed to the significant variation in the amount of musical training provided in previous studies. Escobar et al. (2020) made a similar observation among musicians and non-musicians in speech perception in the adverse condition. They confirmed that listeners with better WM abilities, regardless of previous musical training, had dominance when listening to speech in background noise. Music and abacus training have varying effects on WM. Training in music demands for more kinds of cognitive skills, such as memory skills, motor, and task switching whereas abacus training which is much simpler focuses mainly on visuospatial processing. Even though they have different effects on working memory, enriched experiences improve one's basic cognitive capacity and have substantial effects on learning and speech perception.

2.7. Effect of Chess Training on WM Capacity and Speech Perception

Chess is a game that requires calculation and planning, which in turn requires the ability to concentrate and to memorize sequences of moves and resulting positions. It also requires the ability to exert patience and self-control, as 'quick' moves could cost them the game. Hence, chess training could improve one's high-level cognition abilities. Long-term chess practice can improve cognition and behavioral skills.

A meta-analytic study was done by Burgoyne et al. in 2016 to evaluate the association between chess skill and cognitive abilities. The study revealed that chess skill correlates positively and significantly with four broad cognitive abilities (comprehension-knowledge, STM, processing speed, and fluid reasoning). A similar observation was made by Bart (2014) in his review article and suggested that chess requires higher cognitive skills. By practicing chess, children generally improve WM, fluid intelligence, and concentration capacity.

In 1996, Robbins et al. assessed the role of WM in different aspects of chess thinking. It included various experiments; one was to examine the immediate memory for the chess positions which was shortly presented. The subject had to recall the set-up position of the chess pieces and place the pieces accordingly on another board after a 10 sec study period. Different secondary tasks were imposed to block separate components of WM. To suppress the articulatory loop, the subject had to repeat the word in par with a metronome set to a frequency of one per second. Blocking the visuospatial sketchpad, by manipulation of a keypad where the subject had to press four keys in a calculator keyboard in each row from left to right before moving to the next row and blocking the central executive by random letter generation, i.e., the subject had to produce a random string of letters of the alphabet aloud, in par with the metronome. Observation made was blocking the visuospatial sketchpad, and the central executive had equivalent disruptive effects compared to the control group. Even though the suppression of the articulatory loop did not impact recall measures.

Fattahi et al. (2015) assessed the function of the auditory memory of expert chess players. A dichotic auditory-verbal memory test was performed for 30 expert chess players and 30 non-chess players aged between 20-35 years. A significant difference was noted between the groups. The role of auditory memory in expert chess players was done to infer that enhanced auditory memory activity is related to improving cognitive output due to long-term chess playing. A study was carried out by Joseph (2018) to analyze the effect of chess training on cognitive efficiency in children. They analyzed the impact of 1-year chess learning on the processing speed for children (grades 3–9).Two subtests from Wechsler Intelligence Scale for Children (WISC-IV India) were used to measure the processing speed, namely Symbol Search and Coding. The analysis revealed significant gains in chess-trained group processing speed as compared to the control group. The study thus establishes a link between the chess learning and the speed of processing. Improving processing speed in children improves the other academic and cognitive performance indicators.

Joseph et al (2016) carried out a study on 100 middle school children to examine the effect of chess training on academic performance. Student’s academic marks collected from school before and after one year of chess training. Chess training comprised of one-hour training sessions that were standardized once a week over a year. There was a significant progress in academic performances observed in social studies, science, and English. The study concluded that chess effects children's cognitive development. They observed a significant improvement in the academic performance of the chess-trained children.

The meta-analytic study carried out by Sala and Gobet (2016) suggests that chess instruction in schools improves children's reading, cognitive and mathematical skills moderately. The same authors made a contradictory observation in another meta-analytic study in 2017 assessing the impact of music and chess instruction on kid’s cognitive and academic skills and found only small to moderate effect. The authors hence concluded that transfer of learning rarely occurs with these types of training.

