Correlation Between Phonological Working Memory and Speech Production in Bilingual and Trilingual Children

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Registration Number - P01II22S123028

Dissertation Submitted in Part Fulfilment for

the Degree of Masters in Science (Speech Language Pathology)

University of Mysore

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July 2024

CERTIFICATE

This is to certify that this dissertation entitled "Correlation between Phonological Working Memory and Speech Production in Bilingual and Trilingual Children" is a bonafide work submitted in part fulfilment for the degree of Masters in Science (Speech-Language Pathology) of the student Registration Number P01II22S123028. This has been carried out under the guidance of the faculty of this institute and has not been submitted earlier to any other University for an award of any other Diploma or Degree

Mysuru, July 2024

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DECLARATION

This is to certify that this dissertation entitled "Correlation between Phonological Working Memory and Speech Production in Bilingual and Trilingual Children" is the result of my own study under the guidance of Dr. Amoolya G., All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for an award of any other Diploma or Degree.

Mysuru, July 2024 **Registration Number: P01II22123028**

ACKNOWLEDGEMENT

In this journey of research spanning over past few months, there are lessons, experiences and people that have proven to be invaluable. As I present the final culmination of my work, I would like to express my gratitude and appreciation to those who made this possible.

To the director, **Dr. M. Pushpavathi ma'am**, I'm grateful for every opportunity that this institute have provided.

Heartfelt thanks to **Dr. M. Irfana ma'am** under whom I've started my research journey. From face-to-face discussions to google meets you always swooped in when I needed help. I'm gratefull for the patience trust and you had in me and for everything that I could learn from you.

The most sincere thanks to **Dr. Amoolya. G ma'am**. Thank you for the guidance, support and patience with which you have correct all of my most silly mistakes.

This dissertation would not have been possible without the consent and support from the **Principal and management** of the institutes that permitted me to undertake data collection. Their inquisitiveness towards my profession and research and their genuine goodwill towards me have taken me by surprise. They made a lot of this easier and I'm extremely grateful for this.

Adrent appreciation to **Dr. Brajesh Priyadarshi** and all the linguists – **Dr. Amudha, Dr. Tariq, Dr. Winston Cruz, Dr. Ravishankar** at Central Institute of Indian Languages (CIIL) for your valuable inputs.

To my dear classmates, **Muskan and Sharon**, thanks for your direct contribution to my dissertation. You guys immediately agreed to my request and showed up and for this, I am deeply grateful.

A special thanks to **Sruthi Das**. You have been around from the day we selected our guides to the day of submission. You listened to every one of my ideas that never came to be, to a number of mock RP presentations, and all of my worries and concerns, you gave me solutions and ideas and put a smile on my face with your amazingly humorous self. I owe you big.

Thank you, **Niranjana** for clearing my silliest of doubts and always giving me a better perspective. Your support and presence has got me through so much.

A huge bunch of thanks to **my classmates** for the peaceful and amusing environment you girls created every day, and for having each other's back no matter what.

All of this would be incomplete without an expression of utmost gratitude to **my parents and my sister**. You have given me so much love, support and ideas for all these years including this very work.

I extend my gratitude to everyone who has contributed in any capacity to this work. I'm indebted to all of you.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

Phonological working memory (PWM) refers to the capacity to temporarily retain verbal information. In both monolingual and bi-/multilingual contexts, PWM has been identified as playing a crucial role in vocabulary acquisition, the maintenance of linguistic information, and the processing of spoken and written language. Understanding the contribution of phonological working memory in the speech production of multilinguals is an under-researched area. The present study aimed at investigating if there existed a correlation between the phonological memory capacity and accuracy of speech production in non-native languages. The study recruited 60 participants from Tamil-speaking schools, divided into four groups by age and language proficiency: Bilingual (6-8 years, 10-12 years) and Trilingual (6-8 years, 10-12 years). All participants had Tamil (L1) and learned English (L2) with the Trilingual group also studying Hindi (L3). Tasks included a nonword repetition task in Tamil and delayed word repetition tasks in English and Hindi to assess phonological working memory and speech production accuracy. Results were analyzed based on percentage accuracy scores from recorded and transcribed responses. Results indicated no significant correlation between phonological working memory and speech production. Additionally, results revealed a significant age effect on phonological working memory and on speech production. No effect of language group was noted. The role of PWM as a potential predictive factor of additional language acquisition in the Indian population similar to the one considered in our study becomes questionable. The present study points towards considering the languages and their linguistic properties to understand the influence of bi-/multilingualism on phonological working memory capacity in Indian children.

CHAPTER I

INTRODUCTION

Working memory is a component of memory that is involved in storing temporary information and manipulating it, which is considered necessary for a variety of complex cognitive activities. The early models of memory such as Atkin and Shiffrin's two-component model (Atkin & Shiffrin, 1968), defined the existence of a temporary storage system that stored information before it reached long-term memory. This temporary short-term storage system was also considered to serve as the working memory. However, inconsistencies observed from neuropsychological evidence obtained from patients led Baddley and Hitch (1974) to propose a different assumption to the organization of the memory system. In their model, Baddley and Hitch proposed that the unitary component of STM could be separated into three constituent components namely – the phonological loop, the visual sketchpad, and the central executive. These three together form a unified working memory system that facilitates the performance of various complex cognitive tasks. The phonological loop is a transient verbal–acoustic storage system reported to be dealing with the processing and storing of spoken language. The visuospatial sketchpad is proposed to be involved in storing and manipulating visual stimuli. Both of these are managed by a restricted attention control system called the central executive.

The phonological loop stores a temporary memory trace of the phonological information in the phonological store and mentally repeats the sounds to maintain the phonological representations active in the subvocal rehearsal system. Subvocal rehearsal is independent of overt articulation skills, as demonstrated by dysarthric patients exhibiting subvocal rehearsal. In contrast, dyspraxic patients are unable to rehearse (Caplan & Waters, 1995). According to neuroimaging studies and case studies of individuals with phonological loop abnormalities, Brodmann area 44 has been associated with the process of storage and Broca's area has been associated with subvocal rehearsal. The majority of studies support a left-sided activation of both cortical regions.

In an attempt to uncover the functional significance of the phonological loop, Baddley hypothesized that the system might have developed to aid the acquisition of language. In order to test this, experiments were carried out where a patient with phonological loop damage was required to learn words in a foreign language as well as learn native word pairs. The results showed ease in learning the native word pairs but a failure in learning the novel words. This places the phonological loop in a critical role in learning a new language. These findings have been supported by Service (1992) who showed that English native children with good phonological memory were better learners of Finnish vocabulary and syntax than those with lower spans. These findings were also observed in adult learners of a second language (Atkins & Baddley, 1998; Gathercole et al., 1999). Thus, the phonological loop's capacity to encode, store, and retrieve sound sequences seems to be crucial for language learning.

Further studies to understand the phonological loop and verbal memory capacity in acquiring native language were carried out. The storage component of the phonological loop was found to be impaired in children (mean age = 8 years) with Specific language impairment (SLI) who were tested using nonword repetition measures (Gathercole & Baddley, 1989). Nonword repetition measures have also been found to be substantially correlated to vocabulary in school-going children (Gathercole & Baddley, 1990; Gathercole et al., 1992; Baddley et al., 1998). During the initial years of language development, good phonological memory skills facilitate vocabulary acquisition and later the vocabulary knowledge will facilitate repetition of unfamiliar words.

1.1 Phonological working memory

Phonological working memory (PWM) is defined as the ability to maintain verbal information in memory for a brief period of time. In literature, studies have employed various measures to measure PWM most commonly backward digit span, forward digit span and nonword repetition tasks. Of the various ways to measure phonological working memory capacity, one widely used method is the Non-Word Repetition (NWR) Task. NWR is a neuropsychological task in which participants listen to and repeat nonsense words that resemble real words but lack semantic content. This task necessitates the storage, retrieval, and reproduction of a sequence of phonemes that are devoid of meaning. Although NWR is not primarily a linguistic assessment, it crucially involves phonological abilities. The primary involvement of the NWR task is in sub-lexical knowledge—that is, understanding of fine-grained phonological representations—rather than semantic or lexical knowledge (Gathercole & Baddeley, 1989; Baddeley et al 1998., Munson, 2001; Edwards et al., 2004).

According to Gathercole et al (1997) and Bowey (2001), in both monolingual and bi-/multilingual contexts phonological working memory (PWM) contributes to vocabulary acquisition, maintenance and processing of linguistic information or reading. The effectiveness of the phonological memory system's ability to encode information has been linked to one specific factor ' the structural knowledge of one's language' (Windsor et al., 2010; Harrington & Sawyer, 1992; Cheung, 1996). In addition to various aspects of language, studies have also been conducted to understand the possible role of PWM in the production of native and non-native speech sounds and its accuracy in children and adults (Adams & Gathercole 1993; Jacquemot & Scott, 2006; Munson et al., 2005; Lewis et al., 2011; Shriberg et al., 2009; Torrington-Eaton & Ratner, 2016)

These results of studies implicate the role of phonological working memory in the overall performance in a second/additional language and its function in the acquisition and discrimination of features and their phonological representation in the sound system of a language.

1.2 Multilingual phonology

A significant portion of the global population, estimated at over half, uses multiple languages in their everyday lives (Grosjean, 2010). While pinpointing the exact number of people speaking three or more languages worldwide is challenging, a European Commission study (2013) revealed that a quarter of the teenagers in EU were proficient in three languages. Multilingualism is prevalent worldwide, particularly in regions like West Africa, Malaysia, and India. This suggests that over a billion people worldwide are likely multilingual, and this number is likely on the rise (Rocha-Hidalgo and Barr, 2022). In India, as per the 2011 census, 26% of Indians are bilingual while 7% are trilingual.

The field of phonological acquisition, which investigates the process of learning sound systems in new languages, has historically concentrated its efforts on individuals classified as monolingual or bilingual. Research dedicated to the acquisition of phonological systems in a third language (L3) remains comparatively scarce. This disparity is likely attributable to the increased complexity inherent in L3 phonological acquisition. Unlike second language acquisition (SLA), L3 acquisition involves the potential influence of either the first language (L1), the second language (L2) or both on the learner's developing L3 phonology (Cenoz et al., 2001; Gut, 2010;

Liu & Lin, 2021; Murphy, 2003; Wrembel et al., 2019). Consequently, an in-depth knowledge of multilingual language competence cannot be solely achieved through the isolated study of L1 and L2 phonological acquisition.

Need for the study

Research over past decades has substantiated the importance of phonological working memory in speech production and language acquisition in native language learning of children and adults. Previous studies have also studied the role of phonological working memory in second-language speech production in terms of accuracy of syntax, semantics, complexity, lexical density and fluency (Fortkamp, 2000). This study identified working memory as assessed by the speaking span test as a significant predictor of speech accuracy, complexity, fluency and weighted lexical density in adult L2 learners of English. In this study, the aspects of L2 learning considered reflect the processes of grammatical encoding but not conceptualization and storage of articulation.

There is scarce literature on early child multilingual phonological acquisition, despite the rising body of research regarding the acquisition of first and second language, including the phonological aspect. The majority of the investigation's focus is on socio-pragmatic and morpho-syntactic features; phonological issues have been disregarded. Researching the phonological development of young children who are bilingual is crucial since phonological proficiency is a precursor to delayed speech, language, and literacy development and delay (Stackhouse & Wells, 1997; Dodd, 2005). Lim et al (2015) study findings suggest a comparable competence of phonological acquisition in multilinguals as with monolinguals and bilinguals. Moreover, multilinguals may acquire certain consonants faster than monolinguals.

The role of phonological working memory in speech and language development in multilinguals is less studied. Moreover, within the larger context of multilingualism, the acquisition of multilingual phonology is frequently referred to as a less developed area of study. While most studies were aimed at investigating the contribution of working memory in linguistic skills and the learning capacity of adult foreign language learners, studies on development of phonological working memory in multilingual children are underdeveloped.

Conclusions from previous research have led to the hypothesis that PWM could be a significant predictor in the phonological feature acquisition in relation to the field of phonology, potentially aiding the formation of more accurate representations and realizations. More empirical data will be needed to map the interaction pattern between PWM and phonological accuracy.

