Effect of Massed and Distributed Practice with and without Summary Feedback on Speech Motor Learning in Typical Kannada Adults

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CERTIFICATE

This is to certify that the dissertation entitled " **Effect of Massed and Distributed Practice with and without Summary Feedback on Speech Motor Learning in Typical Kannada Adults**" is a bonafide work submitted in part fulfillment for degree of Master of Science (Speech Language Pathology) of the student Registration Number: **P01II21S0028** 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 the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled " **Effect of Massed and Distributed Practice with and without Summary Feedback on Speech Motor Learning in Typical Kannada Adults**" has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled " **Effect of Massed and Distributed Practice with and without Summary Feedback on Speech Motor Learning in Typical Kannada Adults**" is the result of my own study under the guidance of Dr. B. V. M Mahesh, Assistant professor in Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

Motor learning is the process of acquiring the capability of producing skilled actions (Schmidt 1988). This represents a relatively permanent change in the capability to produce skilled actions based on the processes associated with practice and experience. Speech-motor learning takes place in three different phases which includes acquisition, retention, and transfer phases. The acquisition phase is also known as the practice phase, where include a target motor task is performed for a predetermined number of times under a known practice condition. Feedback provided during the acquisition phase plays a very important role as this would enhance the overall performance. It has been observed that after certain amounts of practice, participants' reliance on the external feedback reduces which indicates the induced automaticity in the task performance (Schmidt & Lee 2005).

In the retention phase, the consistency of the movement pattern learnt following a brief rest period could be examined. Finally in the transfer phase the learnt motoric sequences skills could be expected to generalize for novel target conditions. To enhance the performance, retention and transfer of novel motoric movements, speech-motor learning literature specifies various *conditions of practice* (for e.g., Practice amount, Practice Distribution, Practice Schedule etc.) and *types of feedback* (for e.g., Feedback type, Feedback frequency) which are together called principles of motor learning (PML) (Schmidt 1988; Mass et al.,2008).

Practice distribution describes the distribution of a certain (fixed number of trials) amount of practice throughout time. Here, *massed practice* refers to the practice of a given motor task or a sequence for fixed number of trials within a short period of time. Whereas *distributed practice* is understood as practicing a given task for a fixed number of trials over longer period of time. Numerous limb motor studies (keyboard press tasks) have favored distributed practice over massed practice because distributed practice has been demonstrated to be more effective in motor learning and the learnt sequences were sustained for longer duration (Baddeley & Longman 1978; Carron et al., 2013; Know & Lee et al., 2014; Lee & Genovese 1989; Shea et al., 1979). Very limited number of studies have addressed the effects of practice distribution on speech motor learning. In a study carried out using LSVT program on Parkinsonism, long term retention has been reported even when it resembles a massed practice regimen (Spielman et al., 2007; Ramig et al.,2001)

Limited number of studies have addressed the effects of feedback on sppech motor learning. Few studies investigated the effectiveness of summary feedback and suggests that during acquisition, increased feedback result in decreased motor performance and learning (Steinhauer et al. (2000) but in a study by Adams and Page (2002), it was reported that high-frequency feedback improved acquisition whereas better retention was seen in the group that received low-frequency feedback.

Need of the study

There is some evidence in the limb motor learning on practice distribution wherein distributed practice is known to outperform the massed practice in motor learning (Carron et al., 2013; Know & Lee et al., 2014). Though few evidences in non-speech motor control (finger press response studies) indicates the upper hand of distributed practice, no systematic investigations have been carried out in speech motor literature.

Few studies that reported on practice distribution were on individuals with Parkinson disease (Ramig, Sapir, Countryman, et al., 2001; Ramig, Sapir, Fox, et al., 2001). These two investigations reported the long-term benefits of LSVT (Ramig, Sapir, Countryman, et al., 2001; Ramig, Sapir, Fox, & Countryman, 2001) following a massed practice regimen and did not explore on the distributed practice effect of LSVT. However, a study by Spielman et al., (2007), showed that extended LSVT (for 8 weeks) were comparable to the traditional LSVT (for 4 weeks) across a range voice and articulatory measures indicating no superiority of the distributed practice over the massed practice regimen.

Additionally, as feedback conditions are known to interact with the motor learning, an attempt is made in this study to use summary feedback along with practice distribution (Adams & Page 2002; Katz et al., 2010; Steinhauer et al., 2000). Considering the paucity and mixed findings of very few investigations in the speech motor literature, it is worth investigating the effect of the practice distribution on speech motor learning in typical adults. Additionally, this study also proposes to explore the interactive influences of these practice distribution with the feedback conditions. Practice distribution has important clinical implications for speech and language therapy in general, and speech motor disorders in particular, as therapeutic benefits are expected to be retained for a long term even after the cessation of treatment. The expected benefits in practice distribution are generally attributed to the enhanced opportunity for memory-consolidation processes of the learnt targets.

Aim of the study

The aim of the study is to understand the effect of practice distribution and summary feedback on speech motor learning in native Kannada speaking adults.

Objectives of the Study

1. To investigate the speech motor learning of nonsense Kannada word sequences during the ***practice phase*** as a function of
   a) Practice Distribution (Massed versus Distributed) and
   b) Feedback Condition (With and without summary feedback)
   c) Syllable length (6 vs 9 syllable)
2. To investigate the speech motor learning of nonsense Kannada word sequences during the ***retention phase*** as a function of
   a) Practice Distribution (Massed versus Distributed) and
   b) Feedback Condition (With and without summary feedback)
   c) Syllable length (6 vs 9 syllable)
3. To investigate the speech motor learning of nonsense Kannada word **sequences *between practice and retention phases*** as a function of
   a) Practice Distribution (Massed versus Distributed)
   b) Feedback Condition (With and without summary feedback)
   c) Syllable length (6 vs 9 syllable)

Hypothesis

1. There is no significant effect of massed versus distributed practice on acquisition and retention of Kannada non-sense syllable sequence.

2. There is no significant effect of feedback condition on acquisition and retention of Kannada non-sense syllable sequence**.**

3. There is no significant effect of syllable length conditions on acquisition and retention of Kannada non-sense syllable sequence.

CHAPTER 2

REVIEW OF LITERATURE

Any motor skill that must be learned includes a complicated relationship between a person's innate abilities and the intricacy of the skill itself. The performer would make intentional efforts to learn the motor skill during the early stages of skill development. At this time, it is likely that the motor performance will be slower, more prone to mistakes, and heavily influenced by other unrelated tasks. However, continued practice makes the motor skill more adept, leading to faster execution with fewer mistakes and easier handling of other task interference by the performer. As a result, there has been a change in the learning of the motor skill, and the performer now executes the task with a high degree of automaticity and less conscious control (Ackerman, 2007; Chow et al., 2008).

The spatial and temporal dimensions are often where motor skill acquisition takes place, and these dimensions would be stored in the motor memory and executed whenever a need arose with the least amount of effort and energy (Schmidt & Lee, 2005). According to few studies, learning a motor skill results in morphological changes to the brain, including enhanced synaptogenesis and dendritic arrogation (Doyon et al., 1998; Doyon et al., 2002; Graybeil, 1999; Rose, 1977).

Few theories have explained on the mechanisms of how speech motor plan/programme is learnt, and few of these theories have their base from limb motor literature. Generalized motor programs (GMPs), which specify the relative time and relative force of muscle instructions necessary to carry out members of a class of actions, are stored in the brain, according to Schmidt's (1975) schema theory of motor control and learning.

Schema Theory (1988)

Schema theory believes that any kind of motoric movements can be retrieved from the short-term memory store. The motoric movements are driven by motor programs which provides systematic instructions for any motoric movements before its initiation. In order to develop an accurate motor program initial set of information are necessary. This information is nothing but the beginning conditions such as the position of the effectors, the motor commands being prepared, the expected sensory consequences of the movement and the final outcome. All these information is stored as schemas as per the schema theory and these schemes are the memory representations that will link the relations between the beginning set of information.

After executing a particular movement, the information regarding the movement is stored as Generalized motor programs in the short-term memory. These generalized motor programs create two important schemas called recall schema and recognition schema. The recall schema stores the goal and any information pertaining to the initial conditions which are required to execute the moment. Recognition schema will help in predicting the sensory consequences for a given movement goal. Therefore, the recognition schema will compare the actually produced movements with that of the sensory consequences which were expected and any errors will be used to update the recall schema. Schema theory hypothesizes that before the recognition schema acquires the ability to correct the errors, it learns the reference of correctness. In most cases the reference of correctness is a care giver, and for an impaired speaker, it will be a speech language pathologist.

Schema theory specify how new abilities are applied as well as the kind and quantity of enhanced or external feedback given to the learner. A set of motor learning principles that discriminate between elements that temporarily increase performance and those that lead to significant long-term learning have been identified as a consequence of several experiments on motor learning in the limbs (Maas et al., 2008; Schmidt & Lee, 2005). Due to the difference between short-term learning and long-term learning, it is necessary to measure short-term performance changes from training session, as well as long-term retention of learned skills after training ends and the transfer of learned skills to related but unlearned skills.

Speech Motor Learning Phases

Speech-motor learning takes place in three different phases which includes acquisition, retention, and transfer phases. The acquisition phase is also known as the practice phase, where include a target motor task is performed for a predetermined number of times under a known practice condition. Feedback provided during the acquisition phase plays a very important role as this would enhance the overall performance. It has been observed that after certain amounts of practice, participants' reliance on the external feedback reduces which indicates the induced automaticity in the task performance (Schmidt & Lee 2005).