Thus from the above studies, we can conclude that working memory capacity (WMC) plays a crucial role in adverse conditions. Previous research is done on how WMC is related to speech perception in noise and how it improves with cognitive training. However, the role of chess training on speech understanding in noise and its relationship with auditory WM have not been explored. Hence, the current study was taken up to compare the auditory WM and speech perception in noise in children with and without chess training.

Chapter 3

Methods

The objective of this study was to investigate the relation between auditory working memory and speech perception in noise in children with and without chess coaching.

3.1. Research Design:

The study was carried out using standard group comparison, where the scores of children with chess training were compared with children without chess training.

3.2. Participants

The study was attended by a total of 30 participants aged 9 to 11 years who were divided into two groups. The group 1 included 15 children with chess coaching (mean age =10 years) and group 2 included age-matched children without chess coaching (mean age =10 years). The participants included in the study were native speakers of Kannada.

3.2.1 Participant selection criteria:

All participants had no history of hearing loss, ear disease, ototoxic drug intake, head trauma, ear surgery or speech-language problems. These details were noted through a structured interview with the participant. Further, on the day of the test, none of the participants had any illness. All the participants had speech recognition thresholds (SRT) within ±12 dB of pure tone average (average threshold of 500 Hz, 1000 Hz, 2000 Hz & 4000 Hz) and had speech identification scores (SIS) greater than 80% at 40 dB SL (ref SRT) .Normal functioning of the middle ear as indicated by bilateral 'A' type of tympanogram and acoustic reflex (ipsilateral and contralateral) present at the normal sensation levels at 500 Hz and 1000 Hz were also met by all the participants.

For group 1, children with minimum 167 days of training (250 hours) on a regular basis i.e., 1.5 hrs per day and who passed beginner's level were considered for the study. Participants were selected from the same chess academy to control the external variables. Prior to study a written informed consent was obtained from participant parents / guardians.

3.3. Instrumentation

- A calibrated two-channel *Inventis Piano* diagnostic audiometer with the TDH-39 headphone (Telephonic 815 broad hollow road, Farmingdale, New York11735) were used for estimating air conduction thresholds and speech audiometry.
- B-71 bone vibrator (Radioear, KIMMETRICS, Smithbergs, MD 21783) was used to assess the bone conduction thresholds.
- A calibrated Grason-Stadler Inc. Tympstar system (GSI VAISYS Healthcare, Wisconsin, USA) was used for tympanometry and reflexometry.
- Working memory and speech perception in noise assessment were done using HP notebook-15-da0295tu laptop and Sennheisser HD449 circumaural headphones calibrated to produce 85 dB SPL output.

3.4. Test Environment

Pure tone audiometry and speech audiometry were performed in an electrically and acoustically shielded room where the levels remained within the allowed limits (ANSI S3.1-

1999-R2013). All the other experiments were carried out in a noise controlled room with good illumination, ventilation, and minimum distraction.

3.5. Test Procedure

3.5.1 Routine Audiological Evaluations

Otoscopy was done to rule out any external deformity, presence of impacted wax and any ear infections. The preliminary evaluation involved pure tone, speech and immittance audiometry. A detailed case history to rule out any otological, neurological, and medical conditions was taken from all the participants. Thresholds of pure tone hearing were obtained using the modified Hughson Westlake method (Carhart & Jerger, 1959).The threshold was measured from 250 Hz to 8000 Hz for air conduction and from 250 Hz to 4000 Hz for bone conduction across octave frequencies by using a calibrated two-channel *Inventis Piano* diagnostic audiometer. Speech recognition threshold (SRT) was estimated using spondee word list in the participant's native language. Speech identification scores were obtained at 40dB above SRT using the standardized phonemically balanced word list in participant's native language. A probe tone frequency of 226 Hz was used for tympanometry with the pressure level varied from +200 daPa to -400 daPa. Both ipsilateral and contralateral acoustic reflex thresholds were obtained at octave frequencies from 500 to 4000 Hz using the same aforementioned probe tone frequency.

The actual experimental procedure included two tests to fulfill the aim of the study: speech perception in noise test and working memory measure.