Aim

The present study aims to understand the relationship between phonological working memory and speech production in multilingual school-going children.

Objectives

a) To understand the relationship between phonological working memory and speech production in Bilingual (Tamil-English) and Trilinguals (Tamil-English-Hindi) across age groups.

Hypothesis: There is no significant relationship between phonological working memory andspeech production in Bilingual (Tamil-English) and Trilinguals (Tamil-English-Hindi) across age groups

b) To compare the phonological working memory and speech production between Bilinguals(Tamil-English) and Trililinguals (Tamil-English-Hindi)

Hypothesis: There is no significant difference in phonological working memory and speech production between Bilinguals (Tamil-English) and Trilinguals (Tamil-English- Hindi)

c) To investigate the effect of age on phonological working memory and speech production in Bilinguals (Tamil-English) and Trilinguals (Tamil-English-Hindi)

Hypothesis: There is no significant effect of age on phonological working memory and speech production in Bilinguals and Trilinguals.

CHAPTER II

REVIEW OF LITERATURE

2.1 PWM and Language acquisition and production

Extensive research conducted over several decades has conclusively demonstrated that young children's phonological memory abilities are critically associated with three fundamental facets of language development. Specifically, robust correlations have been identified with language comprehension (Smith et al., 1986), vocabulary acquisition in native as well as foreign languages (Gathercole & Baddeley, 1989; Gathercole et al., 1992; Service, 1992), and reading development (as reviewed by Wagner & Torgesen, 1987).

In a case study reported by Speidel as early as 1989, he follows the development of language abilities in two bilingual siblings. They had good and similar intellectual abilities with strong language comprehension skills. However, one of the siblings was observed to have a delay in language development, problems with word order and poor articulation. The subject was also found to perform much poorer than his sibling in auditory recall and digit span tasks. It was suggested that the weak articulation skills during the early phases of acquisition led to the phonological memory problems observed. The author concluded that this limitation in the temporary storage capacity can lead to inadequate long-term storage for words and phrases required for adult-like spontaneous speech. This limitation places greater demand on processing resources during spontaneous speech thereby reducing the resources available to recruit additional items in the utterance. Thus, Speidel posits that phonological memory abilities impact both the efficiency of imitating adult models and the temporary storage of these models until they may be assimilated into long-term memory and the syntactic form repository.

In a similar view, Gathercole and Baddley (1989) propose that learning the phonological forms of new words necessitates short-term phonological storage. Therefore, syntactic development and expressive vocabulary skills can be disrupted due to phonological working memory deficits.

To understand the association between PWM and spoken language skills, Adams and Gathercole (1995), carried out a series of tests in toddlers which encompassed tests for PWM, general intelligence, articulatory skills, and receptive vocabulary. The results indicated a reduced repertoire of words in spontaneous speech in those participants with low phonological memory scores. This is supportive of the view that for vocabulary acquisition temporary storage of phonological forms of the novel words in working memory is critical. It was also observed that the participants in the low phonological memory group produced utterances of a shorter length. This is indicative of the role of the phonological loop as a speech output buffer (Gathercole & Baddley, 1993). Research has failed to identify a similar link in adult speakers, thus stipulating a developmental role for PWM in speech production. Grammatical sophistication was observed in the high phonological memory scores group. This is in agreement with Speidel's proposal that the imitated models of syntactic units are temporarily stored in the PWM before transfer to long-term memory. Another speculation presented by Speidel (1989) was that the early articulation skills can directly influence the phonological memory skills. This study by Gathercole and Adams (1995) has extended some support to Speidel's proposal by evidencing more phonological errors in speech production in those with poorer memory scores. However, this difference did not reach statistical significance.

2.1.1 PWM in foreign language learning – bilinguals

The phonological loop appears to be a useful tool for learning new words in a foreignlanguage (Baddley et al., 1988). In a string of studies, Baddley and colleagues have shown that impaired performance in the phonological loop has disrupted novel language learning while learning paired associates in the native language remains comparable to normal. Evidence suggests that poor language skills are observed in both adults and children with poor memory abilities (Baddley et al., 1998). A large body of evidence has demonstrated that WM is a significant factor in foreign language aptitude.

A strong correlation between WM in L1 and WM in L2 and between WM capacity and L2 proficiency is demonstrated by a vast number of evidence.

There are qualitative and quantitative variations in the acquisition of L1 and L2 specifically in adult learners of L2. Universal Grammar-based principles which are essential in the acquisition of L1 are either unavailable or available in a highly constricted degree for learning L2. Consequently, L2 learning relies more heavily on general cognitive learning processes associated with acquisition of higher cognitive skills (Bley-Vroman, 1989). In addition, the L2 learners spend a longer period on bottom-up processes due to the lesser processing facility and as a consequence place greater demands on attentional resources and working memory. Working memory capacity may be comparatively more important in limiting L2 growth as a result of the higher capacity demands made by the slower, more laborious processing of the less proficient L2 learner.

The rigorous framework of information processing theory has been applied to L2 speech analysis in a methodical manner. In the context of information processing theories (IPTs), controlled processes—that is, the deliberate concentration of attention on particular aspects of task performance, like second language learning —represent the first crucial stages towards language automatization (McLaughlin, 1987). Drawing on this perspective and empirical studies of L2 development, Prebianca et al (2009) suggest that L2 speech production is inherently dependent on controlled attention, especially during the early stages of skill acquisition, wherein practice is essential for the automatization of procedures and the liberation of attentional resources for higher-order processing. Consistent with this rationale, numerous researchers (Berquist, 1998; Finardi & Weissheimer, 2009; Fortkamp, 1995; Harrington, 1992; Harrington & Sawyer, 1992; Miyake & Friedman, 1998, among others) appear to agree that working memory capacity may vary throughout the course of L2 development as a function of enhanced linguistic proficiency and the automatization of linguistic knowledge.

To verify if any change to working memory capacity scores occurs due to this process of automatization of L2, Finnardi and Weissheirmer (2009) subjected bilingual adult participants (mean age of 25.5 years) to a speaking span test in their L2. The participants belonged to two different levels of proficiency – basic and intermediate. Their results found a significant positive correlation between working memory capacity scores and L2 speech proficiency and also indicated that the mean of the intermediate language proficiency group was superior to that of the basic group. According to models of skill development in cognitive psychology, performance on complex cognitive tasks progresses from a regulated to an increasingly automatized process (Anderson, 1983; DeKeyser, 2007). This conclusion is consistent with these theories.

Prebianca et al (2014), set out to analyze the relationship between WMC across languages and L2 speech proficiency levels in young adults. The WMC was measured for L1 and L2 using speaking span tests. The results enable us to conclude that Working

Memory Capacity (WMC), as assessed by a speaking span test in L2, appears to amalgamate the relationship between proficiency level and WMC.

According to Miyake and Friedman (1998), general learning mechanisms and principles—like working memory capacity—may be more important for L2 acquisition than for L1 acquisition. Working memory capacity is thought to be more needed during L2 use and acquisition, which puts additional strain on the system and reduces acquisition speed and quality.

Weisheimer and Mota (2011) attempted to analyze the relationship between the working memory capacity and speech production in L2 and verify if there exists a difference between the individuals with lower and higher spans. They utilized a longitudinal research method to attempt to verify any changes in working memory capacity during speech development. The authors analyzed speech samples from fifty-five undergraduate bilingual participants in terms of accuracy, fluency, weighted lexical density and complexity all of which showed an increase in scores for lower as well as higher-span participants within the test phases. The working memory which was assessed by a speaking span test in L2 was found to be increased in lower-span participants but not in higher-span individuals. The authors have attributed this to the attention–view of working memory capacity. According to this perspective, working memory capacity is seen as a domain-general ability crucial for performing higher-level cognitive tasks. Individuals with higher working memory span likely demonstrated greater proficiency in attentional control during the first experiment and showed skill in employing strategies for encoding and retrieving information from memory. On the other hand, people with shorter working memory span seemed to have greater room for growth in terms of both general and specialized working memory capacity. Over time, those with higher working memory spans tended to develop more complex speech, indicating their enhanced ability to restructure, organize, and elaborate language. In contrast, the speech development of individuals with lower working memory spans appeared to be more influenced by the acquisition and use of less common words. This study demonstrates working memory's active involvement in the continuous development of L2 speech abilities, expanding on our understanding of its traditional position as a predictor of L2 speech performance.

2.1.2 PWM in foreign language learning – In multilinguals

Phonological working memory capacity has been studied closely in multilingual individuals. It has often been attributed as a cognitive process that influences language proficiency in multilinguals as well as a product of language learning in individuals who have learned or acquired multiple languages.

An integrative review by Hirosh and Degani (2017) on studies investigating the differences between multilingual and monolingual speakers in their ability to learn a new language has identified few underlying cognitive processes and categorizes them as having a direct or indirect effect on the observed multilingual advantage. The transfer of knowledge and the representation from previously learned languages and the execution of learned strategies and skills are proposed to be the direct effects on the different aspects of linguistic knowledge such as grammar, phonology, word learning, and literacy. This review has identified several linguistic and non-linguistic cognitive factors which include verbal and nonverbal working memory as exerting an indirect effect on foreign language learning.

Biedron and Szczepaniak (2012) in their comparison of the performance of accomplished multilinguals (Polish-German-French) and philology students (monolingual Polish speakers who learn English as a foreign language), in short-term memory tasks and working memory tasks, revealed that the performance of accomplished multilinguals was higher than that by the mainstream philology students. In addition, the most difference was observed in the tasks that had linguistic materials. Given that they had higher performance in all of the memory tests, the authors suggested that both the phonological loop and the executive center had important factors in determining the outcome of SLA. The study could not conclude if the observed greater WM capacity caused the multilingual advantage or if it resulted from the language learning experience.

Along similar lines, the study by Papagno and Vallar (1995) also showed a close association between phonological working memory and foreign language acquisition. In comparing Italian polyglots (who were fluent in 3 or more languages) and non-polyglots (who studied one foreign language) on tests of general intelligence, vocabulary knowledge, visuospatial and verbal long-term and short-term memory in their native language and paired associate learning of new words and words, the researchers found a greater performance level in polyglots in phonological short term memory tests as assessing using nonword repetition test and auditory digit span test. The two groups were comparable in their general intelligence, knowledge of native vocabulary, and performance in visuospatial memory tasks. The polyglots were also capable of learning more new words than the non-polyglots reflecting their ability in vocabulary acquisition. They have also identified phonological lexical knowledge, an advantage possessed by polyglots, also contributes to their ability to acquire new words in a foreign language. The authors conclude that the level of foreign language acquisition can be predicted by performance in phonological STM.

Cockcroft et al (2017) studied the multilingual advantage in components of working memory namely verbal processing, verbal storage, visuospatial processing, and visuospatial storage. The researchers found the strongest effect of multilingualism on processing-loaded working memory tasks and less strong finding for verbal storage which was evaluated using the Digit span test and visuospatial storage as assessed by the Block recall task. The monolingual English young adult speakers showed better performance in Nonword Recall in English than the age-matched multilingual participants who had poorer proficiency in English. In spite of lower socioeconomic status and poorer verbal abilities of the multilinguals, the multilingual advantage was apparent in all working memory tests and no disadvantage in comparison to monolingual participants was exhibited. This advantage has been concluded to be reflective of a general cognitive control process.

Bouffier et al (2020), investigated the association between language proficiency, working memory and attention in multilingual adults. In line with previous findings, this study showed a moderate to strong degree of association between language proficiency and verbal working memory. The association was greatest for the L3 whose learning was still in progress while L1 and L2 showed slightly lesser association. On the other hand, no significant association between attentional abilities, both auditory and visuospatial, and language proficiency was obtained. This difference in association has been assumed to be because of the fact that the L3 (French) belongs to a language family that is different from that of L1 and L2, both of which are part of the same group. The lack of robust evidence of the role of attentional abilities presents an argument against the ‘bilingual cognitive advantage’. According to this hypothesis, an association between the more general executive functions and L2/L3 proficiency would be expected. However, in this study that was not the case. An additional finding from this investigation revealed a robust correlation between the verbal working memory measures and auditory attention abilities, but not between the visuospatial attention and verbal WM measures.