In the retention phase, the consistency of the movement pattern learnt following a brief rest period will be examined. Finally in the transfer phase the learnt motoric sequences skills are expected to generalize for novel condition. To enhance the performance, retention and transfer of novel motoric movements, speech-motor learning literature specifies various *conditions of practice* and *types of feedback* which are together called principles of motor learning (PML) (Schmidt 1988; Mass et al.,2008). Practice conditions involve a) Practice amount (small and large practice), b) Practice Distribution (Massed and Distributed), c) Practice Variability (Constant and

Variable), d) Practice Schedule (Blocked and Random), e) Attentional focus (Internal and External) and f) Target complexity (Simple and Complex). Feedback conditions include a) Feedback type (Knowledge of Performances and Results), b) Feedback frequency (High and Low or Summary-KR), and c) Feedback timing (Immediate and Delayed). The following table describes various practice and feedback conditions along with their descriptions for better understanding.

Table 1

Details on the Various Practice and Feedback Conditions and Their Descriptions

Conditions of Practice	Hierarchy Levels	Description
Amount of Practice	Minimal amount of practice and sizeable amount of practice	**Minimal**: Fewer than usual Practice runs or sessions **Sizeable:** Lots of Practice tests or sessions
Amount of Practice distribution	Massed practice and distributed practice	**Massed practice:** Practice a large number of repetitions or sessions in a short amount of time. **Distributed practice:** Practice over a longer length of time with a specified number of repetitions or sessions
Variability in Practice	Constant Practice and Variable Practice	**Constant Practice:** Working on the same target in the same situation (for instance, the syllable-initial /f/). **Variable Practice:** Working on several targets in various circumstances/situations
Schedule of Practice	Practice using either blocked form or random form	**Blocked Practice:** Different goals are Practiced in distinct, subsequent blocks or therapy phases **Random Practice:** Interspersing different targets

Focus of Attention	Internal focus of attention and external focus of attention	**Internal focus of attention:** Paying close attention to one's own physical actions (e.g., articulatory movement) **External focus of attention:** Attention towards the results of action (e.g., acoustic signal)
Unit Complexity	Simple and complex	**Simple:** Easier sounds and sound sequences already learned (e.g., bilabials) **Complex:** Difficult sounds and sound sequences that were later learned (e.g., sibilants)

Practice Distribution: Massed Versus Distributed Practice

The current study proposes to investigate the effect of practice distribution i.e., the effect of massed versus distributed practice on speech motor learning. Practice distribution describes the distribution of a certain (fixed number of trials) amount of practice throughout time. Here, *massed practice* refers to the practice of a given motor task or a sequence for fixed number of trials within a short period of time. Whereas *distributed practice* is understood as practicing a given task for a fixed number of trials over longer period of time. Several limb motor studies have favoured the distributed practice over the massed practice as motor learning is shown to be effective and long lasting in distributed practice (Shea et al., 1979).

Research utilizing a serial reaction time (SRT) test compared the efficacy of motor sequential learning according to two distinct types of practice schedules: distributed practice and massed practice. Distributed practice was delivered across two 12-hour inter-session intervals, including sleep, as compared to two 10-minute inter-session intervals for massed practice. The response time (RT) and response accuracy

(RA) were measured using the pre-test, mid-test, and post-test. The three tests were compared between and within groups, and the results of the within-group comparison revealed a substantial main effect. The findings indicated that, in comparison to massed practice, a distributed practice schedule can improve the efficacy of motor sequential learning in 1-day learning formats as well as for 2-day learning formats (Kwon et al., 2015).

Woodworth (1938) cited many studies which appeared to support the trainings done using distributed practice over massed practice, across a wide range of tasks from archery to maze learning as well as the skills of learning to type. However, the specific details of these studies were not clearly traceable. Baddeley & Longman (1978) studied the ability of 45 postmen to alter the alphanumeric code on a typewriter. These participants were in the age range between 40 to 80 years. The study participants were divided into 4 groups, one group received typewriting lesson of one session of one hour a day (1*1), a second group was given two sessions of one hour a day (2*1), a third group was given one session of two hours a day (1*2) and fourth group received 2 session of 2 hours per day. Results indicate that 2 hours of massed practice was detrimental in keyboard learning and hence the authors opined that the training has to be spread out throughout the day.

Though there are no systematic evidences existing in the speech motor literature, non-speech studies, targeting the keyboard finger press responses have supported the distributed practice over the massed practice. When practicing key press entries over a period of 15 days (massed) or 60 days (distributed), the distributed practice group demonstrated efficient motor retention of the key press responses even after 9 months of training, but the gains obtained during massed practice vanished soon after the training was completed (Baddeley & Longman 1978). Similar such longer motor retention in the non-speech tasks were reported by other investigators (Shea et al., 2000; Lee & Genovese 1989)

A handful of studies have measured the effect of practice distribution in speech motor literature. Long term benefits with Lee Silverman Voice Therapy (LSVT) are being reported by few studies. LSVT, is usually carried out typically for 4 sessions for 4 weeks. Long term retention has been reported (for at least 6 months) even when it resembles a massed practice regimen (Fox et al., 2002; Ramig et al., 2001). However, a follow up study showed comparable effects in the long-term retention even when the LSVT training program was extended for 8 weeks (Spielman et al., 2007).

A review on the motor learning reported that a minimum rest period of 24 hours is suggested to observe the retention effects of the practice distribution (Lee & Genovese, 1988).

Effects of feedback on motor learning

Feedback provided during the acquisition of any motor task is helpful in updating the recall and recognition schema and thereby helps in retaining the learnt sequences for a longer time. Several studies have been conducted on the usage of feedback in the enhancement of motor learning. Among these feedbacks, knowledge of results (KR) and knowledge of performance (KP) are commonly investigated (Schmidt & Lee, 2005). KR is the information that is given following the conclusion of a movement on how the movement was performed in reference to the goal. It frequently relates to the departure from a spatial or temporal objective, but it can also refer to broader criticism offered, for instance, by the clinician (e.g., " You failed to reach the target "). KP, on the other hand, relates to the character or type of the movement pattern.

This involves both biofeedback and comprehensive guidance from a therapist (such as, "Your tongue did not raise enough for that sound"). Both KR and KP direct the performer to the appropriate movement and serve as an outline for rectification of errors on upcoming trials.

Steinhauer and Grayhack et al. (2000) used a vowel nasalization speech task on 30 individuals in the 18–40 age range to determine the efficacy of summary feedback. Each of the 10 individuals were randomly assigned to any of the three groups a) feedback is given after each trial; b) feedback was given after every 5 trial and c) No feedback was provided. Nasalance score was shown as visual feedback. Better retention was observed for the last two groups where they either followed no feedback or summary feedback after 5 trials. Adams and colleagues (2002) examined the impact of a feedback schedule on 18 Parkinson's disease patients between the ages of 48 and 70. Each participant received either a) summary feedback after every fifth trial (n = 9) or b) feedback given after every trial (n = 9). They rehearsed saying a popular bilabial phrase across 2 distinct lengths 2400 and 3600 milliseconds. After two days of training, a retention test showed that high-frequency feedback led to better acquisition, whereas low-frequency feedback led to better retention.

Schema theory (Schmidt, 1975; Schmidt & Lee, 2005) can be used to explain improved overall performance in low frequency/summary feedback conditions in several studies as mentioned. Generalized motor program (GMP), recall schema, and recognition schema are the three pillars of schema theory. Every movement will have a unique GMP (set of predetermined physical parameters), which will first be stored in short term memory. Later, all the information connected to that specific movement will generate two schemas, namely the recall and recognition schema. The progress in accurate error detection and correction systems, which are updated in schemas, is enabled by learning opportunities provided by faulty movements while learning a novel target. High frequency feedback may improve performance, but because of the reliance on external feedback, it may make it harder for people to remember what they learned.

Many experts believe that the most effective feedback is concurrent or immediate terminal input, which is sent as soon as possible after the movement. In contrast to terminal feedback, concurrent feedback hinders learning (e.g., Schmidt & Wulf, 1997; Vander Linden, Cauraugh, & Greene, 1993). Although concurrent feedback significantly improves performance during practice, it clearly lowers performance on retention and transfer phase (Park, Shea, & Wright, 2000; Schmidt & Wulf, 1997; Vander Linden et al., 1993, for examples).

Many studies have been conducted on the effect of feedback frequency. Using a lever positioning task, Winstein and Schmidt (1990) discovered that while performance of the two groups did not differ during practice, the 50% feedback group was more accurate at retention than the 100% group. This finding suggest that Feedback helps the person make the right movement, but too much of it might be detrimental. If learners do not properly absorb intrinsic feedback when augmented input is available, they might become dependent on it. Because of this, they might not be able to create enough error detection and correction systems (recognition schema) that would enable them to perform well when the enhanced feedback is removed.

According to Wulf and Shea (2002), the impacts of feedback frequency also depend on how sophisticated a skill is. Reducing augmented feedback can help with the learning of elementary skills, but more frequent feedback may be necessary for the learning of complicated skills (e.g., Swinnen et al., 1997). It's interesting to note that reduced frequency feedback seems to aid GMP learning but not parameter learning (Wulf et al., 1994; Wulf & Schmidt, 1989; Wulf et al., 1993). As per the stability hypothesis (Lai & Shea, 1998; Shea & Lai, 2001) frequent feedback induces more trial-to-trial corrections and thus leads to less stability than reduced frequency feedback.

Guadagnoli and Kohl (2001) reported that, while utilizing a force-production task, learning was enhanced for a low frequency condition (feedback after 20% of practice attempts) as contrasted to a high frequency condition (feedback after 100% of trials), when feedback was given to participants without first asking them to observe their mistakes. However, 100% feedback produced more useful learning than 20% feedback when participants were expected to estimate their errors. They contend that the learner's actions prior to obtaining KR have an impact on how that KR will be utilized. This relationship therefore shows that regular feedback facilitates the explicit modifying of internal error detection mechanisms in respect to an external reference of correctness. On the other hand, when error estimations are not explicitly required, learners may be more subtly encouraged to engage in such processing when given less feedback.