3.5.2. Speech Perception in Noise

For measuring the speech identification in noise, test material given by Vaidyanath & Yathiraj (2012) i.e. Speech in noise in Kannada (SPIN−K) was used. This included 4 lists, each list containing 25 bisyllabic words taken from "phonetically balanced word identification test in Kannada" and 8−speaker speech babble served as the noise. The compact disk version of SPIN-K was played on a computer. The same audiometer used for pure-tone audiometry was used for routing the output. The participant heard the stimuli through Sennheisser HD449 circumaural headphones. The test was administered at 0dB SNR monaurally at 40 dB SL. The kids were directed to repeat those words while ignoring the noise. The verbal response of the participants was obtained and scoring was done based on the response obtained from the participants. For the correct response a score of 1 was given, and for wrong response 0.

3.5.3. Working Memory Ability

For working memory abilities, digit span forward and backward recall was assessed. Presentation of the stimuli and collection of the responses were through Smriti Shravan software (Kumar & Maruthy, 2013) installed in the laptop. The numbers were measured from one to nine lists, and a growing level of difficulty was introduced with level 1 being the easiest and level 6 being the hardest. Level 1 consisted of three digits while eight digits were present in level 6 which were randomly presented. Subjects had to memorize them in sequence.

The software itself provides an option to mark their responses soon after the presentation of the stimulus. Hence, participants were instructed to click on the numbers in the same order for forward span and in reverse order for backward span. Length of the sequence was increased each time as the participant gave correct response and reduced for incorrect responses.

Working memory capacity has been measured as the total number of digits that the person can remember correctly in the digit span test. Practice trials were given before the actual testing. A total of 6 reversals were presented where first two reversals were discarded and final four reversals were taken for the estimation of digit span.

3.6. Statistical Analyses

Working memory scores and SPIN-K scores were analyzed using appropriate statistical procedures using SPSS version 21. The following statistical procedures were used to analyze the data.

- Normality of the data were checked using Shapiro-Wilk test to see if chess training had any effect on the SPIN-K and working memory scores.
- Mann-Whitney U Tests were carried out because the data were not normally distributed.
- Further, to check the relationship between speech perception in noise and working memory tests, Spearman rank correlation test was performed.

Chapter 4

Results

The primary aim of the study was to compare the auditory working memory and speech perception in noise in children with and without chess training. The study had three major objectives to be fulfilled and is given below:

- To compare the working memory ability using the digit span test in children with and without chess coaching.
- To compare speech perception in noise in children with and without chess coaching.
- To find out the relationship between working memory, speech in noise in children with and without chess coaching.

In order to meet the objectives mentioned, the data of 30 children (with and without chess training) were subjected to statistical analysis. The parameters measured were working memory measures and speech perception in noise obtained using Smriti Shravan software (Kumar & Maruthy,2013) and Speech In Noise in Kannada (SPIN - K) (Vaidyanath & Yathiraj, 2012) respectively. These data were analyzed using Statistical Package for the Social Sciences (SPSS version 21, IBM Corp., Armonk, NY, USA) software. Descriptive statistics were carried out to estimate the mean, median and standard deviation for SPIN-K and working memory scores.

Table 4.1.

Mean, Median and Standard Deviation for Children with Chess Training

Group 1	Mean	Median	Standard deviation
Forward Digit	5.02	5.00	1.00
Backward Digit	3.49	3.60	0.84
SPIN R	19.80	20.00	1.32
SPIN L	18.40	18.00	1.64

Table 4.2.

Mean, Median and Standard Deviation for Children without Chess Training

Group 2	Mean	Median	Standard deviation
Forward Digit	4.35	4.50	0.76
Backward Digit	2.60	2.30	0.80
SPIN R	15.73	16.00	2.74
SPIN L	15.40	16.00	2.23

Normality of the data were checked using Shapiro-Wilk test to see if chess training had any effect on the SPIN-K and working memory scores. It was noted that few of the test parameters did not fulfill the assumptions of normality (p<0.05) (Table 4.3).Hence non-parametric tests were used for the inferential statistics. It is explained under each of the topics.