Of particular interest in the present study is the phonology of multilinguals. Individual differences have been observed in the phonology of L2 learners. This has been attributed to several causes among which are cognitive factors such as working memory and attention. A greater working memory capacity may provide students more time to process and learn from the input by allowing them to have longer access to it and improved storage quality may support more accurate perception and learning, and (Goldstone, 1998). Additionally, research suggests that these cognitive variables affect L2 phonological processing and speech in addition to phonological acquisition (Aliaga-Garcia et al., 2011; Bundgaard-Nielsen et al., 2011; Darcy et al., 2014; Lev-Ari & Peperkamp, 2013; Safronova & Mora, 2012). To understand the links between cognitive abilities and L2 phonological processing, Darcy et al (2015), subjected English monolingual and Korean – English Bilingual participants to a wide range of tasks. The working memory capacity was assessed using an array of tests including forward digit span, backward digit span, forward nonword recall, and backward nonword recall tasks. These were completed in the L1 and L2. The participant's performance in various phonological tasks was calculated to compute an overall phonological score. The results indicated that the variable most strongly associated with the total phonological score appears to be the L2 complex span. Three primary and statistically significant relationships between L2 working memory, L2 complex span, and L2 storage capacity and phonological processing scores were found in the study. These findings suggest that those who have larger working memory capacities and, to some extent, faster processing speeds, have more phonological processing skills in their second language (L2) that are comparable to those of native speakers.

2.2 PWM in Speech production and perception

2.2.1 Role of PWM in Speech perception

Various researchers have attempted to examine the potential influence of phonological working memory capacity in the phonological perception of L2 in bilinguals.

The recognition of English vowels by Italian-English bilinguals with differing levels of ability and linguistic experience was studied by Mackey et al (2001). The percentage of errors in the categorization of English consonants in word-initial and word-final positions was found to have a strong negative connection with nonword repetition scores. According to the authors' conclusion, individual variations in PWM, tap skills that are essential to create long-term memory representations of phonetic segments. This study offered some preliminary evidence that the perception of L2 consonants may be influenced by individual differences in PSTM.

According to Crevino-Povedano and Mora's perceptual studies (2011, 2015), phonological working memory is crucial for L2 learners to build target-like cue-weighting. Participants in the vowel perceptual classification task of /iː/ - /ɪ/ were Catalan/Spanish speakers of English and Spanish EFL learners. The classification of /iː/ - /ɪ/ was found to be significantly impacted by PSTM, according to the study. Compared to the low PSTM group, the high PSTM group exhibited considerably higher classification accuracy for both artificial and natural stimuli. Learners exhibiting higher Phonological Short-Term Memory (PSTM) may gain an advantage over those with lower PSTM in leveraging more difficult or less readily available cues during the categorization of L2 vowels.

In contrast to the earlier study, findings from Safronova and Mota (2015) indicate that there was no significant disparity between low and high-ability groups in achieving target-like cue-weightage for L2 perception. This observation persisted despite the higher Phonological Short-Term Memory (PSTM) group demonstrating superior performance in word identification tasks, which assess perceptual phonological competence.

Jacquemot and Scott (2006) in their study, proposed the high chance of involvement of the phonological working memory model posited by Baddeley (2003), in the speech acquisition process. Given its function in the short-term processing of phonological input, the phonological store may overlap with speech perception, according to Jacquemot and Scott (2006), whereas the subvocal rehearsal mechanism may overlap with the speech production system.

2.2.2 Role of PWM in Speech Production

Although there is a strong suggestion that phonological memory processes and speech production are closely related, especially in the preschool years, very little research has looked into the potential contributions of phonological working memory (PWM) and phonological short-term memory (PSTM) to speech output (Gathercole & Adams, 1993). A possible reason is the lack of any direct associations between language production and short-term memory in skilled adults. This does not, however, exclude its role in language-learning children. In adults, speech production is an automatic process placing less demands on the controlled processing. This means that adults have a specialized speech output buffer that is not dependent on the general-purpose working memory buffer. In contrast, children's speech output is slow, effortful, prone to errors, and unpracticed indicative of a language development process that is undergoing automatization. According to Bock's (1982) theory of speech production, lower-level processes like articulation and word generation may be particularly susceptible to the shift from controlled to automatic processing. Considering that young children do not produce speech automatically as adults do, the working memory plays a crucial role in early childhood speech acquisition due to the effortful nature of the process of speech production in young children

According to research by Adams and Gathercole (1995), preschoolers with typically developing language skills and lower phonological memory scores on tests like the audition digit span task and non-word repetition (NWR) tend to make more speech errors than their peers with higher phonological memory scores.

According to Waring et al (2019), PWM maybe useful in predicting speech accuracy in preschoolers with typical development. In their study, the researchers found that better PWM abilities were observed in children who had typical speech production skills and a percentage consonant correct (PCC) score above 12 than those with typical speech production skills with PCC scores between 8 and 11. PWM accounted for a 5.3% variance in overall phonological accuracy. They propose that higher PWM ability, independent of auditory discrimination ability, chronologicalage, and vocabulary size, is linked to higher accuracy in speech output. The authors hypothesized that manipulating the phonological information in working memory can facilitate sound change. A possible alternative is that early variation in a child's speech output can lead to differences in later PWM capabilities i.e., an accurate output can influence subvocal rehearsal and storage which in turn leads to more accurate and faster mental manipulation of phonological information. Furthermore, the existence of a reciprocal or bi-directional relationship between speech accuracy and PWM has been postulated. This view is supported by studies that compare children who have acquired L2 at an older age to those who are exposed to one or more languages from birth.

Verbal short-term memory in children with speech sound disorder (SSD) compared to typically developing (TD) children has been the subject of several investigations (Lewis et al., 2006; Shriberg et al., 2009; Tkach et al., 2011).

By measuring the speech sound disorder (SSD) population's short-term capacity using forward-digit span task performance, multiple researchers have discovered lower short-term capacity. Using non-word repetition tasks, a significant amount of additional evidence has been discovered. Even in cases when articulation is regulated, children with SSD regularly demonstrate lower accuracy in non-word repetition than TD children (Lewis et al., 2011; Munson et al., 2005; Shriberg et al., 2009). These findings might point to a WM deficiency that would impair kids' capacity to organize and process phonological input.

Lewis et al (2011) in an attempt to examine the endophenotypes that can distinguish the subtypes of SSD namely SSD alone, SSD with language impairment, and Childhood Apraxia of Speech (CAS). One among the five endophenotypes was phonological memory measured using nonword repetition, sentence imitation and digit span test. In the study, phonological memory was identified to be associated with all three categories of SSD, the presence of comorbidities, and the severity of speech sound disorder. These results support the view that poor ability to hold speech sounds in memory will cause the formation of inaccurate and less robust phonological representations.

Neuroimaging support for PWM deficits in those with SSD has been demonstrated by Tkach et al (2011), using functional Magnetic Resonance Imaging (fMRI). The fMRI experiment was carried out using an overt NWR task in adolescents who had a history of SSD and in the control group. The study reports hypoactivation in the right inferior frontal gyrus (IFG) and right superior temporal gyrus (STG) which have been implicated in maintenance, storage, and encoding processes that subserve verbal WM and speech perception respectively (Chen & Desmond, 2005; Chein & Fiez, 2001; Hickok & Poeppel, 2004; Indefrey & Levelt, 2004). Therefore, the functional integrity of the phonological loop has been affected in these individuals. Other brain regions namely pre and post-supplementary motor areas, supramarginal gyrus, inferior parietal, and cerebellum have shown hyperactivity bilaterally which is a possible indication of increased cognitive effort and a compensatory reliance on other parts of the articulatory rehearsal network and phonological store.

In their exploratory study to understand the domain-general processes underlying adult-like productions of speech sounds in preschoolers, Torrington-Eaton and Ratner (2016) compared Executive Functions (EF) profiles of preschoolers with SSD, low-average, high-average profiles using tasks tapping cognitive flexibility, inhibitory control and working memory. The results identified inhibitory control and working memory as the cognitive processes used by preschoolers to perform the tasks. Concerning working memory, the study demonstrated a significant association between forward digit span and speech accuracy suggesting the importance of short-term memory in storing accurate production models. In the absence of appropriate production models, accuracy is difficult to achieve. The PWM's mental manipulation component is another component with a role in speech sound change. Mental manipulation involves isolating discrepancies between the child’s speech productions and the mature target representations, subsequently updating or overwriting of phonological rules. Thus, they postulate that PWM might be involved in resolving error patterns of early-developing sound prior to execution, resulting in target speech production that is adult-like. Theoretically, a child's capacity to identify discrepancies between one’s own production and the adult target representation after internal feedback and/or external and internal self-monitoring may depend on their PWM skills i.e., a child perceiving adult speech may “hold on” to the adult production in the phonological working memory and compare it with their own phonological representation through internal feedback. Following this, the realization rule(s) are updated and this leads to more adult-like speech production and accuracy. Therefore, speech sound change could theoretically be impacted by a less developed PWM capacity.

2.2.3 Role of PWM in multilinguals

The role of phonological working memory in the speech and language development in multilinguals is less studied. Moreover, within the larger context of multilingualism, acquisition of multilingual phonology is frequently referred to as a less developed area of study.

To examine phonological working memory’s role as a crucial predictor in the acquisition of phonology in a new language, Polish researchers Krzysik and Wrembel (2019), carried out an experiment where phonological working memory and speech accuracy were measured in multilingual adolescents (mean age of 12.6) who were native speakers of Polish and acquiring English as L2 and German as L3. The PWM was measured using a nonword repetition task in Polish (L1) and speech accuracy was measured from a delayed repetition task in L2 and L3. They hypothesized that higher scores of phonological working memory (measured through NWR) are associated with higher accuracy of production indicating more target-like phonological representation.

The results demonstrated a moderate positive relationship (r=0.41) between NWR scores and global accuracy scores. However, a significant relationship was not identified between PWM measure and accuracy in L2 and L3 separately. speech perception which was measured through a non-word repetition task and speech production which was measured through delayed repetition in L2 and L3. This finding suggests that an increased memory capacity could facilitate the formation of more precise phonological categories in multilingual speech production. Consequently, these results imply that phonological working memory is instrumental in the identification and representation of phonological features in multilingual individuals.

While most studies were aimed at investigating the contribution of working memory in linguistic skills and learning capacity of adult foreign language learners, studies on the development of phonological working memory in multilingual children are underdeveloped.

The findings put forward by the studies on the list suggests that PWM is associated with multiple facets of bilingual and multilingual language production and processing. Furthermore, variations in PWM capability between individuals may potentially predict language development to some extent in the area of bilingual or multilingual phonology. However to map the possible patterns of interaction between PWM capacity levels and phonological accuracy, more empirical data is needed.

2.3 Use of Non-Word Repetition Task

During the repetition of non-words, individuals are required to perceive, store and retrieve the phonological units/sounds in the exact sequential order presented. This task has been showed to be highly corelated to various language measures in both typically and atypically developing children.

Adams and Gathercole (1995) conducted a study to examine the association between phonological memory and oral language development in a sample of 38 children with typical language abilities, aged between 2 years and 10 months and 3 years and 1 month. The participants were categorized into groups with high and low phonological memory capacity. The findings indicated that children with superior non-word repetition skills, representing the high-phonological memory group, demonstrated the ability to construct longer and more syntactically complex sentences compared to their counterparts in the low-phonological memory group.

Building on their prior work, Adams and Gathercole (2000) delved deeper into the influence of phonological working memory on grammatical development. They recruited two groups of 15 children (aged 4.6-5.0 years) with typical language abilities, matched on nonverbal IQ but exhibiting varying non-word repetition skills. The study revealed a positive correlation, where children with stronger non-word repetition, indicative of robust phonological working memory, produced sentences with greater grammatical complexity and utilized a more diverse lexicon compared to their counterparts with weaker phonological working memory. This aligns with the predominant research focus in this domain, which explores the link between phonological working memory and vocabulary acquisition.