According to recent research (Ballard et al., 2000; Steinhauer & Grayhack, 2000), high-frequency, quick feedback is often given by clinicians to both AOS speaker and intact speaker and were benefited from reduced feedback frequency. Using an alternating-treatments approach, an impact of input frequency (100 vs. 60 %) on retraining speaking abilities in AOS was measured and it was observed that 2 of the 4 participants responded better to lower frequency input in terms of retention and transfer (Austermann Hula et al., 2000). Results in the other 2 participants may have been impacted by problems with the intricacy of the stimuli. Based on their findings the investigators opined that reduced frequency feedback is advantageous for learning motor skills, particularly for GMP learning.

Studies on limb motor learning (e.g., Wulf et al., 1993) show that parameter learning rises with an increase in the external knowledge of results (KR) feedback frequency. Nevertheless, it appears that giving performers excessive amounts of external KR feedback impairs their capacity to learn movement patterns, or GMPs. This suggests that restricting the availability of external result information is critical for fostering performers' acquisition of the GMPs' essential characteristics. According to studies conducted to date (Lee et al.1998,; Sparrow & Summers, 1992; Winstein & Schmidt, 1990), lower KR is either just as beneficial as or even more successful in fostering learning. No research has shown that 100% KR has a better impact on learning than lower KR.

This review's findings suggest that low frequency feedback and distributed Practice are more effective than massed Practice in helping non-speech motor tasks to be retained over the long term. However, there have only been a few handfuls of research that have integrated feedback and Practice distribution conditions to study speech motor learning. To understand the impacts of such Practice on the short-term retention of the learnt speech movement, the effects of both Practice distribution and summary feedback conditions are explored in the current study.

CHAPTER 3

METHOD

Participants

A total of 36 typical young adults, who are native Kannada speakers, in the age range of 18 to 40 years (mean age =22.08; SD =2.91) were recruited for the study. Based on practice distribution (massed and distributed practice), two groups were formed. Group I (massed practice) was further divided into (a) massed practice with summary feedback (MPSF) and (b) massed practice with no feedback (MPNF). Similarly, group II (distributed practice) was further divided into (c) Distributed Practice with Summary Feedback (DPSF) and (d) Distributed Practice with No Feedback (DPNF). Nine individuals who were bachelor and master students studying in All India Institute of Speech and Hearing, Mysore were recruited as study participants were randomly assigned to any of these four subgroups.

Inclusion criteria for selection of group I and II

- Participants, who were native Kannada speakers of the age range 18-40 years were included in the study.

Exclusion criteria for selection of group I and II

- Participants with history of speech, language, and neurological issues.
- Participants who were been under any medications (anxiety or depression) that affect verbal task performance (from the medical records of the participant).
- Participants with sensory issues (visual and auditory) were ruled out.
- Participants with Oro-motor issues and/or articulatory difficulties were ruled out.

- Individuals with recent exposure to other sequential learning experiments were excluded.

To provide an auditory model of the constructed nonsense syllable sequences, a native Kannada-speaking female with good enunciation skills was utilized.

Materials

This study was having 2 nonsense word sequences of Kannada which vary in 6 and 9 syllable lengths. Fifty words of 3 syllable lengths were chosen from a study done by Ranganatha (1982) where they have listed most frequently used Kannada words. Non words from these word lists were constructed by transposing and substituting the syllables by considering the phonotactic constraints of Kannada. The constructed 3 syllable nonwords was subjected for word-likeness rating on a 4-point rating scale (0 = This is definitely a word in Kannada, 1 = This may be a word in Kannada, 2 = Unlikely to be a word in Kannada, and 3 = Not a word in Kannada) through google form by 10 adult native Kannada speakers. Those non words which are rated as '3' were considered as the stimuli for the current study.

Stimuli

Non-words that were rated '3' by the native Kannada speakers were listed and two different nonsense syllable sequences with different syllable lengths were constructed. The nonsense syllable sequences were as follows

a) 6 syllable lengths non sense Kannada word/syllable sequence: ಲೆಡಕ ರುತೂಯ

b) 9 syllable lengths non sense Kannada word/syllable sequence: ದೂಯವು ಯೆಗಳೆ ರುಲುತ

Procedure

Pilot study

A pilot study was conducted to set the durational target of the two nonsense syllable sequences. Twenty native adult Kannada speakers were asked to read the constructed nonsense word sequences 10 times presented on a computer screen. The duration of nonsense syllable sequences was recorded using PRAAT software. The average duration recorded for both sequences was tabulated. The duration of the recorded speech sample was halved so that participants had to maintain this temporal target in addition to recalling the syllables (spatial targets). Therefore, a durational target of 0.65 seconds was set for the 6-syllable nonsense syllable sequence, and a durational target of 1.06 seconds was maintained for the 9-syllable nonsense syllable sequence. A written informed consent will be obtained from all the participants before enrolling them into the study.

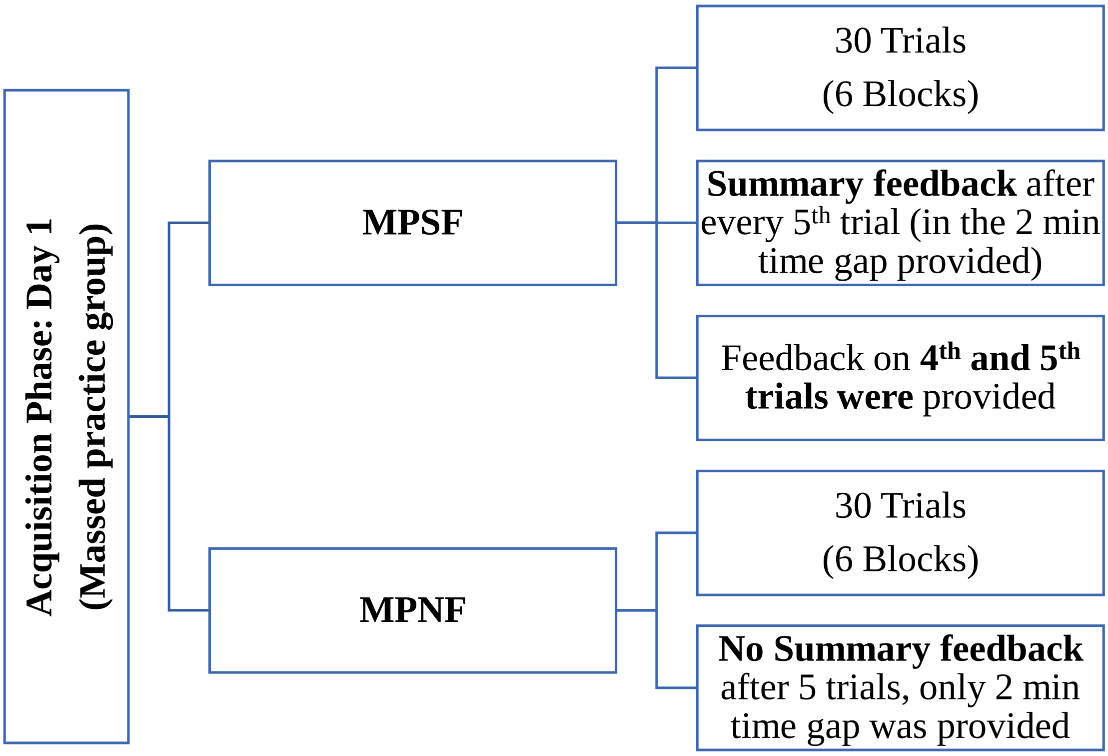
Data Recording

Testing was carried out in a quiet room setup with no distraction. Data recording was carried out in a quiet room setup with no distraction. Before the enrolling the participants into the study, OPME (oral peripheral mechanism examination) was carried out and working memory subtest of Cognitive Linguistic Assessment Protocol (CLAP) for adults (Kamath, 2001) was administered to rule out oro-motor and working memory difficulties respectively.

Participants were provided with an auditory (by a female native Kannada speaker) and a visual model (using PowerPoint) of both 6 and 9 nonsense syllable targets. Participants were not given any practice trials. In the acquisition phase, participants were instructed to ‘repeat the target phrase shown on the computer screen as accurately as possible within a given duration of time (either 0.65 seconds or 1.06 seconds). A total of 30 trials were practiced by all the four groups included in the study. For MPSF group, all 30 trials were practiced and summary feedback of the last 2 trials in terms of ‘articulatory accuracy’ and ‘temporal target’ was provided after every 5 trials. After the 5th trial, a 2-minute gap was provided where the investigator measured the recorded duration of 4th and 5th trials along with articulatory accuracy data. This 2-minute time gap was used to provide the feedback to the participants. Two types of feedbacks provided were a) articulatory accuracy and b) Temporal/Durational feedback. Feedback of the articulatory accuracy was provided in terms of a) percentage of consonants correct and b) percentage of vowels correct c) type of articulatory errors (substitution, omission, distortion, or addition). The duration of the 4th and 5th trial was showed as a bar graph on the computer screen as temporal feedback. A total of 6 summary feedbacks have been given to the participants. For MPNF group, all 30 trials were practiced without any feedback on articulatory accuracy or temporal target. Here again, a 2-minute gap was provided after every 5 trials, but with no feedback. These details of the acquisition phase of speech motor learning for the massed practice groups is shown in Figure 1.