Table 4.3.

p Value of Both SPIN-K and Working Memory Scores for Both the Groups

Measures	**Without Chess Training**	**With Chess Training**
Forward Digit	0.04	0.65
Backward Digit	1.33	1.61
SPIN R	0.00	0.05
SPIN L	0.05	0.2

Further to see if there is any significant difference within the group Wilcoxon signed-rank test was done. In group 1, auditory working memory tests result revealed that there was a significant difference between auditory forward syllable span test and auditory backward syllable span test (z = -3.418, *p* = .001) and for speech perception in noise test results revealed that there was no significant difference between speech perception in noise- right and speech perception in noise- left test (z = -0.460, *p*= .645). For group 2, both auditory working memory tests and speech perception in noise test revealed significant difference between auditory forward syllable span test and auditory backward syllable span test (z = -3.412, *p* = .001) and for speech perception in noise test results revealed that there was no significant difference between speech perception in noise- right and speech perception in noise- left test (z= -2.946, *p* = .003).

4.1. Forward Digit Span Scores

Table 4.4 shows the median and one standard deviation of the forward digit span score across the two groups (one who received chess training and one without chess training).Group 1 with children who had received chess training obtained maximum median value of 5 compared to group 2 who did not receive the training. Mann-Whitney Test was carried out to compare the forward digit span scores between the groups. Results revealed no significant difference between the two groups [U= 67.5, p =0.061].

Table 4.4.

Median and Standard Deviation for Forward Digit Span

Groups	Median	Standard deviation
Group 1	5.00	1.00
Group 2	4.50	0.76

Note. Group 1 (with chess training) and group 2 (without chess training)

4.2. Backward Digit Spans Scores

Table 4.5 shows the median and one standard deviation of the backward digit span score across the two groups.).Group 1 with children who had received chess training obtained maximum median value of 3.6 compared to group 2 who did not receive the training. Mann-Whitney Test was carried out to check whether there was any significant differences in the backward digit span scores between two groups. Results revealed significant difference between the two groups [U= 50, p=0.009].

Table 4.5.

Median and Standard Deviation for Backward Digit Span

Groups	Median	Standard deviation
Group 1	3.60	0.84
Group 2	2.30	0.80

Note. Group 1 (with chess training) and group 2 (without chess training)

4.3 Speech Perception in Noise

Table 4.6 shows median and one standard deviation of SPIN-K scores of Group 1 and Group 2 for both right and left ear. Mann-Whitney Test was carried out to check the significance of difference in the SPIN-K scores between two groups. The results showed that SPIN-K scores were significantly better in the Group 1 compared to Group 2 for both the ears. For the right ear U = 8.0 and $p = 0.000$ while for left ear U = 32 and $p = 0.001$.

Table 4.6.

Median and Standard Deviation for SPIN-K Scores

Groups	Ear	Median	Standard deviation
Group 1	Right	20.00	1.32
	Left	18.00	1.64
Group 2	Right	16.00	2.74
	Left	16.00	2.23

Note. Group 1 (with chess training) and group 2 (without chess training)

4.4. Relationship between Working Memory and Speech in Noise in Children with and without Chess Training

Spearman rank correlation test was used to check if there is any correlation between SPIN-K scores with working memory measures (forward and backward digit span) in children with and without chess training. As shown in the table 4.7, there is a negative correlation between SPIN-K score of right ear with the working memory measures and a positive correlation between SPIN-K score of left ear with the working memory measures in chess trained children. However, these correlations were not statistically significant. This suggests that the SPIN scores in left ear improved as the working memory span was increased but not in right ear.

Table 4.7.

Correlation Scores of Working Memory Scores with SPIN-K Scores for Group 1(with Chess Training)

Working memory measures	**Speech perception in noise**			
	Right ear		Left ear	
	ρ value	*p* value	ρ value	*p* value
Forward digit span	-.104	0.713	.270	0.331
Backward digit span	-.263	0.343	.318	0.248

*Note.*ρ = correlation coefficient

Similar observation was made in correlation analysis of children without chess training. As shown in table 4.8, there is a negative correlation between SPIN-K score with the working memory measures for both ears, as the SPIN –K scores were similar in both ears. However, these correlations were not statistically significant. This suggests that the SPIN scores did not show an improvement with the increase in working memory span for both the ears.