The influence of existing vocabulary knowledge and learned sound patterns on nonword repetition has also been explored in several studies. A review of the literature suggests a positive correlation between repetition accuracy and a nonword's similarity to known lexical entries. Bowey's (2001) research supports this notion, demonstrating that “any manipulation that increases phonological complexity decreases nonword repetition performance” (p.443). Numerous techniques have been used by researchers to manipulate phonological complexity, such as comparing nonwords with and without consonant clusters, utilising adult judgements of word-likeness, and changing the frequency of individual segments or combinations, embedded real words, attested consonant sequences, and embedded real words. All of these factors are connected and can be explained as a whole by phonotactics, which is the body of rules defining acceptable sound sequences in a given language.

Moreover, repetition of non-words is a simple task that can be performed without much difficulty by young children. This task can reflect possible underlying deficits in cognitive processes such as long-term word knowledge, working memory or phonological memory (Gathercole, 1995) and therefore is a potential indicator of phonological working memory even in young preschool children. The non-word repetition task is reported to be informative about children's linguistic processing and representations.

Nonword Repetition (NWR) has been used to study language and learning difficulties in various populations of children, including those with Specific Language Impairment (SLI), reading problems, articulation disorders, Williams syndrome, Down syndrome, lead exposure, cochlear implants, and fluency disorders.

A study by Prema et al. (2010) investigated the use of Nonword Repetition (NWR) as a potential marker for identifying children with Specific Language Impairment (SLI) in Kannada. They compared the performance of a child with SLI to a typically developing child matched for age and other factors. The results showed lower accuracy (46.6%) in nonword repetition for the child with SLI compared to the typically developing child (93.3%). Notably, the child with SLI consistently produced error patterns such as devoicing, additions, liquid gliding and omission and backing, a phonological process not observed in typically developing children. Thus, they suggested that NWR might be a useful tool for SLI assessment in Kannada, but further research with larger samples is needed.

Another study in the Indian context was conducted by Shylaja and Swapna (2010) who compared non-word repetition (NWR) abilities in Kannada-speaking children with delayed language (DLD) to typically developing children, all matched on language age (3-4 years old). The results showed that children with DLD had lower NWR accuracy than typically developing children and that the accuracy decreased with word length for both groups with 4 and 5-syllable words better distinguishing DLD performance. This study proposed NWR, particularly with longer words, as a helpful method for assessing phonological working memory deficits in Kannada-speaking children with DLD.

Apart from SLI, several studies have iterated the reduced ability of those with SSD to produce NWR. Munson et al. (2005) compared how children with Phonological Disorders (PD) and typically developing children repeated nonwords with varying sound sequence frequencies. Both groups performed better with high-frequency sequences, but children with PD were less accurate overall. Interestingly, the PD group didn't struggle more with low-frequency sequences compared to their peers. The study also found a link between vocabulary size and the size of the frequency effect (better vocabulary meant less difference between low and hugh frequency performance). This suggests that vocabulary growth, not speech perception or articulation, plays a bigger role in processing unfamiliar sound sequences. Finally, the researchers propose that production difficulties in children with PD might stem from problems building strong representations of sounds used in speech, rather than difficulties with abstracting sounds from existing words.

2.4 Multilingual phonology

Despite the growing recognition of multilingualism as a legitimate field of research in linguistics over the past three decades (Gut, 2010; Garcia-Mayo, 2012; Klein, 1995; Wrembel et al., 2019), a research gap persists within the domain of L3 acquisition. While a substantial body of experimental and theoretical work exists for L3 morphosyntax and lexicon (Gut, 2010; Wrembel et al., 2019), the area of L3 phonology and phonetics has received comparatively less attention. Notably, amongst the various L3 acquisition models, only the Phonological Permeability Hypothesis proposed by Cabrelli Amaro and Rothman (2010) specifically targets the under-researched area of L3 phonological acquisition.

Among existing models of L3 acquisition, only the Phonological Permeability Hypothesis (PPH) by Cabrelli Amaro and Rothman (2010) specifically addresses L3 phonological acquisition. Only the Phonological Permeability Hypothesis (PPH) by Cabrelli Amaro and Rothman (2010) explicitly addresses L3 phonological acquisition among the models of L3 acquisition that are currently in use. According to the PPH, the influence of a third language (L3) is more likely to affect the second language (L2) than the first language (L1) when the second language (L2) is learned after the critical period, or before puberty. The different cognitive representations of L1 and L2 are thought to be the cause of this (Cabrelli Amaro & Rothman, 2010; Luo et al., 2020). As per Candrelli Amaro (2016), p. 699, the PPH states that "even an ostensibly native-like L2 is more vulnerable to L3 influence than an L1".

The PPH emphasizes the significance of the age of L3 acquisition (AOA) in phonological acquisition. However, the hypothesis does not provide specific predictions regarding how multilingual speakers perceive and produce speech sounds.

Instead, it focuses on the general direction of cross-linguistic influence (Luo et al., 2020).

In light of the PPH, the increased permeability of the L2 to L3 influence may be explained by differences in stability between the L1 and L2 systems. This leads to the hypothesis that the L1, which is still developing in younger speakers, may be more vulnerable to regressive cross-linguistic influence (CLI) from any additional language than the L1 of adults. This hypothesis is supported by evidence indicating that L1 continues to develop throughout childhood and into puberty (Bent 2015; Hazan and Barrett 2000; Johnson 2000).

Wang and Nance (2023) have reviewed the available experimental and theoretical studies on sequential third language (L3) acquisition to understand its implications and lay the groundwork for future research in L3 phonology. The earliest studies in multilingual phonology began nearly five decades ago with the works of Chamot (1973), Rivers (1979), and Singh and Carroll (1979). Subsequent significant developments, such as Sharwood-Smith and Kellerman's (1986) research on cross-linguistic influence and the diary studies by Williams and Hammarberg (1998), spurred further academic interest and systematic research in this field.

Wang and Nance (2023) reviewed previous research and found multiple characteristics that support cross-linguistic transmission in L3 phonology. Wrembel (2010) states that in the beginning of L3 phonological acquisition, there is a higher transfer from a second language (L2) than from a first language (L1). However, when L3 experience rises, the impact of L2 on L3 phonological acquisition diminishes (Hammarberg, 2001; Wrembel, 2010; Luo, Li, & Mok, 2020).

Studies suggest that increased experience with a third language (L3) can improve sound discrimination, particularly in the initial stages of learning (Luo et al., 2020). Luo et al (2020) investigated this effect by comparing the perception of Cantonese vowels among speakers with different levels of L3 experience (Mandarin L1, English L2, Cantonese L3). Their findings revealed a rapid increase in perceptual accuracy for contrastive Cantonese vowel pairs among multilingual participants during the early stages of L3 acquisition. However, the study did not find a significant benefit of further exposure on perceptual accuracy at later stages.

Furthermore, research by Cal and Sypiańska (2020) suggests that proficiency levels in both L2 and L3 influence L3 acquisition. They found that lower proficiency in either language can lead to the more proficient language exerting a stronger influence on L3 phonological categories. Additionally, the interaction between L2 and L3 proficiency levels (L2LoP and L3LoP) can impact L3 production. For example, Cal and Sypiańska (2020) observed that the first formant value of a Spanish vowel in their study fell between the values characteristic of L2 English and L3 Spanish vowels. This review has highlighted a bias in participant selection within the existing body of L3 phonological acquisition research. The majority of studies have focused on participants who are undergraduates or older adults (e.g., Llama et al., 2010; Luo et al., 2020), with limited investigation into children and adolescents. In terms of age of acquisition, few studies have included participants who acquired their L3 before the age of 18. Furthermore, research often employs participants who have only recently begun learning their L3 (e.g., Liu & Lin., 2021; Onishi, 2016). Studies investigating learners with extended L3 learning periods (e.g., around ten years in Zhang & Levis, 2021) are less prevalent. This focus on recent learners creates a gap in understanding the impact of sustained exposure on L3 phonological acquisition. Additionally, the intensity of L3 instruction and the language proficiency of participants vary considerably across existing studies, making it difficult to draw definitive conclusions about the L3 learning process.

A notable limitation identified in this review is the bias towards Indo-European languages, particularly Germanic and Romance languages (e.g., English, German, French, Portuguese, Spanish,) as target languages (L3) in L3 phonological research. Non-Indo-European languages are far less frequent in this domain, with some exceptions including Arabic (Benrabah, 1991; reanalyzed in Archibald, 2022), Mandarin Chinese (Gabriel et al., 2016), and Japanese (Tremblay, 2007).

Furthermore, the review highlights a focus on segmental properties within L3 phonology and phonetics studies. These studies primarily investigate either acoustic measurements like voice onset time (VOT) or vowel formants. Suprasegmental features, on the other hand, have received less attention. Previous research on suprasegmental features in L3 acquisition has explored aspects such as vowel neutralization (Gut, 2010), word stress (Louriz, 2007), and vowel reduction (Cabrelli Amaro, 2013, 2016; Cabrelli Amaro & Wrembel, 2016), speech rhythm (Gabriel et al., 2015).

Based on this review, it is evident that expanding the research scope and timescale is crucial. This expansion should encompass greater linguistic diversity, a wider range of participant ages and educational backgrounds, and a more comprehensive examination of the learning process itself. The review underscores the scarcity of research in this field and emphasizes the need for expansion in terms of research areas and methodologies employed. Additionally, it highlights the numerous variables that can potentially confound current research findings, thus limiting the generalizability of results.

CHAPTER III

METHOD

The present study aimed at understanding the relationship between phonological working memory and speech production in bilingual and trilingual school-going children. A cross-sectional research method was used for the study.

3.1 Participants

A total of 60 participants were included in the study. They were divided into four groups. Group I had 15 participants who were Tamil – English Bilinguals, Group II had 15 participants who were Tamil-English Bilinguals between age group of 10-12, Group III included 15 6–8-year-old participants who were Tamil - English - Hindi Trilinguals and Group IV included 15 Tamil-English-Hindi Trilingual participants in the age range of 10-12 years.

All of the participants were native speakers of Tamil who were exposed to English as the medium of instruction at school. The participants in the trilingual group (Groups III and IV) additionally learned Hindi at school. The participants were recruited from CBSC and State board syllabus schools where Hindi is a part of the curriculum. Language proficiency in L2 and L3 was estimated using the Teacher Questionnaire of the language use questionnaire (Shanbal JC, 2010). Based on the score obtained, the participants were classified as being high proficient (rating of 3 or 4) or low proficient (rating of 1 or 2). The teacher's opinion of the participant’s proficiency will also be considered along with the scores. This was done so that the groups were balanced for language proficiency.

Other inclusion criteria considered were:

1. Typically developing children with normal speech and language skills
2. Academic performance in the previous year being more than 70%
3. No history of speech, language, cognitive or academic difficulties
4. No history of frequent middle ear infections or reported hearing loss
5. Normal visual acuity or corrected vision
6. No other neurological deficits or structural anomalies

3.2 Stimuli

The phonological working memory was tested using a list of non-words in L1 (Tamil). For preparing the non-words, age-appropriate meaningful Tamil words were selected from textbooks and dictionary. The non-words will be prepared using UniPseudo (http://www.lexique.org/?page_id=582) an algorithm for generating non-words from a customizable database that is provided by the user. Using phonological or orthographic forms of the input or any other string representation in any language, the algorithm produces pseudowords in that language. UniPseudo uses an algorithm that is based on Markov chains. The non-words will be recorded by native Tamil speakers and presented in order of increasingsyllable length from 2 syllables to 5 syllables.

The speech production was tested using a delayed word repetition task with separate word lists for L2 (English) and L3 (Hindi). The target features in each task are determined by the contrast in the phonological systems of the three languages i.e., the word list will contain words having target features that are exclusive to that language. The List 1 included English words with phoneme /z/ in the initial, medial, and final positions. List 2 included words in Hindi with aspirated stops in different word positions (Narasimharao, Jaswal & Koshal, 1976). The stimuli are recorded by native speakers. All the target words that are recorded will begin with a carrier phrase – "This is ………" followed by "What is this?" This was done to introduce the delay in repetition.

A list of words and non-words were made for each task. The final list will be prepared based on the agreement task. Three Linguists served as judges for both agreement tasks i.e., non-word repetition and production tasks to prepare the final list of 20 words and non-words. The agreement criteria will be 75% and above to decide the non-word and word list for the respective tasks.