Figure 1

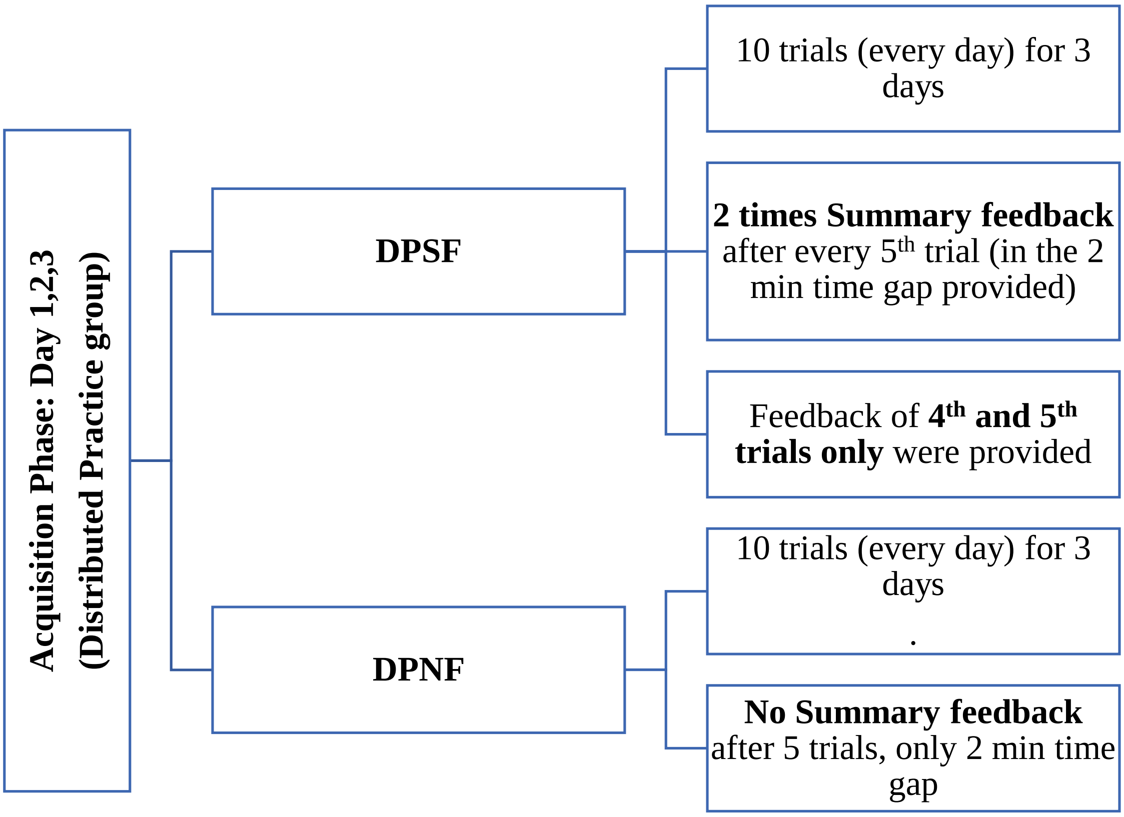
Flow Chart Showing the Acquisition Phase for the Massed Practice Group



For distributed practice groups (DPSF and DPNF), the acquisition phase was spread across 3 separate days, wherein only 10 trials were practiced for each day, amounting to a total of 30 trials. Feedback on articulatory and temporal accuracy was provided to the DPSF group twice a day after every 5 trials. However, for the DPNF group, speech motor practice was carried out for 3 separate days with 10 trials for each day and no feedback after every 5 trials. The procedural details of the acquisition phase for the distributed practice groups are shown in figure 2.

Figure 2

Flow Chart Showing the Acquisition Phase for the Distributed Practice group.



Instrumentation

The acoustic duration of the stimulus was recorded across the practice and retention phases using PRAAT software (Boersma & Weenink, 2022). Participants' voices were recorded at a sampling frequency of 44.1 kHz in PRAAT using a personal computer attached to a Logitech H111 wired headset.

Data Analysis

Mean percentage consonants correct, mean percentage vowels correct, type of SODA errors (Substitution, Omission, Distortion and Addition) and mean absolute duration of the two non-sense syllable sequences were measured for Practice and retention phases across the groups.

Normality of the data was checked for both practice and feedback conditions across acquisition/practice and retention phases. As the data were non-normally distributed, Kruskal Wallis test was done to check for the presence of significance between the groups. A follow up analysis to the Kruska Wallis was carried out using Mann Whitney U test for the measured dependent variables of the study. For within group comparisons of speech motor learning (acquisition/practice vs. retention) phases and syllable length conditions, Wilcoxon Signed rank test was used. All these analyses were carried out using SPSS software (version 23). Another native Kannada speaker who was a speech language pathologist analysed 20% of the dependent variables across acquisition and retention phases to check the data reliability.

CHAPTER 4

RESULTS

The current study analysed the effect of Practice conditions (massed and distributed) and feedback (with and without summary feedback) on speech motor learning of 6 and 9 syllable Kannada non-sense syllable sequences. The study had four groups (n= 9 each for 4 groups) of two practice conditions (Massed and distributed) and these groups were further divided based on feedback (with and without summary feedback). For easier discussion of results, the groups were named as massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). The effect of speech motor learning was measured on few selected dependent variables such as absolute duration, Percentage consonant correct (PCC), percentage vowels correct (PVC) and the frequency of SODA errors of articulation. Test of normality was carried out using the Shapiro-Wilk test and non-parametric tests were used to analyze the study's dependent variables as they were non-normally distributed ($p < 0.05$). In the acquisition phase, analysis was carried out at 2 different levels. Analysis was carried out in a conservative way wherein the dependent measures were first compared for the last 10 trials of the acquisition/practice phase and this was followed by similar analysis carried out for all the 30 trials of the practice phase. This was done to see the overall trends in the speech motor acquisition in the last 10 trials as well as for the all 30 trials. The durational target for first nonsense syllable sequence 1 was 1 second and for sequence 2 was 0.650 second. Results are discussed for acquisition and retention phases separately as first two objectives. In the third objective, comparison is made between the phases of speech motor learning for each selected dependent variable

Inter-rater Reliability: Inter-rater reliability was calculated between the researcher and an experienced Kannada speaking Speech Language Pathologist for 20 percentage of the sample selected randomly. four samples were selected from each group for the same. All the parameters were reassessed, and Kappa Coefficient was used to analyze the inter-rater reliability of the data. The reliability came between 0.70 to 0.75 which is substantial.

Intra-rater Reliability: Intra-rater reliability was done for 20% of the sample, between the first assessment and the second assessment done by the researcher itself. The test was done for all the parameters. four samples were taken from each group comprising 20%. The Cronbach's Alpha test was done to find the intra-rater reliability. The Cronbach alpha was found to be between 0.80 and 0.87 making the reliability.

1. **The effect of practice conditions (massed and distributed) and feedback on the acquisition of kannada non-sense syllable sequence**

A) Absolute Duration

Kruskal Wallis test was initially used to check the effect of practice conditions on the Kannada non-sense syllable sequence duration for the acquisition phase across 10 and 30 trials separately. Practice and feedback conditions did not differ for the durational acquisition of syllable targets for the last 10 trials across the syllable length conditions [6 syllable: [$\chi^2(3) = 6.67$, $p = 0.083$]; 9 syllables [χ^2 (3) = 3.97, p =0.265]. However, for 30 trials, practice and feedback conditions showed significant differences across both 6 syllable [$\chi^2(3) = 8.34$, $p = 0.03$] and 9 syllables nonsense sequences [χ^2 (3) = 10.04, p =0.01]. Descriptive statistics for the acquisition phase for practice and feedback conditions across syllable lengths and trials is shown as Table 2.

Table 2

Descriptive Statistics of Absolute Duration for 10 and 30 Trials across 6 and 9 Syllable Non-Sense Sequences in the Acquisition Phase

Conditions of practice/feedback	10 trials			30 trials		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
6 syllable sequence						
MPSF	0.66	0.63	0.09	0.69	0.65	0.10
MPNF	0.62	0.60	0.06	0.64	0.64	0.07
DPSF	0.69	0.70	0.04	0.74	0.71	0.09
DPNF	0.71	0.66	0.11	0.76	0.74	0.09
9 syllable sequence						
MPSF	1.05	1.03	0.09	1.13	1.09	0.22
MPNF	0.97	0.90	0.11	1.05	1.04	0.11
DPSF	1.01	1.05	0.08	1.13	1.13	0.07
DPNF	1.07	1.06	0.12	1.21	1.22	0.08

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Mann Whitney U test was used as a follow up analysis for the 30 trials. Differences for mean absolute duration were observed between MPNF and DPSF group where the MPNF group were closer in achieving the durational target of 0.650 second. Differences were also seen between MPNF and DPNF Here again, massed practice group were closer to achieve the durational target in comparison to the DPNF group. With respect to 9 syllable sequence, only marginal statistical significances were observed when the absolute duration was compared between MPNF and DPNF and between MPNF and DPSF groups. A highly significant difference was obtained when compared between MPNF and DPNF. Here, massed practice groups were closer to achieve the target duration when compared distributed practice.

When the absolute duration was compared between DPSF and DPNF groups, DPSF had shorter absolute duration, indicating better target reach when distributed practice is carried out along with summary feedback. Results were insignificant when comparison was made between MPSF vs. MPNF and MPNF vs. DPSF groups. The results of Mann Whitney results are shown in Table 3.

Table 3

Mann-Whitney Results for between Group Comparison of Absolute Duration for 30 Trials in the Acquisition Phase

Practice and Feedback conditions	**6 syllables**			**9 syllables**		
	U	**Z**	***p* value**	**U**	**Z**	***p* value**
MPSF vs MPNF	30	0.92	0.35	36	0.39	0.69
MPSF vs DPSF	23	1.5	0.13	29	1.01	0.31
MPSF vs DPNF	24	1.45	0.14	19	1.89	0.058*
MPNF vs DPSF	15	2.2	0.024*	19	1.89	0.058*
MPNF vs DPNF	13	2.42	0.015*	8.5	2.8	0.005**
DPSF vs DPNF	37	0.31	0.75	18	1.98	0.047*

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

B) Percentage Consonant Correct (PCC) and Percentage Vowels Correct (PVC)

Kruskal Wallis test was used to analyse the effect of Practice between the groups for PCC and PVC. Results suggested highly significant difference with respect to PVC but not for PCC. PVC showed highly significant difference for 6 syllables [χ^2 (3) =

13.00, $p < 0.01$] and 9 syllables (χ^2 (3) = 12.00, $p < 0.01$) for 10 trails and this trend continued for 6 syllables [χ^2 (3) = 12.53, $p < 0.01$] and 9 syllable sequences [χ^2 (3) = 8.05, $p = 0.04$] of 30 trials too. Descriptive statistical data of PCC and PVC for all the groups across trials and syllable lengths for the acquisition phase is provided in table 4 and 5.