Table 4.8.

Correlation Scores of Working Memory Scores with SPIN-K Scores for Group 2 (Without Chess Training)

Working memory measures	Speech perception in noise			
	Right ear		Left ear	
	ρ value	*p* value	ρ value	*p* value
Forward digit span	-0.304	0.271	-0.052	0.853
Backward digit span	-0.168	0.550	0.69	0.807

Note. ρ = correlation coefficient

Chapter 5

Discussion

The main aim of the current study was to assess the relationship between WM and speech perception in noise in children with and without chess coaching. The present study evaluated the WM measures and speech perception in noise in children with and without chess coaching. The study also explored the relationship between WM capacity and speech perception in noise skills. Thirty participants divided into two groups, and their working memory measures and SPIN-K scores were measured. The results of the study are discussed below;

5.1. Comparing the Working Memory Ability using the Digit Span test in children with and without Chess Coaching

The results of the current study showed no significant difference between the two groups (one who received chess training and one without chess training) for the forward digit span test. In contrast, a significant difference was observed for backward digit span scores, i.e., children who received chess training performed better in backward digit recall than those without the training.

Both the groups performed better on the forward digit span task than the backward digit span task due to the latter task's increased difficulty. The forward recall involves only storage and retrieval. It works mainly on the immediate memory. In contrast, in the backward recall task, an additional step of manipulation (reversing the order) is involved in making the task more difficult. Therefore, the group with no chess training performed equally well in forward digit recall to the group who received chess training.

The differences among these test results can also be attributed to their differences in terms of attentional demands. Though both the tests employ STM, backward digit recall requires an attention-demanding digit sequence transformation. Hence, this task can be considered as a complex span measure of WM (Alloway et al., 2006).Backward digit recall has also been more sensitive to the effects of brain dysfunction and aging than forward digit recall. Therefore, we can assume that any kind of skill training, i.e., chess training can immediately bring about a difference in backward recall span than in forward span. Gliga and Flesner (2014) also have reported an interaction which is statistically insignificant in their study of 40 school-going children. They suggested that memorizing chess positions using numbers and letters does not necessarily bring about an increase in digit memory. Another study by Schneider et al., (1993) agrees with the present results. They evaluated the role of chess expertise in memory recall in both adults and children, and chess skill for children showed hardly any effect in memorization of digits.

In contrast, Fattahi et al., 2015 reported an advantage for chess trained over non-chess trained in working memory measures in adults. The dichotic auditory-verbal memory test was carried out for the two groups. The study revealed a significant difference. They suggested that having professional skills in chess and the long term chess playing probably might have influenced in this increase in auditory memory function. This difference in results obtained from the current study can be due to the difference in the selected population and due to the test stimuli. The task was relatively simple as they did not consider the order in which the real words were recalled.

5.2. Comparing the Speech Perception in Noise in Children with and without Chess Coaching

A significant difference between the two groups was noted. The scores in the group with chess-training were better compared to non-chess trained, indicating that there was an effect of chess training on SPIN-K in children taken up for the present study. Listening and comprehension of speech is a complex task and it requires the utilization of both sensory and cognitive processes. Usually, during speech perception, the listeners derive and store the meaning from the input sound and use the stored information to summarize with the audio stream. But when these acoustic inputs get distorted with the noise, recalling these acoustic inputs with stored vocabulary becomes difficult. Thereby exerts a higher load on the WM (Souza et al., 2015). Children with better WM are said to perform better in academics and language learning (Alloway et al., 2009; Klingberg, 2010; Morrison & Chein, 2011). It also brings about an improvement in speech perception in noise. Long term practice and being skilled in chess can bring about an improvement in the individual's cognitive abilities (Charness et al., 2005; Aciego, 2012; Joseph , 2018). This can be the reason for the improved SPIN –K scores seen in chess-trained children (Klatte et al., 2007; Zekveld, et al., 2011; MacCutcheon et al., 2019).