Separate lists were prepared for the younger and older age groups for the NWR and Hindi word repetition tasks, however, the same list was used for both age groups for the English word repetition task.

3.3 Procedure

Participants are subjected to two tasks – a non-word repetition task (for measuring phonological working memory) and a production task (for measuring speech accuracy).

Task 1: Non-word repetition task

For the non-word repetition task, the recorded non-word stimuli were presented using headphones at a comfortable level of listening in a quiet environment. The stimuli were presented in increasing order of difficulty (from two-syllable to five-syllable). The participants were instructed to repeat the words they heard as accurately as possible. The participant responses were then audio-recorded. The responses were then transcribed using IPA (International Phonetic Alphabet, 2015). The accuracy of responses were rated on a 3-point scale. A rating of “2” was given for 100% accuracy in repetition, a rating of ‘1’ was given for ≥50% accuracy in the repetition of the stimuli, while a rating of ‘0’ was given for <50% accuracy in the response.

Task 2: Production task

For production tasks, L2 and L3 production ability was measured using delayed repetition tasks separately for each language. The delayed repetition was used to avoid the risk of direct imitation. In this task, the participant’s phonological representation was checked using two subtasks. The target features in each task were determined by the contrast in the phonological systems of the three languages.

Subtask I: This subtask included target words with /z/ in the initial, medial, and final positions. The phoneme /z/ is present in English but unavailable in the Tamil phonological system.

Subtask II: This subtask includes target words with aspirated stops - /p^h/, /b^h/, /t̪^{h}/, /d̪^{h}/, /t^h/, /d^h/, /k^h/, /g^h/. These features are chosen because they occur in the phonological system of the L2 (Hindi) but not in L1 Tamil.

The recorded word lists were presented to the participants using headphones. Each participant was instructed to listen to the stimuli and repeat only the target word. 5 practice trials were conducted for the participant to be familiarized with the task. The responses were audio recorded and offline transcription was carried out. The responses were rated on a 2-point rating scale. A rating of “1” was given for accurate production of the target feature and a rating of “0” for substitution, addition, or omission errors of target features.

Ethical considerations were taken into account in carrying out the study. The data collection followed the All India Institute of Speech and Hearing, Mysore, ethical committee guidelines for Bio-behavioural Sciences for human subjects (2009). Consent was obtained from the authorities of the institutes from where the participants were recruited and from caregivers.

3.4 Instrumentation

The stimuli were recorded and presented using the Audacity® Cross-Platform Sound Editor. The stimuli were presented using headphones (boat Bass Heads 900 wired headphones). To record the responses, "Dolby On: Record Audio & Music" (version 1.8.3) app was used. Following that off-line transcription of the responses was done.

3.5 Outcome Measure

The dependent variables analyzed in the present study were the accuracy of responses in both repetition and production tasks. The accuracy of L2 and L3 production at phonemic level was measured using a 3-point rating scale in Subtask I and a 2-point rating scale in Subtask II. The rating scores were converted into percentages for statistical analysis. 20% of the overall data were subjected to intra-judge reliability.

3.6 Statistical Analysis

The independent variables for the study are age and language group. The dependent variables are the percentage of accurate production in nonword repetition task and production task. Comparisons are done within and across language and age groups based on appropriate statistical tests after the normality test

CHAPTER IV

RESULTS

The study aims to understand the relationship between phonological working memory and speech production in multilingual school-going children. A total of 60 participants across two age groups participated in the study. The participants performed two tasks namely *the nonword repetition task* and *the delayed word repetition task*. The data was tabulated and statistical analysis was carried out using the Statistical Package for the Social Sciences (SPSS) software (Version 26.0).

The results of the study are compiled as follows:

4.1 Relationship between NWR and WR in Bilingual and Trilingual Groups

4.1.1 Relationship between nonword repetition and delayed word repetition scores in L2 across language and age groups

Using descriptive statistics, the mean and standard deviation were calculated for the nonword repetition accuracy scores, delayed word repetition accuracy scores in L2, and delayed word repetition accuracy scores in L3 for each age group and language group. Table 4.1.1 depicts the descriptive statistics of NWR in all groups.

Table 4.1.1

The Results of the Accuracy Rating in the Nonword Repetition Task (NWR)

Measures	Groups			
	Bilingual 6-8 (Group I)	Bilingual 10-12 (Group II)	Trilingual 6-8 (Group III)	Trilingual 10-12 (Group IV)
Mean	70.83	85.67	75.17	85.50
Standard Deviation	7.05	6.78	11.36	5.61
Minimum	60.00	70.00	45.00	75.00
Maximum	80.00	92.50	87.50	95.00
Range	20.00	22.50	42.50	20.00

Table 4.1.1 shows the mean scores, standard deviation and range of the four participant groups in the nonword repetition task. In the bilingual 6-8 year old group (Group I), nonword repetition scores had Mean = 70.83 and Standard Deviation (SD) = 7.05. The nonword repetition scores obtained from the bilingual 10-12 year old age group (Group II) had Mean = 85.67 and SD = 6.78. In the Trilingual 6-8 year old group (Group III), nonword repetition scores yielded Mean = 75.17 and SD = 11.36. Finally, the nonword repetition scores from the Trilingual 10-12 year age group (Group IV) showed Mean = 85.50 and SD = 5.61. The participants' mean scores indicate higher scores for participants in the age group of 10-12 years in both the language groups.

Table 4.1.2 depicts the descriptive statistical measures carried out for word repetition scores in L2

Table 4.1.2

The Mean, Standard Deviation and Range Scores for L2 Production

Measures	Groups			
	Bilingual 6-8 (Group I)	Bilingual 10-12 (Group II)	Trilingual 6-8 (Group III)	Trilingual 10-12 (Group IV)
	WR1	*WR1*	*WR1*	*WR1*
Mean	49.00	70.67	58.00	74.33
Standard Deviation	13.91	16.24	18.97	9.80
Minimum	20.00	40.00	15.00	60.00
Maximum	75.00	95.00	95.00	90.00
Range	55.00	55.00	80.00	30.00

Note: WR1= delayed word repetition task in L2

Table 4.1.2 shows the mean scores, standard deviation and range of the four participant groups in delayed word repetition task in second language. The word repetition scores in L2 (WR1) measured for the bilingual 6-8 year old group (Group I) showed Mean = 49.00 and SD = 13.91. The WR1 scores for the bilingual 10-12 year old group (Group II) had Mean = 70.67 and SD = 16.24. A Mean = 58.00 and SD = 18.97 were calculated for the WR1 scores in the Trilingual 6-8 year old group (Group III). Finally, the WR1 scores from the Trilingual 10-12 year old age group (Group IV) had Mean = 74.33 and SD = 9.80. The participants' mean scores indicate higher accuracy in the production of target features for participants in the age group of 10-12 years for L2 in both the language groups.

After completing the calculation of mean, SD, and range, the Shapiro-Wilks test was conducted for the purpose of testing the normality. The test of normality revealed that the majority of the data was normally distributed. Thus, parametric tests were employed to compare the NWR and WR1 scores for all four groups.

To examine the relationship between phonological working memory and speech production, Pearson's correlation coefficient was used. Table 4.1.3 depicts the correlation between nonword repetition and delayed word repetition in L2.

Table 4.1.3

Correlation between Nonword Repetition and Delayed Word Repetition in L2

Groups	Pearson's coefficient (r)	p
Bilingual 6-8	-0.073	0.796
Bilingual 10-12	0.012	0.966
Trilingual 6-8	0.155	0.581
Trilingual 10-12	- 0.059	0.836

NWR and WR1 do not show any correlation in Groups I ($r = -0.073$), II ($r = 0.012$), and IV ($r = -0.059$). However, a low non-significant positive correlation was observed in Group III ($r=0.155$, $p > 0.05$). The results indicate a low level of correlation between nonword repetition and delayed word repetition tasks in the younger age group of Trilinguals.

4.1.2 Relationship between non-word repetition and word repetition scores in L3 in Trilinguals across age groups

The mean, standard deviation, and range were calculated for word repetition scores in L3 for both age groups of the trilingual group. The same is depicted in Table 4.1.4.

Table 4.1.4

The Mean, Standard Deviation, and Range Scores for L3 Production

Measures	Groups	
	Trilingual 6-8 (Group III)	Trilingual 10-12 (Group IV)
	WR2	*WR2*
Mean	37.67	31.00
Standard Deviation	10.15	13.65
Minimum	25.00	10.00
Maximum	60.00	55.00
Range	35.00	45.00

Note: WR2 = delayed word repetition task in L3

Table 4.1.4 shows the mean scores, standard deviation and range of the trilingual participant groups in delayed word repetition task in third language. In the Trilingual 6-8 year old group (Group III), the word repetition scores (WR2) had Mean = 37.67 and SD = 10.15. A mean = 31.00 and SD = 13.65 were calculated for the WR2 in the Trilingual 10-12 age group (Group IV). Unlike WR1 scores where participants' mean scores indicated higher accuracy in the production of target features for participants in the age group of 10-12 years for L2, in L3 no such trend was observed.

Pearson's Correlation was used to examine the relationship between nonword repetition and word repetition scores in L3 across age groups. Table 4.1.5 depicts the r and p values.

Table 4.1.5

Correlation between Nonword Repetition and Delayed Word Repetition in L3

	Pearson's coefficient	p value
Trilingual 6-8	0.073	0.795
Trilingual 10-12	- 0.485	0.067

NWR and WR2 do not show any correlation in Group III (r = 0.073) and Group IV (r = -0.485). The results indicate no correlation between the nonword repetition and delayed word repetition tasks in both age groups of Trilingual participants.

4.1.3 Comparison of non-word repetition and global word repetition scores across age groups

Table 4.1.6

The Mean, Standard Deviation and Range of Global Word Repetition (GWR) scores

Measures	Groups	
	Trilingual 6-8 (Group III)	Trilingual 10-12 (Group IV)
	GWR	*GWR*
Mean	47.83	52.67
Standard Deviation	13.16	8.53
Minimum	22.50	40.00
Maximum	77.50	70.00
Range	55.00	30.00

Table 4.1.6 shows the mean scores, standard deviation and range of the global accuracy scores for the trilingual participant groups. In Trilingual 6-8 year old group

(Group III), the word repetition scores (WR2) had Mean = 37.67 and SD = 10.15. A mean = 31.00 and SD = 13.65 were calculated for the WR2 in the Trilingual 10-12 age group (Group IV). Unlike WR1 scores where participants' mean scores indicated higher accuracy in the production of target features for participants in the age group of 10-12 years for L2, in L3 no such trend was observed.

Table 4.1.7

Correlation between Nonword Repetition and Global word repetition scores

	Pearson's coefficient	p value
Trilingual 6-8	0.140	0.619
Trilingual 10-12	- 0.422	0.117

NWR and GWR show a statistically non-significant low degree of positive correlation in Group III (r = 0.140) and a moderate level of statistically non-significant negative correlation in Group IV (r = -0.422). The results indicate low correlation between the nonword repetition and delayed word repetition tasks in the younger age group of Trilingual participants and a moderate degree of correlation between the nonword repetition and delayed word repetition tasks in the older age group of Trilingual participants.

4.2 Comparison of NWR and WR between Bilinguals and Trilinguals

4.2.1 Comparison of nonword repetition between bilingual and trilingual within each age group

To examine the difference in phonological working memory between the bilingual participants and the trilingual participants, the nonword repetition scores was compared between the bilingual and trilingual groups. For this, Two-Way ANOVA was employed.