Table 4

Descriptive Statistics of PCC for 10 and 30 Trials across 6 and 9 Syllable Non-Sense Sequences in the Acquisition Phase

Conditions of practice/ feedback	**10 trials**			**30 trials**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
6 syllable sequence						
MPSF	100	100	0	99	100	0.60
MPNF	99.44	100	1.66	98.47	100	4.03
DPSF	99.75	100	0.49	99.34	99.66	0.78
DPNF	99.05	100	1.12	99.81	100	3.52
9 syllable sequence						
MPSF	100	98.88	4.01	97	98.14	1.81
MPNF	93.91	92.22	5.74	96.74	97.4	3.63
DPSF	96.74	100	3.63	98.42	99.60	2.74
DPNF	98.47	100	4.03	97.25	98.88	0.39

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Table 5

Descriptive Statistics of PVC for 10 and 30 Trials across 6 and 9 Syllable Non-Sense Sequences in the Acquisition Phase

Conditions of practice/feedback	**10 trials**			**30 trials**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
6 syllable sequence						
MPSF	89.44	91.66	8.62	91.97	92.22	5.26
MPNF	81.1	81.66	6.56	82.98	84.44	8.35
DPSF	95.05	93.33	3.88	95.67	98.88	5.014
DPNF	91.29	90	7.5	95.05	97.77	6.21
9 syllable sequence						
MPSF	92.34	92.22	2.83	90.28	92.96	7.55
MPNF	94.21	84.44	3.34	88.05	87.77	4.99
DPSF	94.21	95.55	3.34	94.21	95.9	3.34
DPNF	92.13	90.55	6.02	95.6	97.77	4.99

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Further Mann-Whitney test was carried out to understand the group differences, if any, for PVC across syllable lengths for 10 and 30 trials separately. When PVC was compared between MPNF and MPSF for the last 10 trails of acquisition phase, marginal difference was seen for 6 syllables whereas a highly significant difference was seen for 9 syllable nonsense sequences. MPSF group was able to produce more percentage of vowels correctly compare to MPNF across both 6 and 9 syllable sequence for 10 trials.

For comparisons made between MPNF and DPNF, last 10 trials showed significant differences across both 6 syllable and 9 syllable sequences. In both the cases distributed practice showed better performance which was reflected in as higher percentage of correct production of vowels. When PVC were compared between MPNF and DPSF, highly significant differences were seen for both 6 syllable and 9 syllables non sense sequences. Here, again distributed Practiced showed better immediate performance in the production of vowels. Mann Whitney results for between group comparisons is showed as table 6.

Table 6

Mann-Whitney Results for Between Group Comparison of PVC for 10 Trials in the Acquisition Phase

Practice and Feedback conditions	**6 syllables**			**9 syllables**		
	U	**Z**	***p* value**	**U**	**Z**	***p* value**
MPSF vs MPNF	18	1.95	0.05*	12	2.4	0.01**
MPSF vs DPSF	22	1.65	0.09	24	1.47	0.14
MPSF vs DPNF	37	0.26	0.79	24	1.46	0.14
MPNF vs DPSF	4	3.23	0.001**	8.5	2.8	0.004**
MPNF vs DPNF	10	2.66	0.008**	12	2.4	0.01**
DPSF vs DPNF	27	1.2	0.23	35	0.44	0.65

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Comparisons made between the Practice/feedback conditions for 30 trials showed, highly significant difference between MPNF and MPSF for 6 syllable sequences; for both 6 and 9 syllables, MPNF and DPNF; MPNF and DPSF conditions were observed to be significantly different.

In conclusion distributed practice groups showed higher accuracy in production of vowels in the nonsense syllable sequences than massed practice groups and this performance seen in distributed practice got further enhanced in the presence of summary feedback. The results of Mann-Whitney for the between group comparisons of PVC is shown in Table 7.

Table 7

Mann-Whitney Results for between group comparison of PVC for 30 trials in the acquisition phase

Practice and Feedback conditions	**6 syllables**			**9 syllables**		
	U	**Z**	***p* value**	**U**	**Z**	***p* value**
MPSF vs MPNF	9.5	2.74	0.006**	34	0.54	0.56
MPSF vs DPSF	24	1.41	0.156	28	1.06	0.25
MPSF vs DPNF	36	0.35	0.72	20	1.81	0.07
MPNF vs DPSF	6	3.05	0.002**	15	2.25	0.024**
MPNF vs DPNF	14	2.3	0.019**	13	2.43	0.015**
DPSF vs DPNF	32	0.75	0.45	36	0.35	0.72

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

C) Substitution Omission Distortion and Addition Errors.

Descriptive statistics for the SODA errors for 6 and 9 syllable length conditions across 10 and 30 trials for the practice phase is shown in table 8 and 9. Overall frequency of the SODA errors for the acquisition phase is shown as table 10 and 11.

Table 8

Descriptive Statistics of SODA Errors in the Acquisition Phase for 10 Trials.

		6 syllables				9 syllables			
Groups		**S**	**0**	**D**	**A**	**S**	**0**	**D**	**A**
	Mean	1.8	4	0	0	0.7	5.8	0.7	0.7
MPSF	**Med**	0	5	0	0	1	4	0	0
	SD	4	3.9	0	0	0.7	5.4	1.6	1.1
	Mean	3.8	8.1	0	0	4.7	13.6	0.11	0
MPNF	**Med**	4	10	0	0	3	13	0	0
	SD	3	5.1	0	0	4.1	9.1	0.3	0
	Mean	0.22	2.9	0	0	1.11	3	0	0
DPSF	**Med**	0	4	0	0	0	1	0	0
	SD	0.44	2.14	1	0	2.26	4	0	0
	Mean	1.33	4	0	0.11	2.44	2.44	0	0
DPNF	**Med**	0	2	0	0	0	2	0	0
	SD	1.73	4	0	0.33	3.84	2.65	0	0

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Table 9

Descriptive Statistics of SODA Errors in the Acquisition Phase for 30 trials.

		6syllables				9syllables			
Groups		**S**	**0**	**D**	**A**	**S**	**0**	**D**	**A**
	Mean	2.7	10.9	0.6	0.33	2.3	19.7	1.2	5
MPSF	**Med**	2	13	0	0	2	16	1	0
	SD	4.3	6.3	1.7	0.7	2	18.6	1.6	10.7
	Mean	9.4	23.2	0	0	9.8	25.3	0	0.6
MPNF	**Med**	7	21	0	0	10	27	0	1
	SD	9.4	17.4	0	0	9.3	17	0	0.52
	Mean	1.6	9.9	0.11	0.22	5.3	12	0	0.22
DPSF	**Med**	1	6	0	0	2	5	0	0
	SD	2	5.6	0.33	0.66	8	12.5	0	0.44
	Mean	3.3	11.8	0	0.67	8	5.22	0	0.56
DPNF	**Med**	0	12	0	0	5	3	0	0
	SD	4.6	12	0	2	9.3	6.8	0	1.66

Note: S. = Substitution; O. = Omission; D. = Distortion; A. = Addition

Table 10

Frequency Analysis of SODA Errors for Kannada Non-Sense Syllable Sequences in the Acquisition Phase for the Last 10 Trials

	6 syllables				9 syllables			
Groups	**S.**	**OM.**	**DI.**	**AD.**	**S.**	**OM.**	**DI.**	**AD.**
MPSF	16	36	0	0	6	52	6	6
MPNF	34	73	0	0	42	122	1	0
DPSF	2	26	0	0	10	27	0	0
DPNF	12	36	0	1	22	22	0	0

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). S. = Substitution; OM. = Omission; DI. = Distortion; AD. = Addition

Table 11

Frequency Analysis of SODA Errors for Kannada Non-Sense Syllable Sequences in the Acquisition Phase for the Last 30 Trials

	6 syllables				9 syllables			
Groups	**S.**	**OM.**	**DI.**	**AD.**	**S.**	**OM.**	**DI.**	**AD.**
MPSF	24	98	5	3	21	177	11	45
MPNF	85	209	0	0	88	228	0	5
DPSF	14	89	1	2	48	108	0	2
DPNF	30	106	0	6	72	47	0	5

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). S. = Substitution; OM. = Omission; DI. = Distortion; AD. = Addition

A) Substitution

Kruskal Wallis test was used to check the effect of practice conditions on the Kannada non-sense syllable sequence for substitution error in acquisition phase for 10 and 30 trials separately. Practice and feedback conditions did not differ for the substitution error of syllable targets for 30 trials across syllable lengths [6 syllable [$\chi^2(3) = 5.6$, $p = 0.131$] and 9 syllables [$\chi^2(3) = 5.06$, $p = 0.167$]. However, Practice and feedback conditions showed significant differences across both 6 syllable [$\chi^2(3) = 9.13$, $p = 0.02$] and 9 syllables nonsense sequences for 10 trials [$\chi^2(3) = 8.59$, $p = 0.03$].

Further Mann-Whitney test was used, only for 10 trials, to investigate which groups have significant differences across syllable length conditions. For 6 syllable length condition, differences were observed between MPNF vs. DPSF (MPNF group showed more substitution error); MPNF vs. DPNF (MPNF showed high substitution error). Results were not statistically significant when MPSF vs. MPNF; MPSF and DPSF; MPNF vs. DPNF and DPSF vs. DPNF groups were compared.

For 9 syllable length, Results were highly significant when substitution was compared for MPSF vs. MPNF; MPNF vs. DPSF groups. The overall trends observed for 30 were comparable to the 10 trial comparisons where summary feedback produced less substitution error and distributed practice groups outperformed massed practice conditions. Table 12 shows the Mann-Whitney results for the substitution errors across syllable lengths for last 10 trials of the acquisition/Practice phase.