It was also observed that the right ear scores were relatively higher in chess-trained children than non-chess trained. Different cortical areas get stimulated during the chess game. The left hemisphere is more active than the right whilst playing chess (Atherton et al., 2003; Nejati & Nejati, 2012). Hence, this can be attributed to the differences seen in the SPIN-K scores between the two ears.

The role of chess training on speech understanding in noise has not been explored earlier, and the present study is the first in this direction.

5.3. Relationship between WM, Speech in Noise in Children with and without Chess Coaching

Correlation analysis showed that SPIN-K scores had no significant correlation with the WM measures (forward and backward digit span) in children taken up for the present study. Though the correlation was not statistically significant, SPIN scores in the left ear improved as the working memory span was increased but not in the right ear for chess trained children. Hence, this can probably be attributed to the chess training received by the participants as the right ear had already achieved its ceiling scores, so further improvement in performance was visible only for the left ear. From the present study results it can be implied that working memory and speech identification in noise is not dependent.

Conway et al. (2001) reported that WM is responsible for maintaining the activation of relevant information while suppressing the distracters. Füllgrabe et al.(2015) have failed to detect a link between reading span and speech in noise identification scores in older listeners. Füllgrabe and Rosen in 2016 reported a weak correlation between WM and speech perception in noise in younger age populations and that this correlation improves with the increasing age. Previous researchers had reported both significant and non-significant correlations between WM capacity and speech perception in noise in children (Osman & Sullivan, 2014; McCreery et al., 2017; Magimairaj et al 2018). Hence, it can be concluded that based on the difficulty of the task, children make use of cognitive and sensory cues and they rely more on cognitive cues during the performance of complex tasks and in adverse listening conditions.

Lavaya.S (2017), reported a significant correlation between working memory scores and SNR-50 scores for bisyllabic nonsense words and not with SNR-50 scores of sentences. This result indicates that higher working memory capacity is required for recognizing lower redundant speech signals in the presence of noise. Millman and Mattys (2016) have also reported that WM capacity was related to speech in noise in the least favorable SNR. Hence, the differences in the test stimuli could also have also resulted in varying study outcome.

Chapter 6

Summary & Conclusion

Chess training improves one's high order cognition abilities, such as attention, problem-solving and memory (Kazemi et al., 2012; Burgoyne et al., 2016). Long term training in chess can bring about a change in the individual's cognitive performances and behavioral skills. The present study aimed to compare the auditory working memory and speech perception in noise in children with and without chess training.

To fulfill the aim of the study, 30 participants in the age range of 9 to 11 years were taken and were divided into two groups. Group 1 included 15 children with chess coaching, and group 2 included age-matched children without chess coaching. The working memory abilities were measured using digit span forward and backward recall. Speech in noise in Kannada (SPIN‑K) (Vaidyanath & Yathiraj, 2012) was used to assess the speech perception in noise.

Results of the present study showed a significant difference in SPIN-K scores and digit span backward recall among the two groups. In contrast, no significant difference was observed for digit span forward recall. Further, the Spearman rank correlation test showed that there exists no significant correlation between SPIN-K scores with working memory measures (forward and backward digit span) in children with and without chess training.

6.1. Implications of the study

1. This study adds on to the literature on chess training and its effect on working memory and speech perception in noise in children.
2. The current study is an evidence of the positive effect of chess training.

3. The study helps in understanding the relationship between working memory capacity and speech perception in noise in chess trained children.

6.2. Future directions and limitations of the study:

1. The study was conducted in a small sample size of 15 chess trained children. For better generalization of the results, larger sample size is required.
2. The study results are limited to kids in the age group of 9–11 years only. To verify the results obtained in the present study, children in other age groups should be studied.
3. Studies to assess the effect of chess training on a clinical population like learning disability and other disorders that have impaired auditory processing can be considered.
4. Use of a varied number of tests to assess the auditory working memory and speech perception in noise.
5. Studies need to be done to check the factors influencing or affecting the effects of chess training on children.

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