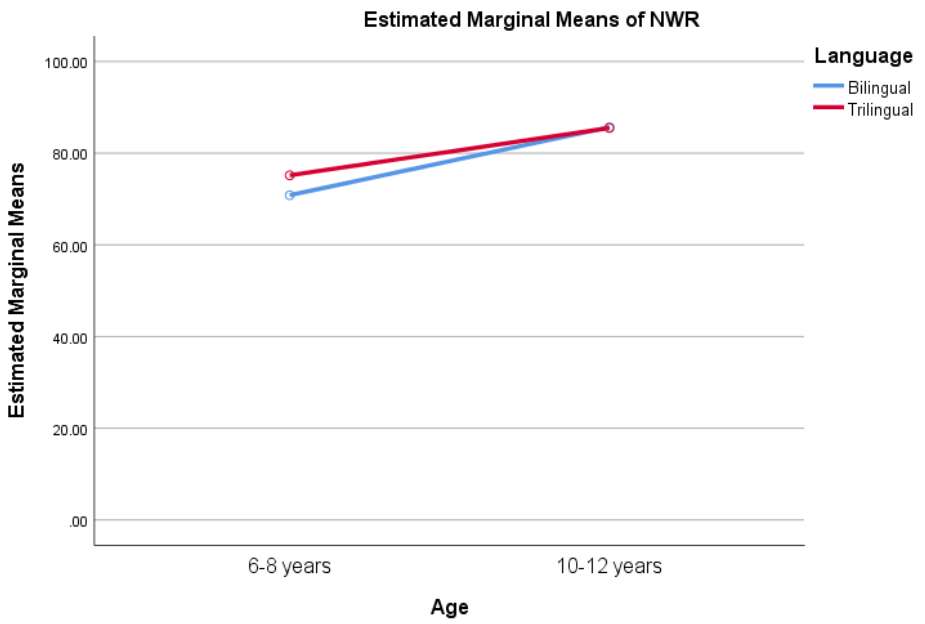
Table 4.2.1

Comparison of Nonword Repetition between Bilingual and Trilingual within each Age Group

Source	df	F	p	Partial Eta Squared
Language	1	1.017	0.318	0.018
Age	1	37.101	0.001	0.399
Language*Age	1	1.186	0.281	0.021
Error	56			

Figure 4.1

Graphical Representation of Age and Language Effect on Nonword Repetition Scores (NWR)



Two-way ANOVA was employed to analyze the effect of language group on nonword repetition scores. The test revealed that the number of languages known i.e., the language group did not have a statistically significant effect on nonword repetition scores, $F(1, 56) = 1.017$, $p = 0.318$.

4.2.2 Comparison of delayed word repetition in L2 between bilingual and trilingual within age groups

To examine the difference in speech production between the bilingual participants and the trilingual participants, the word repetition scores in L2 were compared between the bilingual and trilingual groups. For this, Two-Way ANOVA was employed.

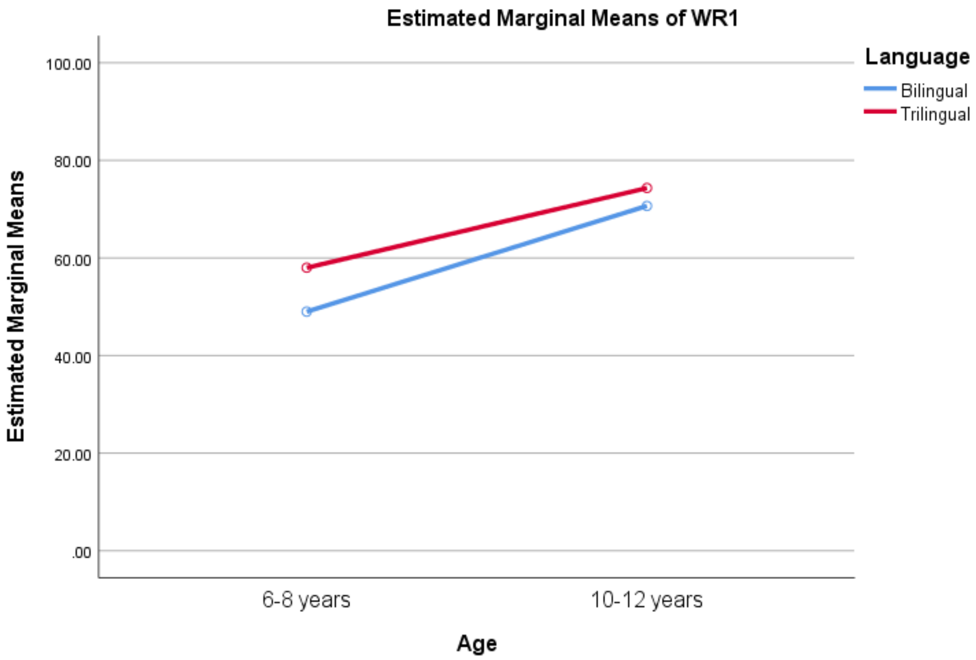
Table 4.2.2

Comparison of Word Repetition in L2 between Bilingual and Trilingual within each Age Group

Source	df	F	p	Partial Eta Squared
Language	1	2.635	0.110	0.045
Age	1	23.715	0.001	0.298
Language*Age	1	0.467	0.497	0.008
Error	56			

Figure 4.2

Graphical Representation of Age and Language effect on Word Repetition Scores in L2 (WR1)



A Two-way ANOVA was employed to analyze the effect of language group on word repetition scores in the second language (L2). The test revealed that the number of languages known i.e., the language group did not have a statistically significant effect $F(1, 56) = 2.635$, $p = 0.110$ on nonword repetition scores.

4.3 Comparison of NWR and WR between age groups

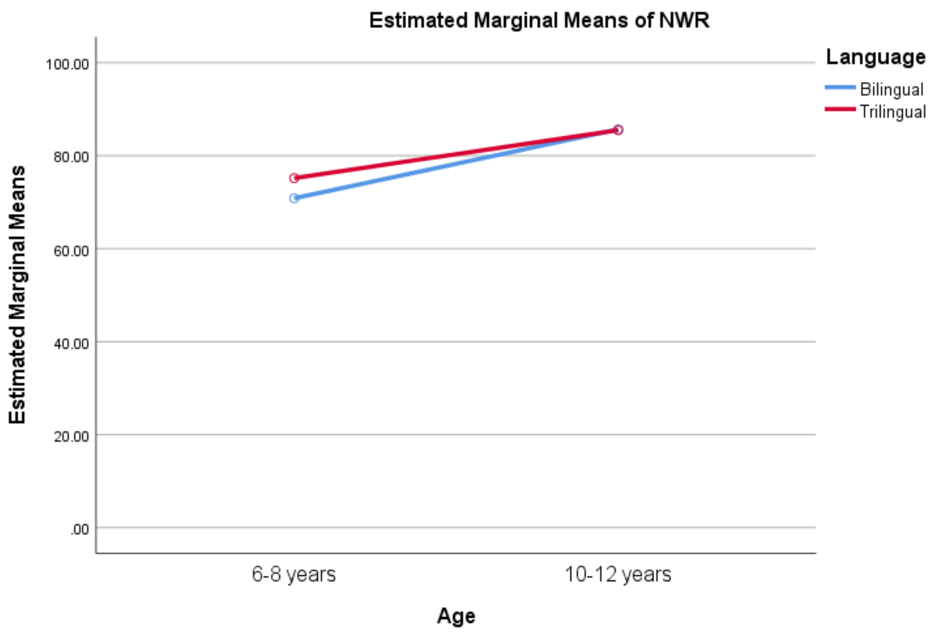
4.3.1 Comparison of nonword repetition between 6-8 year olds and 10-12 year olds across language group

The effect of age on phonological working memory across language groups was examined by comparing the nonword repetition scores of the lower age group with those of the older age group. Two-Way ANOVA test was employed for the comparison.

Using Two-way ANOVA test, the effect of age on nonword repetition scores was analyzed. The test revealed that age had a statistically significant effect $F(1, 56) = 37.101$, $p \leq 0.001$ on nonword repetition scores as shown in Table 4.2.1**.** In the two-way ANOVA test, no significant interaction between language and age was observed.

Figure 4.3

Graphical Representation of Age and Language Effect on Nonword Repetition Scores (NWR)



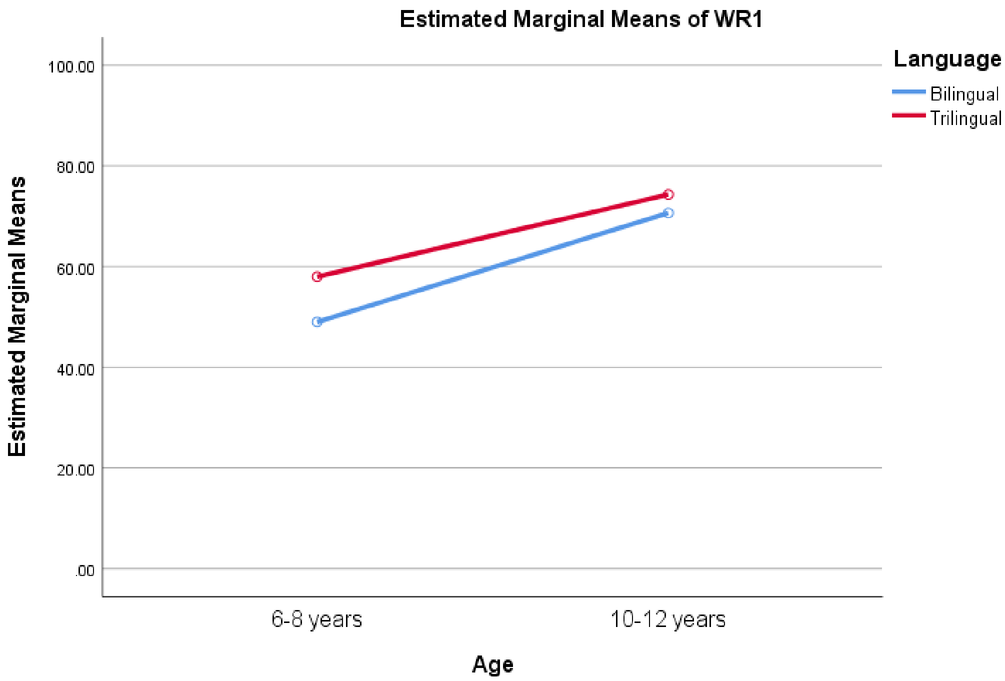
4.3.2 Comparison of word repetition in L2 (WR1) between 6-8 years and 10-12 years

Comparison between the word repetition scores in L2 of the lower age group with that of the older age group was carried out to examine the effect of age on speech production in bilinguals and trilinguals. For this, the Two-way ANOVA test was employed.

Using Two-way ANOVA test, the effect of age on word repetition scores in participant's second language was analyzed. The test revealed that age had a statistically significant effect F(1, 56) = 23.715, p = 0.001 on nonword repetition scores as shown in Table 4.2.2. In the two-way ANOVA test, no significant interaction between language and age was observed.

Figure 4.4

Graphical Representation of Age and Language Effect on Word Repetition Scores in L2 (WR1)



4.3.2 Comparison of word repetition in L3 (WR2) between 6-8 years and 10-12 years in the Trilingual group

Comparison between the word repetition scores in L3 of the lower age group with that of the older age group was carried out to examine the effect of age on speech production in trilinguals. For this, the independent t-test was employed.

Table 4.3.1

Comparison of Word Repetition in L3 between 6-8 years and 10-12 years in the Trilingual group

Language Group	**Independent t-test**	
	t	p
Trilingual	1.517	0.14

Comparison of delayed word repetition task in L3 in 6-8 year olds and 10-12 year olds was carried out using the Independent t-test. This was employed only for the Trilingual group (Group III and Group IV). The results show no significant difference (p=0.140) between the two age groups. Thus, no statistically significant age effect was observed for performance in the delayed word repetition task.

Intra-judge reliability

Twenty percent of the data was subjected to intra-judge reliability. Cronbach's alpha was used as depicted in Table 4.4.1. From Table 4.4.1 it can be concluded that high intra-judge reliability was obtained for nonword repetition, word repetition in L2 and word repetition in L3.

Table 4.4.1

Intra-judge Reliability Scores for NWR, WR1 and WR2

Dependent Variables	**Cronbach's Alpha**
NWR	0.982
WR1	0.968
WR2	0.932

The results revealed a high intra-judge reliability for NWR, WR1 and WR2.