Table 12

Mann-Whitney Results for Between Group Comparison of Substitution for 10 Trials in the Acquisition Phase

Practice and Feedback conditions	6 syllables			9 syllables		
	U	Z	*p* value	U	Z	*p* value
MPSF vs MPNF	21	1.8	0.71	10	2.7	0.007**
MPSF vs DPSF	38	0.24	0.8	37	0.34	0.733
MPSF vs DPNF	34.5	0.63	0.52	36	0.42	0.66
MPNF vs DPSF	11	2.7	0.005**	14	2.3	0.017**
MPNF vs DPNF	20	1.8	0.059*	22	1.6	0.105
DPSF vs DPNF	27	1.37	0.171	34	0.58	0.56

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

B) Omission

Kruskal Wallis test was used to check the effect of acquisition/practice and feedback conditions on the Kannada non-sense syllable sequence for omission type of error in acquisition phase for 10 and 30 trials separately. Practice and feedback conditions did not differ for the omission error of syllable targets for 30 trials across syllable lengths [6 syllable ($\chi^2(3) = 3.4$, p =0.329] and 9 syllables ($\chi^2(3) = 5.58$, p =0.134)]. However, significant differences were observed for 9 syllable nonsense sequences for 10 trials [$\chi^2(3) = 8.29$, $p = 0.040$] but not for 6 syllable sequences [χ^2 (3) = 5.7, p =0.125].

Further Mann-Whitney test was used, only for 10 trials, to investigate which groups have significant differences for 9 syllable length. Differences were observed between MPNF vs. DPSF group (MPNF showed more omission error); MPNF vs.

DPNF (MPNF showed more omissions than DPNF). Also, distributed practice along with summary feedback outperformed the massed practiced groups. Other comparisons were statistically insignificant (MPSF vs. MPNF; MPSF vs. DPSF; MPSF vs. DPNF and DPSF vs. DPNF groups). Table 13 shows the Mann-Whitney results for the omission errors across for 9 syllable lengths for last 10 trials of the acquisition/practice phase.

Table 13

Mann-Whitney Results for Between Group Comparison of Omission for 10 Trials in the Acquisition Phase

Practice and Feedback conditions	**9 syllables**		
	U	**Z**	***p* value**
MPSF vs MPNF	22	1.63	0.1
MPSF vs DPSF	26	1.25	0.21
MPSF vs DPNF	24	1.47	0.147
MPNF vs DPSF	16	2.2	0.02*
MPNF vs DPNF	15	2.27	0.02*
DPSF vs DPNF	39	0.091	0.92

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

C) Distortion

Kruskal Wallis analysis did not show differences in the distortion errors between the groups for 10 trials across nonsense syllable lengths [6 syllable ($\chi^2(3) = 0$, p =1.00) and 9 syllables ($\chi^2(3) = 3.96$, p =0.26). However, practice and feedback conditions showed significant differences in 9 syllables of 30 trials [$\chi^2(3) = 16.83$, p = 0.001], but not for 6 syllables sequences [χ^2 (3) = 2.06, p =0.56]. Follow up analysis using Mann-Whitney test revealed statistically significant differences between MPSF vs. MPNF; MPSF vs. DPSF and MPSF vs. DPNF groups. Interestingly, only MPSF group showed more distortion type of errors compared to all other groups. In fact, other than MPSF, all other groups showed 'zero' mean errors on distortions while repeating the non-sense syllable sequences of 9 syllable length. Table 14 shows the Mann-Whitney results for distortion errors of 9 syllable length across all the 30 trials of acquisition/practice phase.

Table 14

Mann-Whitney Results for Between Group Comparison of Distortion for 30 Trials in the Acquisition Phase

Practice and Feedback conditions	9 syllables		
	U	Z	*p* value
MPSF vs MPNF	18	2.5	0.012**
MPSF vs DPSF	18	2.5	0.012**
MPSF vs DPNF	18	2.5	0.012**
MPNF vs DPSF	40	0	1
MPNF vs DPNF	40	0	1
DPSF vs DPNF	40	0	1

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

D) Addition

Kruskal-Wallis analysis did not show any practice or feedback effect on addition error for 30 trials across syllable length conditions [6 syllables ($\chi2(3) = 2.01$, $p = 0.57$) and 9 syllables ($\chi2(3) = 4.5$, $p = 0.209$). However, differences were observed for practice and feedback conditions for 9 syllables [$\chi2(3) = 9.5$, $p = 0.23$] but not for a 6-syllable nonsense sequence [$\chi2(3) = 3.0$, $p = 0.39$] for 10 trials.

Further Mann-Whitney test was used, only for 10 trials, to investigate which groups have significant differences for 9 syllable length. Follow up analysis using Mann-Whitney test revealed marginal significant differences between MPSF vs. MPNF; MPSF vs. DPSF and MPSF vs. DPNF groups where the MPSF group showed more addition type of error compare to all other groups. here again, massed practice group showed more addition type of error compared to distributed groups.

Table 15

Mann-Whitney Results for Between Group Comparison of Addition for 30 Trials in the Acquisition Phase

Practice and Feedback conditions	**9 syllables**		
	U	**Z**	***p* value**
MPSF vs MPNF	27	1.83	0.06#
MPSF vs DPSF	27	1.83	0.06#
MPSF vs DPNF	27	1.83	0.06#
MPNF vs DPSF	40	0	1
MPNF vs DPNF	40	0	1
DPSF vs DPNF	40	0	1

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).
= Marginal statistical significance

2. To investigate the speech motor learning of nonsense Kannada sequence during the practice phase as a function of syllable length (6 vs9 syllables).

Wilcoxon signed ranks test was carried out in order to look for the effect of syllable length across each group. In MPSF group, syllable length effect was seen only for duration (z=2.66, $p < 0.01$) and PCC (z=2.22, p=0.026) across 10 trials. Trends were similar even when groups were compared for 30 trials [Duration (z=2.66, $p < 0.01$) and PCC (z=2.52, p=0.012)].

In MPNF group, significant syllable length effect was seen for a) absolute duration (z=2.66, p<0.01), b) PCC (z=1.99, P=0.046) and c) omission errors (z=2.37, p=0.018) for last 10 trails. Whereas the syllable length effect was observed for a) duration (z=2.66, $p < 0.01$) and b) PVC (z=1.95, p=0.050) and c) addition errors (z=2.23, p=0.025) for 30 trials.

In the DPSF group, a significant difference was seen only with duration (z = 2.66, p < 0.01) in both 10 and 30 trials. In the DPNF group, significant differences were seen with a) absolute duration (z = 2.66, p<0.01) and b) omission errors (z = 2.37, p=0.018) for the last 10 trials, whereas for the 30 trials, a difference was seen with duration (z = 2.66, p<0.01) and PCC (z = 2.05, p=0.041).

3. The Effect of Practice and Feedback Conditions on the Retention of Kannada Non-Sense Syllable Sequence

A) Absolute Duration

Kruskal Wallis analyses of Practice and feedback conditions on the non-sense syllable sequence for absolute duration revealed significant differences for only 6 syllables [χ^2 (3) = 10.44, p = 0.015] but not for 9 syllable sequences [χ^2 (3) = 3.625, p = 0.305]. Further Mann-Whitney test was done to investigate which groups exactly have significant differences for 6 syllable length. Marginal significance was seen between MPNF & MPSF groups, whereas highly significant differences were observed for MPNF vs. DPSF and MPNF vs. DPNF groups. Result suggested that, massed practice without feedback group was least close to achieve the durational target in comparison to other groups. Also, massed practice with summary feedback showed better retention of absolute duration than distributed practice without any feedbacks. Descriptive statistics were carried out to estimate the mean, standard deviation (SD) and median, for both 6 and 9 syllables for the retention phase. Table 16 shows the descriptive statistics for the same. Table 17 shows the Mann-Whitney results for the absolute duration in the retention phase.

Table 16

Descriptive Statistics of Absolute Duration across 6 and 9 Syllable Non-Sense Sequences in the Retention Phase

Groups	**6 Syllables**			**9 Syllables**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
MPSF	0.79	0.87	0.35	0.99	1.12	0.96
MPNF	1.06	1.05	0.23	0.71	0.0	1.03
DPSF	0.77	0.76	0.99	1.07	1.09	0.18
DPNF	0.70	0.76	0.28	1.21	1.15	0.25

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Table 17

Mann-Whitney Results for Between-Group Comparisons of Absolute Duration in the Retention phase

Practice and Feedback conditions	6 syllables			9 syllables		
	U	**Z**	***p* value**	**U**	**Z**	***p* value**
MPSF vs MPNF	19	1.9	0.057*	31	0.8	0.40
MPSF vs DPSF	27	1.1	0.23	38	0.17	0.85
MPSF vs DPNF	29	1.01	0.3	33	0.66	0.057*
MPNF vs DPSF	7	2.9	0.003**	23	1.51	0.12
MPNF vs DPNF	4	3.23	0.001**	21	1.74	0.08
DPSF vs DPNF	40	0	1	29	0.97	0.331

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

B) Percentage Consonants Correct (PCC)

Kruskal Wallis test was used to analyse the effect of practice and feedback conditions on the non-sense sequence in terms of PCC, significant difference between the groups were seen only for 9 syllable sequence [χ^2 (3) = 9.025, p =0.029)] but not for 6 syllable non-sense sequences [χ^2 (3) = 4.3, p =0.22)].

Further analysis using Mann-Whitney test revealed statistically significant difference between MPSF and DPSF groups, and a highly significant difference was seen between MPNF and DPNF. Here, distributed practice condition showed higher percentage of correct production of consonants compared to massed practice condition irrespective of feedback condition. Descriptive statistics were carried out to estimate the mean, standard deviation (SD) and median, across 6 and 9 syllables for the retention phase. Table 18 shows the descriptive statistics and table 19 represents the Mann-Whitney results for the PCC.