CHAPTER V

DISCUSSION

The primary aim of the study was to identify the presence of a potential relationship between phonological working memory and speech production accuracy in non-native languages. The study also aimed to understand the possible difference in the PWM capacity between bilinguals and trilinguals. Another objective of the study was to identify a possible age effect on the phonological working memory and speech production accuracy in bilinguals and trilinguals. The study included 60 participants who were native Tamil speakers above 6 years of age. They were divided into four groups based on the number of languages known (Bilingual, Trilingual) and age (6-8 years and 10-12 years). The phonological working memory of the participants was measured using nonword repetition task in their native language – Tamil. The groups were then subjected to a delayed word repetition task in their non-native language(s). The responses in both tasks were measured as accuracy scores in terms of percentages. Since the data passed the Shapiro-Wilks test with $p>0.005$, parametric tests were employed. Pearson's correlation, Two-way ANOVA, and Independent t-test were used to analyze data across language and age.

5.1 Relationship between PWM and Speech Production in Bilingual and Trilingual Groups

The study aimed to find a potential correlation between phonological working memory and speech production accuracy scores in non-native languages. Data analysis revealed that there was no statistically significant correlation between PWM and second language production accuracy (WR1 scores) in the bilingual group and trilingual group. No statistically significant relationship was observed between PWM and speech production accuracy for the third language (WR2 scores) in Trilinguals. The results from the study revealed no statistically significant correlation between nonword repetition scores and global word repetition scores for the trilingual group.

The results for accuracy in L2 and in L3 are similar to that of Krzysik and Wrembel (2019). In their study, the authors revealed that the correlation between NWR and L2 (German) and L3 (English) languages treated separately was not statistically significant. However, the study did show a statistically significant moderate positive relationship between the phonological working memory and speech accuracy in L2 and L3 combined which was not replicated in the current study.

The reason for disparate findings can be accounted for by the difference in the nature of participants and the languages considered. Phonological memory performance is impacted by language-specific phonological knowledge (Jusczyk et al., 1994; Messer et al., 2010; Thorn & Frankish, 2005). In Kaushanskaya and Yoo's study (2013), they compared Korean-English bilinguals' performance in short-term memory (STM), which was assessed by nonword repetition task, and working memory (WM), which was measured by a nonword repetition task accompanied by an animacy judgment task. In comparing the performance in STM and WM in both L1 and L2, they revealed that there were differences in performance in both languages with the relationship between L1 and L2 being significant in PWM but not in STM. One reason that was put forward for this weak correlation between L1 and L2 STM was the phonological distance between the two languages. This study supports the idea that similarities and differences in the phonological systems of languages known to a bi/multilingual can influence their phonological working memory.

In the study by Krzysik and Wrembel (2019), the authors had researched the multilingual phonology of adolescents (mean age = 12.64 years) while in the present study, the participant group was formed by a comparatively younger age group of children. The studies also differ in the languages used. While the participants in Krzysik and Wrembel's work (2019) were sequential trilinguals of Polish-English-German with the duration of exposure in the third language being less than a year, the ones in the current study were Tamil-English-Hindi. All three languages used in Krzysik and Wrembel (2019) belong to the same language family of Indo-European languages. However, of the three languages used in the current study, Tamil belongs to the Dravidian language family while English and Hindi belong to separate subcategories of the Indo-European language family. This difference requires attention because of the typological proximity effect of language in additional language acquisition. These connections are more likely to be made across languages that have more in common than not (Ringbom & Jarvis, 2009).

However, these similarities between the L3 and L1/L2 can sometimes impede multilinguals' ability to learn an L3. It can be argued that the close proximity between these languages could have resulted in the association between nonword repetition in L1 and word repetitions in L2 and L3.

The absence of a correlation between PWM and speech accuracy could be attributed to other factors as well. The development of multilingual phonology and accurate production of non-native productions are influenced by a hoard of factors including environmental ones such as – quality and quantity of language exposure, type of instruction, and context of language use. The participants of the current study are homogeneous in terms of age of acquisition. All participants were exposed to L2 from 4 years of age and were exposed to L3 from 6 years of age. Though there were individual differences in the proficiency of the languages, all four groups were balanced in terms of language proficiency.

Other sources of individual variability such as quantity could have confounded the possible relation between phonological working memory and speech accuracy. Speakers may encounter language from various sources or learning resources, encompassing diverse varieties. Questionnaires like The Language History Questionnaire (Li et al., 2006) and The Language Experience and Proficiency Questionnaire (Marian et al., 2007) recognize that the quality of language exposure can also be influenced by the technology being used, such as TV, radio, or the Internet. The quantity and quality of language exposure have been recognized as contributing factors to individual differences, as evidenced by multiple studies (Marchman et al., 2010; Hurtado et al., 2008; Hurtado et al., 2014). For instance, De Wilde et al (2020) examined how Dutch children acquired English and found that the most effective out-of-school language exposure methods were gaming, social media use, and speaking. The study also noted substantial individual differences among the participants. Despite all participants in the study having the same age of acquisition for their second and third languages, differences in exposure and usage frequency outside of academic settings were possible.

5.2 Comparison of NWR between Bilinguals and Trilinguals

The second objective of this study is to understand the possible difference in the PWM capacity between bilinguals and trilinguals. For this, a comparison of the NWR scores between these languages was carried out. The results show that there exists a difference in the nonword repetition scores between the two language groups in younger children, though it is not statistically significant. Trilingual participants scored higher than the bilinguals. Given that the two groups are controlled in other variables such as native language, years of exposure to native language, age of onset of second language acquisition and duration of second language exposure, the higher performance of trilinguals is attributed to the acquisition and knowledge of an additional language.

The phonological loop, which comprises phonological memory capacity, is known to be in charge of storing memory traces for a brief period of time before rehearsing them to be refreshed. According to Baddeley et al (1998), it plays a crucial role in language acquisition by storing unfamiliar sounds for later transfer to long-term memory. Multilingual individuals have more experience with a wider range of sounds (both native and non-native). This enhanced exposure, as suggested by Wrembel et al (2019) and Enomoto (1994), could lead to greater accuracy in perceiving these sounds. This improved perception might translate to better performance on tasks like non-word repetition, where participants need to remember and repeat unfamiliar sequences of sounds.

A surprising gap exists in the literature regarding the influence of bilingualism on working memory (WM) function. The current research landscape is characterized by a limited number of investigations and conflicting findings, encompassing both verbal and non-verbal WM domains. Some studies report evidence for enhanced performance in bilinguals on verbal WM tasks under specific conditions (Kaushanskaya, 2012; Kroll et al., 2012; Yoo & Kaushanskaya, 2012). This advantage has been observed in tasks involving the native language with comparable proficiency between bilingual and monolingual participants, such as non-word repetition (Kaushanskaya, 2012) and reading span tasks that require temporary information retention (Kroll et al., 2012). Additionally, bilinguals may exhibit superior performance on verbal WM tasks in their second language compared to monolinguals, particularly for tasks with increased difficulty (Yoo & Kaushanskaya, 2012).

Grundy and Timmer (2016) carried out a meta-analysis, and their findings showed a strong small to medium population effect size of 0.20, indicating that bilinguals had a higher working memory capacity than monolinguals. This lends credence to the theory that bilinguals do better than monolinguals on WM span tasks in general, independent of the task's linguistic nature. The findings showed that bilinguals outperformed monolinguals when they completed the task in their L1 but performed worse than monolinguals when they completed it in their L2.

Several studies (Aliaga-García et al., 2011; Krzysik & Wrembel, 2019) have investigated the potential influence of cognitive variables, such as phonological working memory (PWM), on both phonological perception and production in multilingual individuals. These studies have yielded mixed results, ranging from moderate positive correlations between cognitive factors and multilingual phonology to no significant associations. These varied findings put forward the necessity for further research to comprehensively explore the intricate relationships between cognitive abilities and multilingual phonological development.

Bock's (1982) theory of speech production development, proposes a shift from controlled to automatic processing for lower-level skills like articulation and word production. Considering that young children do not produce speech automatically as adults do, the working memory plays a crucial role in early childhood speech acquisition due to the effortful nature of the process of speech production in young children

Similarly, Bley-Vorman (1989) contends that because of their limited competency, L2 learners rely more on bottom-up processing, which increases the demands on their working memory and attention. Working memory capacity may be comparatively more important in limiting L2 growth because of the higher demands placed on it by the slower, more laborious processing of the less proficient L2 learner (Bley-Vorman, 1989). The present study's findings of potentially higher non-word repetition scores in the trilingual group might be explained by this concept. Limited exposure to the third language (Hindi) through formal education likely restricts the quality and quantity of L3 experience. Consequently, processing demands would be higher in this group, placing greater strain on their phonological working memory system.

5.3 Comparison of WR between Bilinguals and Trilinguals

This objective also aimed at understanding the possible differences in the accuracy of speech production in second language (L2) in bilinguals and trilinguals. This was done by comparing the WR1 scores between the language group. There was no statistically significant difference that was seen in the word repetition scores between the two groups. However, a slightly higher score was obtained for the trilingual group for both the older and younger age groups in comparison to the bilinguals.

The experience that learners have had learning languages in the past has a significant influence on the many skills and abilities that are involved in language learning. This has given rise to the claim that monolinguals, bilinguals, and multilinguals approach learning a foreign language in different ways, implying that the latter two are more adept at acquiring the language than the former (Herdina & Jessner, 2000). One possible explanation for the persistence of higher perceptual sensitivity is the increased experience that comes with learning many languages. A better and more accurate perception of the acoustic features of phonemes will result from this. Additionally, by supporting the preservation of increased neurophysiological plasticity, a longer language learning experience may also make it easier to learn new phonetic contrasts.

Studies comparing the perception of monolingual, bilingual, and multilingual people have frequently produced inconsistent results. For example, there were no appreciable differences between monolingual and bilingual children in Davine et al.'s (1971) study comparing children in grades 3 and 4 who received monolingual instruction to children of the same age receiving bilingual instruction in terms of their ability to discriminate phoneme sequences. Due to potential problems with the task and the stimuli employed, which had the participants retain complex sound patterns in memory for a comparatively long time, making the task challenging, the significance of these results remains questionable.

In contrast, Enomoto (1994) did find a difference between the speech perception abilities of monolinguals and multilinguals. This study investigated how well monolinguals and multilinguals discriminate between singleton and geminate stops in Japanese. The results showed that multilinguals performed better than monolinguals, suggesting that extensive language learning experience enhances perceptual sensitivity. Enomoto (1994) interprets this as evidence that more language learning experience enhances perceptual sensitivity. These studies, among many others, contribute to the growing body of research demonstrating a bi/multilingual advantage in speech perception and, consequently, production. However, comparisons between the specific advantages of bilinguals versus multilinguals remain limited.

Wrembel et al (2019) suggest a potential benefit for multilingual learners. Their study examined how adolescents who spoke German (L1), English (L2), and Polish (L3) perceived consonant sounds (specifically sibilants) and vowels. The findings suggest that these multilingual adolescents demonstrated a heightened ability to perceive sounds precisely (perceptual acuteness). This was attributed to their experience learning multiple languages. Interestingly, the participants didn't simply categorize new sounds from Polish (L3) as the same as similar sounds in their native German (L1). This tendency, called single-category assimilation, can hinder learning new sounds. The researchers propose that the multilingual learners' well-developed ability to perceive subtle differences in sounds, honed through acquiring multiple languages, allowed them to bypass this assimilation.

5.4 Effect of age on PWM and Speech production

The present study showed an effect of age on the phonological working memory capacity of school-going children as indicated by an increase in accuracy scores in nonword repetition tasks. This effect was apparent in both the bilingual and trilingual participants. This study aligns with previous research demonstrating the impact of age on phonological working memory capacity. Gathercole et al (1994) developed norms for the Children's Test of Nonword Repetition administered to English-speaking children aged 4-9. Their findings revealed a clear developmental progression, with mean scores increasing from 18.70 (SD ± 6.02) in four-year-olds to 32.30 (SD ± 3.95) in eight-year-olds. Grivol et al (2011) further corroborated these age-related changes in a wider age range comparison study. They reported statistically significant differences in nonword repetition task scores between children (aged 6-8), adults (over 19), and elderly individuals (over 60). Notably, adults achieved higher mean scores (77.27) compared to children (69.43). This suggests that phonological working memory capacity may improve with age, potentially due to faster subvocal recall linked to the development of speech and language skills.