Table 18

Descriptive Statistics of PCC across 6 and 9 Syllable Non-Sense Syllable Sequences in the Retention Phase

Groups	6 Syllables			9 Syllables		
	Mean	Median	SD	Mean	Median	SD
MPSF	69.1	100	42.9	49.37	66.66	41.61
MPNF	98.1	100	5.55	72.83	100	42.71
DPSF	92.6	100	22.2	88.88	100	22.22
DPNF	86.04	100	33.0	95	100	5.9

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Table 19

Mann-Whitney Results for Between Group Comparison of PCC in the Retention phase

Practice and Feedback conditions	6 syllables			9 syllables		
	U	Z	*p* value	U	Z	*p* value
MPSF vs MPNF	25	1.6	0.09	23	1.5	0.12
MPSF vs DPSF	26	1.6	0.10	13	2.4	0.014**
MPSF vs DPNF	34	0.60	0.54	10	2.7	0.006**
MPNF vs DPSF	40	0.08	0.93	33	0.70	0.48
MPNF vs DPNF	31	1.15	0.24	34	0.58	0.55
DPSF vs DPNF	32	1.03	0.30	40	0.051	0.95

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

C) Percentage Vowels Correct (PVC)

Kruskal Wallis test was done in order to look for the effect of practice and feedback condition on the non-sense sequence for PVC, statistically significant differences was seen for the retention phase only for 9 syllable sequences [$\chi2$ (3) = 9.92, p =0.019] but not for 6syllable sequence [χ 2 (3) = 1.92, p =0.57]. Mann-Whitney analysis as shown in table 20 for 9 syllable non-sense sequences. Significant difference was observed between MPSF vs. DPNF groups MPNF vs. DPNF groups, and there was marginal statistical significance between MPSF & DPSF. No other comparisons showed statistical significance. Descriptive statistics of the PVC across 6 and 9 syllable lengths for the retention phase is presented as table 20. Table 21 shows the Mann-Whitney results for the PVC for the retention phase.

Table 20

Descriptive Statistics of PVC across 6 and 9 Syllable Non-Sense Syllable Sequences in the Retention Phase

Groups	**6 Syllables**			**9 Syllables**		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**
MPSF	66.4	100	44.1	49.37	66.66	41.61
MPNF	87.0	83.3	16.2	56.7	77.77	41.07
DPSF	81.7	90.00	27.35	82.95	88.88	20.96
DPNF	66.3	77.77	36.4	92.5	88.88	8.12

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

Table 21

Mann-Whitney Results for between group comparison of PVC in the Retention phase

Practice and Feedback conditions	6 syllables			9 syllables		
	U	Z	*p* value	U	Z	*p* value
MPSF vs MPNF	36	0.42	0.66	36	0.40	0.68
MPSF vs DPSF	37	0.33	0.74	19	1.9	0.055*
MPSF vs DPNF	34	0.54	0.58*	13	2.50	0.012**
MPNF vs DPSF	40	0.046	0.96	22	1.65	0.09
MPNF vs DPNF	25	1.40	0.15	13	2.4	0.013**
DPSF vs DPNF	28	1.12	0.26	32	0.78	0.43

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF).

D) Substitution Omission Distortion and Addition (SODA) errors

Kruskal Wallis test was done in order to analyze the effect of practice and feedback conditions on the non-sense sequence for SODA errors, significant difference between the groups were seen only for omission error in 9 syllable sequences [$\chi^2(3) = 13.32$, $p = 0.004$] with no such differences noted for 6 syllable sequences. Further Mann-Whitney test was carried out to investigate which groups differed in the 9 syllable length conditions. Highly significant difference was seen when omission errors were compared between MPSF & DPSF; MPSF & DPNF; MPNF & DPSF and MPNF&DPNF groups. Massed practice groups, regardless of feedback conditions, showed higher number of omissions compared to any other distributed condition practice groups. Table 22 and 23 shows the descriptive statistical data for SODA errors across 6 and 9 syllable lengths in the retention phase. Table 23 shows the frequency analysis data for the SODA errors and table 24 shows the Mann-Whitney results.

Table 22

Descriptive Statistics of SODA for 6 Syllable Non-Sense Sequences in the Retention Phase

SODA Errors	MPSF			MPNF			DPSF			DPNF		
	Mean	**Med**	**SD**	**Mean**	**Med**	**SD**	**Mean**	**Med**	**SD**	**Mean**	**Med**	**SD**
S	5.56	0	14.88	0.56	0	1.66	5.33	0	13.12	2.22	0	3.42
0	16.77	0	23.2	4.44	5.0	6.34	2.56	0	3.53	9.22	0	19.7
D	0	0	0	0	0	0	0	0	0	0.56	0	1.67
A	0	0	0	1.11	0	3.33	0	0	0	0	0	0

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). S. = Substitution; O. = Omission; D. = Distortion; A. = Addition

Table 23

Descriptive Statistics of SODA for 9 Syllable Non-Sense Sequences in the Retention Phase

SODA	MPSF			MPNF			DPSF			DPNF		
Errors	**Mean**	**Med**	**SD**	**Mean**	**Med**	**SD**	**Mean**	**Med**	**SD**	**Mean**	**Med**	**SD**
S	2.78	0	5.65	1.11	0	3.33	6.22	0	11.4	4.67	5	5
0	42.78	30	39.7	26.56	5	36.2	3.22	0	5.6	2.78	0	5.07
D	0	0	0	0	0	0	0	0	0	0	0	0
A	0	0	0	0	0	0	0	0	0	1.11	0	0.33

Note: S. = Substitution; O. = Omission; D. = Distortion; A. = Addition

Table 24

Frequency analysis of SODA errors for Kannada Non-Sense Syllable Sequences in the Retention phase

	6 syllables				**9 syllables**			
Groups	**S.**	**O.**	**D.**	**A.**	**S.**	**O.**	**D.**	**A.**
MPSF	50	150	0	0	25	385	0	0
MPNF	5	40	0	10	10	239	0	0
DPSF	48	23	0	0	56	29	0	0
DPNF	20	48	5	0	42	25	0	1

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). S. = Substitution; O. = Omission; D. = Distortion; A. = Addition

Table 25

Mann-Whitney Results for Between Group Comparison of Omission Type of Error in the Retention phase

Practice and Feedback conditions	**6 syllables**			**9 syllables**		
	U	**Z**	***p* value**	**U**	**Z**	***p* value**
MPSF vs MPNF	36	0.42	0.66	30	0.94	0.34
MPSF vs DPSF	33	0.72	0.46	10	2.73	0.006**
MPSF vs DPNF	37	0.34	0.73	10	2.75	0.006**
MPNF vs DPSF	34	0.62	0.53	16	2.23	0.025*
MPNF vs DPNF	37	0.33	0.73	16	2.25	0.024*
DPSF vs DPNF	38	0.24	0.80	40	0	1

Note: massed practice with no feedback (MPNF), massed practice with summary feedback (MPSF), distributed practice with no feedback (DPNF), and distributed practice with summary feedback (DPSF). * = $p < 0.05$; ** = $p < 0.01$

The next objective of this study was to investigate the speech motor learning of nonsense Kannada sequence during the practice phase as a **function of syllable length (6 vs9 syllables)**. Wilcoxon signed ranks test was carried out in order to look for the difference in the performance of same subject between 6 and 9 syllables. Significant difference was seen only with Omission type of error (z=1.97, *p*=0.049) in MPSF group, only with duration (z=2.6, *p*<0.001) in DPSF group, and in DPNF group significant difference was seen in duration (z=2.54, *p*=0.01) and PVC (z=2.36, *p*=0.01).

4. Comparison of Acquisition/Practice and Retention Phases of Speech Motor Learning for Kannada Non-Sense Syllable Sequences

A) Absolute Duration

Wilcoxon Signed Rank test was used to compare the absolute duration between the acquisition and retention phases of the last 10 trials, statistically significant differences were observed only for MPNF (z = 2.6, *p* <0.01) and DPSF (z = 2.4, *p* = 0.01) for 6 syllables sequences. Acquisition and retention of nine-syllable utterances were identical. Poor retention of durational target (Target = 0.6 seconds) was observed in both MPNF and DPSF, but in the MPNF group it was more pronounced. Figure 1 displays descriptive statistical data across phases for 6 and 9 syllable length conditions for each group.

Figure 1.

Comparison of Mean Absolute Duration Between the Last 10 Trials of Acquisition with Retention Phases across Syllable Lengths