In the Indian context, the measurement of nonword repetition in Kannada speaking typically developing, and language-impaired children was carried out by Swapna (2011). When compared, the mean scores revealed that the older age group 5-

6 years (mean = 34.99) obtained higher scores than the lower group of 4-5 years (32.44). Thus, the children in the higher age group performed better than the younger age group. The study identified a significant difference between the two age groups This shows that phonological working memory matures as children grow.

Research suggests that phonological working memory capacity, the ability to hold and manipulate sounds in short-term memory, is significantly influenced by age. This capacity undergoes a rapid increase up to the ages of 8-10, after which it reaches a plateau around 11-12 years of age (Gathercole, 1999).

This study also revealed an age effect on speech production accuracy in school children, evidenced by their improved performance on word repetition tasks in a second language. These findings align with the second language linguistic perception model (Escudero, 2009). This model proposes that L2 perception develops through L2 learning experiences. Ultimately, L2 learners can achieve monolingual-like perception of both L1 and L2 because they are processed by distinct perceptual grammars. The observed improvement in perceptual abilities likely translates to enhanced production skills in the L2, supporting the notion that increased experience due to age facilitates more accurate production.

However, such a significant age-related increase in accuracy was not observed in the repetition of the third language. This could be due to the reduced quantity of exposure to Hindi gained by the participants during formal education instruction limited to a short duration per day. Studying the performance of a higher age group than the one considered in the present study will be necessary to investigate the age effect.

CHAPTER VI

SUMMARY AND CONCLUSION

Phonological working memory (PWM) is defined as the ability to maintain verbal information in memory for a brief period of time. In both monolingual and bi-/multilingual contexts phonological working memory (PWM) has been found to contribute to vocabulary acquisition, maintenance and processing of linguistic information or reading. The effectiveness of the phonological memory system's ability to encode information has been linked to one specific factor ' the structural knowledge of one's language'. In addition to various aspects of language, studies have also been conducted to understand the possible role of PWM in the production of native and non-native speech sounds and their accuracy in children and adults.

PWM appears to be connected, albeit with individual differences, to several facets of bilingual and multilingual language production and processing, according to the evidence presented by earlier research. The studies produced a range of results, from modest correlations to none at all between cognitive processes and multilingual phonology, but most of them emphasized the need to broaden the scope of the research and investigate these linkages. Research over the past three decades investigated various aspects and dimensions of multilingualism. However scant research has been carried out in multilingual phonology despite a multilingual context being a very prevalent environment in the Indian context.

The present study aimed to investigate if there existed a correlation between the phonological memory capacity and accuracy of speech production in non-native languages. The study also aimed at uncovering any language – bilingual vs trilingual-effect and age – younger vs older- effect in phonological working memory and the accuracy of speech production.

For the study, 60 participants were recruited from State board and CBSE board schools from a native Tamil-speaking environment. All participants were divided into four groups based on the number of languages known and their age. The four groups were –Bilingual 6-8 year, Bilingual 10-12 year, Trilingual 6-8 year and Trilingual 10-12 years respectively. All the participants had Tamil as their L1 while they were exposed to English as the medium of instruction in school. The participants in the trilingual group, in addition to Tamil and English, were also studying Hindi as part of the school curriculum. All of them were recruited in line with the inclusion and exclusion criteria. A language use questionnaire (Shanbal JC, 2010) was used to ensure the groups were balanced in proficiency. The participants were subjected to two tasks – the nonword repetition task which measures the phonological working memory and the delayed word repetition task to measure speech production accuracy. The nonword repetition task was carried out in Tamil (L1) and the word repetition tasks in English and Hindi (L2 and L3). The audio-recorded stimuli were presented via headphones and the responses were transcribed and rated. The accuracy scores in terms of percentage were calculated for both tasks. Descriptive analysis was carried out and normality tests showed that data followed a normal distribution. Pearson's correlation between the nonword repetition and delayed word repetition scores did not show any statistically significant relationship. Consequently, the result obtained was not in line with the previous studies showing a relationship between phonological working memory and speech production. In the present study, two-way ANOVA analysis indicated a significant age effect for nonword repetition and delayed word repetition in L2 but not for L3. This is concurrent with previous studies showing that phonological working memory and the phonological representations of additional languages mature with age. The analysis showed no significant main effect for language group though the trilingual group tended to have more nonword repetition and speech accuracy scores than bilinguals. Two-way ANOVA did not reveal any significant interaction effect.

Implications

- The present study is the first of its kind in the Indian context, examining the association between phonological working memory capacity and speech accuracy in Tamil-English and Tamil-English-Hindi children.
- The present study showed that the strength of association of phonological working memory and speech accuracy in bilinguals versus multilinguals was not statistically significant. Thus, it indicates that the results obtained in the Western context need not hold good for the Indian context as well. Thus, the role of PWM as a potential predictive factor of additional language acquisition in the Indian population similar to the one considered in our study becomes questionable.
- The present study points towards considering the languages and their linguistic properties to understand the influence of bi-/multilingualism on phonological working memory capacity in Indian children.
- The present study helps to understand the influence of number of languages on phonological working memory capacity.
- The development of phonological working memory in typically developing bi- and multilingual school-going children from 6-8 years to 10-12 years can be understood. This will be useful for comparison with clinical population.
- Role of phonological working memory in speech production can be understood which in turn will aid in assessment and management of the clinical population.

Future directions

- Similar studies with greater sample size must be carried out in order to validate and generalize the results of the present study.
- Similar studies can be carried out in other Indian languages.
- To investigate the age effect on third language acquisition a higher age group than the one in the study can be used.
- Additional variables such as quantity of exposure to languages can be controlled in further studies.

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APPENDIX I-A

PSEUDO-WORD LIST

The following is a list of pseudo words in Tamil generated using the UniPseudo algorithm. The list will be used in a repetition task administered to Bilingual (Tamil-English) and Trilingual (Tamil-English-Hindi) subjects.

The list has been categorized based on number of syllables as 2-syllable, 3-syllable, 4-syllable and 5-syllable pseudowords. The responses will be rated as 2- if 100% accurate repetition, 1 for ≥50% and 0 for <50% accuracy.

For age group 6-8 years

SL.NO	STIMULI	IPA	SCORE
1.	சோன	/so:nə/	
2.	திஜ	/tIʤə/ʃŋ	
3.	தேல	/t̪e:lə/	
4.	பெம	/pemə/	
5.	மசை	/masaI/	
6.	ஜலரா	/ʤalara/	
7.	ஆணலை	/a:nalaI	
8.	மதரா	/mad̪ara/	
9.	கதிக	/kad̪igə/	
10.	சங்கவோ	/saŋkavu/	
11.	காணிலை	/ka:nalaI/	
12.	அறமானம்	/arama:nam/	

13.	இதுகையை	/Id̪ugajaI/	
14.	பஷீதியை	/paʃi:d̪IjaI/	
15.	படகும்ச	/padagumsə/	
16.	விதமாறை	/vId̪ama:raI/	
17.	தலைவதை	/t̪alaIvadaI/	
18.	தடுவரோக	/t̪aduvaro:gə/	
19.	இவளிவான	/IvalIva:nə/	
20.	அழகலாவ	/aɻagala:və/	

APPENDIX I-B

PSEUDO-WORD LIST

For age group 10-12 years

SL.NO	STIMULI	IPA	SCORE
1.	திஜ	/tIʤə/	
2.	ஜோலை	/ʤo:laI/	
3.	ஈரை	/i:raI/	
4.	அலா	/ala:/	
5.	சூல	/su:lə/	
6.	உனவே	/unave/	
7.	மதரா	/mad̪ara/	
8.	தழனை	/t̪aɻanaI/	
9.	அதழி	/adaɻI/	
10.	ஜலரா	/ʤalara/	
11.	சங்கவோ	/saŋkavo/	
12.	நந்ததாக	/nand̪ad̪a:gə/	
13.	பலனையா	/palanaja/	
14.	வளமாறி	/valama:ri/	

15.	ஜீவகனா	/ʤi:vakana/	
16.	அலசுலே	/alasule/	
17.	கிரசான	/kIrasa:nə/	
18.	தடுவரோக	/t̪aduvaro:g/	
19.	இவளிவான	/IvalIva:nə/	
20.	அழகலாவ	/aɻagala:və/	

APPENDIX II

ENGLISH WORD LIST

The following word list has been prepared for a production task to be administered to Bilingual (Tamil – English) and Trilingual (Tamil-English-Hindi) subjects from age 6 to 12. The target sound here is /z/. This was chosen such that it is NOT present in the phonology of the subject's L1 (Tamil). All the target words that are recorded will begin with a carrier phrase – "This is a………" followed by " what did I say?"

SL.NO	STIMULI	SCORE
1.	Zip	
2.	Zoo	
3.	Zoom	
4.	Zest	
5.	Zebra	
6.	Zero	
7.	Zombi	
8.	Zebu	
9.	Zookeeper	
10.	Puzzle	
11.	Wizard	
12.	Prize	

13.	Maize	
14.	Snooze	
15.	Maze	
16.	Bronze	
17.	Sneeze	
18.	Quiz	
19.	Pizza	
20.	Topaz	

APPENDIX III-A

HINDI WORD LIST

Group I – Age group: 6-8years

The following word list has been prepared for a production task to be administered to Bilingual (Tamil – English) and Trilingual (Tamil-English-Hindi) subjects from 6 – 8 years.

The Target sounds are voiced and voiceless aspirated stops in initial, medial and final positions. The targets were chosen such that they are present in the phonology of Hindi but not in Tamil (L1). The response from the subject will be rated as 1 for accurate production and 0 if there is any error in target sound production.

All the target words that are recorded will begin with a carrier phrase – "This is a………" followed by " what did I say?"

SL.NO	STIMULI	IPA	SCORE
1.	फल	/fal/	
2.	फूल	/fu:l/	
3.	सफ़ेद	/safed̪/	
4.	भाई	/bʰaI/	
5.	भालू	/bʰa:lu:/	
6.	जीभ	/ʤibʰ/	
7.	थाली	/t̪ʰa:li/	
8.	हाथी	/ha:t̪ʰi/	
9.	हाथ	/ha:t̪ʰ/	
10.	धागा	/d̪ʰa:ga/	

11.	दूध	/d̪u:d̪^{h}/	
12.	गधा	/gad̪^{h}a/	
13.	खाना	/k^{h}a:na/	
14.	खीर	/k^{h}ir/	
15.	ईख	/ik^{h}/	
16.	आँख	/ãk^{h}/	
17.	घर	/g^{h}ar/	
18.	घोड़ा	/g^{h}oda/	
19.	मिठाई	/mIt^{h}a:ji/	
20.	ढोल	/d^{h}ol/	

APPENDIX III - B

HINDI WORD LIST

Group II – Age Group: 10-12 years

The following word list has been prepared for a production task to be administered to Bilingual (Tamil – English) and Trilingual (Tamil-English-Hindi) subjects from 10 – 12 years.

The Target sounds are voiced and voiceless aspirated stops in initial, medial and final positions. The targets were chosen such that they are present in the phonology of Hindi but not in Tamil (L1). The response from the subject will be rated as 1 for accurate production and 0 if there is any error in target sound production.

SL.NO	STIMULI	IPA	SCORE
1.	तोहफा	/t̪ofa/	
2.	भूमि	/b^{h}u:mI/	
3.	भारत	/b^{h}a:rat̪/	
4.	हथौड़ा	/hat̪hauda/	
5.	कथा	/kat̪^{h}a/	
6.	धोती	/d̪^{h}ot̪i/	
7.	धारा	/d̪^{h}a:ra/	
8.	पौधा	/paud̪^{h}a/	
9.	कंधा	/kand̪^{h}a/	

10.	खेत	/kʰet̪/	
11.	खिलोना	/kʰilona/	
12.	माखन	/ma:kʰan/	
13.	पंख	/pankʰ/	
14.	घोंसला	/gʰõsla/	
15.	घास	/gʰa:s/	
16.	घाटी	/gʰati/	
17.	मेघ	/megʰ/	
18.	पाठशाला	/pa:tʰʃa:la/	
19.	ढाबा	/dʰaba/	
20.	सीढ़ी	/si:dʰi/	