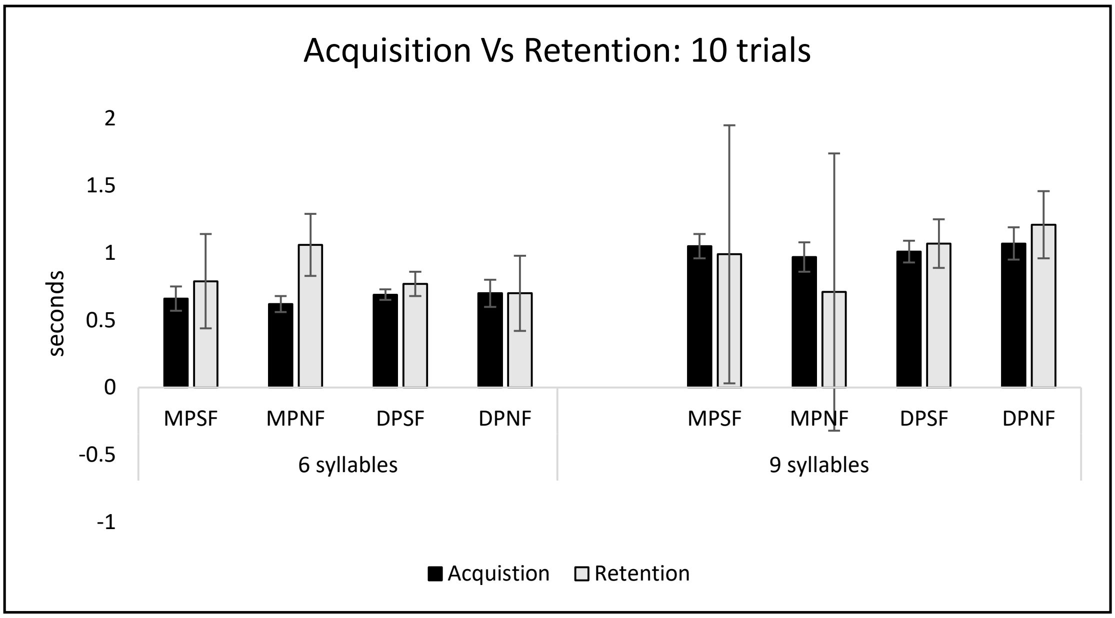
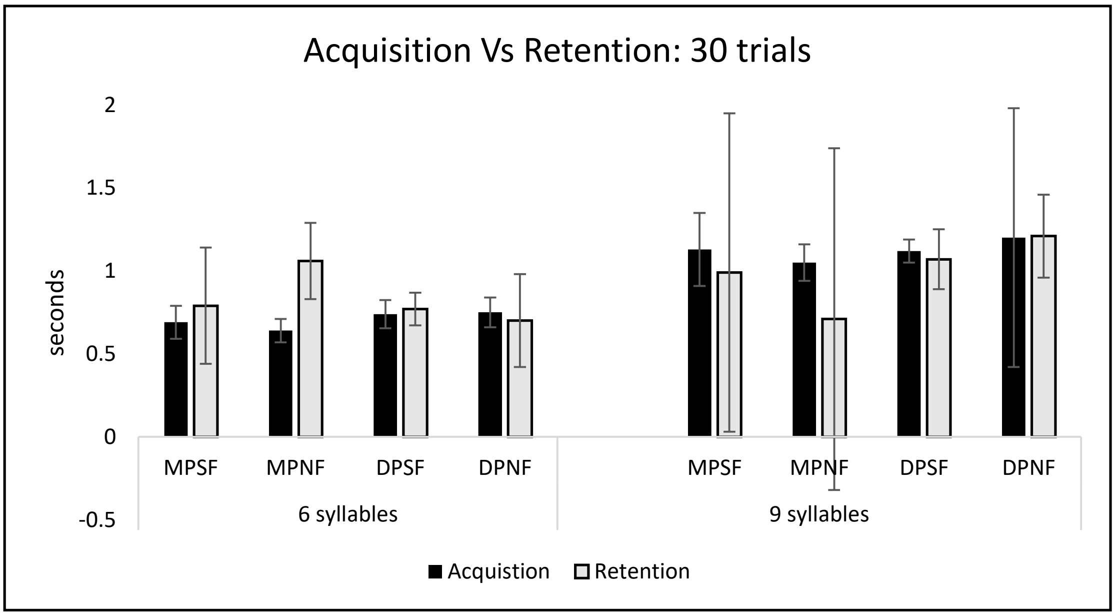


Figure 2

Comparison of Mean Absolute Duration Between the 30 Trials of Acquisition with Retention Phases across Syllable Lengths



When all the trials of the acquisition phase were considered (all 30 trials) and compared, the trends were partially similar where MPNF (z = 2.6, $p < 0.01$) showed poor retention of duration in 6 syllable sequences, but DPSF did not show any variations (z = 1.24, $p = 0.21$). Even though there was no statistical significance, high standard deviations were observed for the MPSF and MPNF groups of 9-syllable utterances, and retention of the durational target was poorer for these groups. Figure 2 displays the descriptive statistics for the absolute duration across acquisition and retention phases.

B. Percentage Consonants Correct (PCC)

Statistically, the Wilcoxon signed ranks test revealed significant differences between the phases of speech motor learning for PCC in the MPSF group for only 9 syllable sequences across trials [10 trials: (z = 2.54, p = 0.01) ; 30 trials: (z = 2.54, p = 0.01)]. Even though not statistically significant, these trends were observed for all the conditions in the massed practice group. Interestingly, using summary feedback with massed practice (MPSF) showed a clear decline in maintaining accuracy in the correct production of consonants. Descriptive statistics were carried out for PCC to estimate the mean and standard deviation for both 6 and 9 syllables across trials for the acquisition and retention phases. These are represented as figure 3 and 4.

Figure 3

Comparison of Mean PCC between the Last 10 Trials of Acquisition with Retention Phases across Syllable Lengths

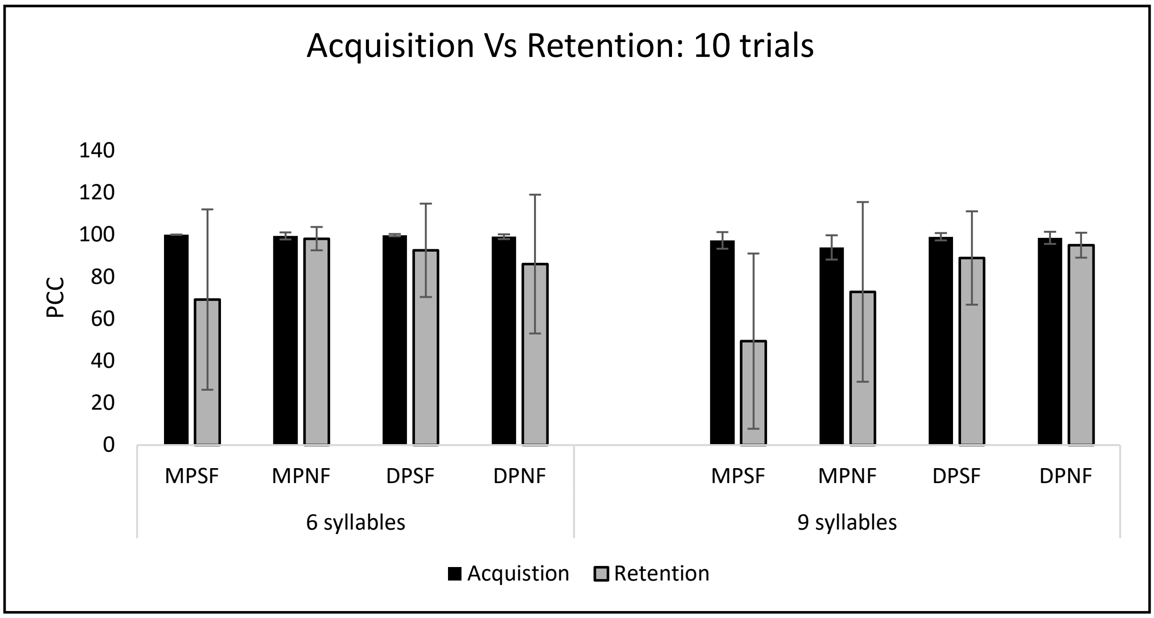
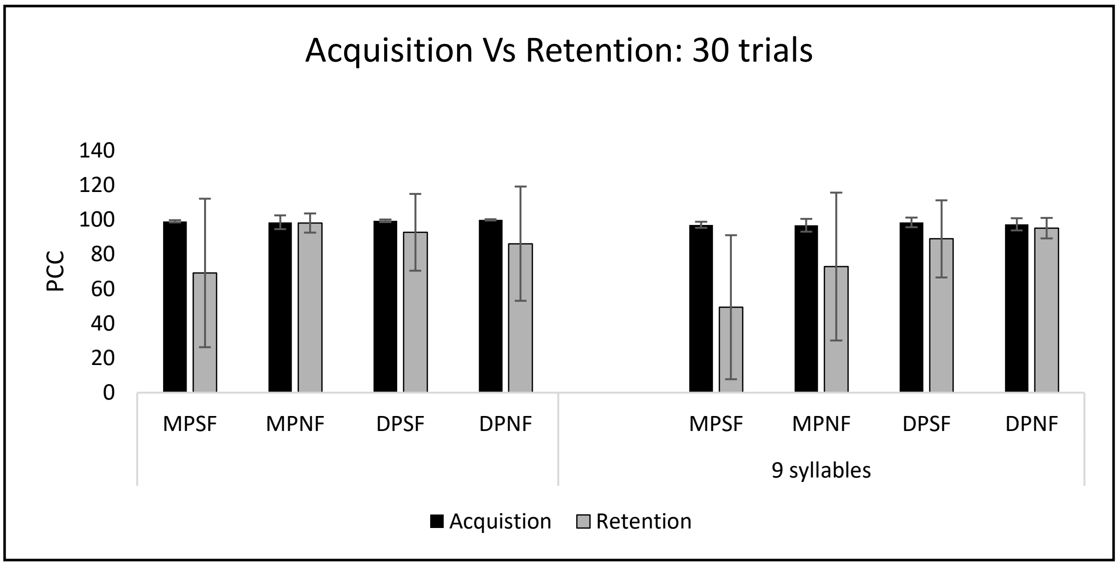


Figure 4

Comparison of Mean PCC *between the 30 Trials of Acquisition with Retention Phases across Syllable Lengths*



C. Percentage of Vowels Correct (PVC)

Wilcoxon signed ranks test was carried out to compare the PVC between acquisition and retention phases. Significant differences were observed in the MPSF group only for the 9-syllable sequence across trials [10 trials: (z=2.31, *p* = 0.02); 30 trials: (z = 2.07, p = 0.038)] and in the DPNF group (z=1.96, *p* = 0.05) only for the 6-syllable sequence across both 10 and 30 trials. Even though not statistically significant, an overall trend of poor vowel accuracy was observed in the retention phases of MPNF and MPSF groups. Descriptive statistics for the PVC is shown as figure 5 and 6 across syllable for last 10 and 30 trials acquisition and retention.

Figure 5

Comparison of Mean PVC between the Last 10 Trials of Acquisition with Retention Phases across Syllable Lengths

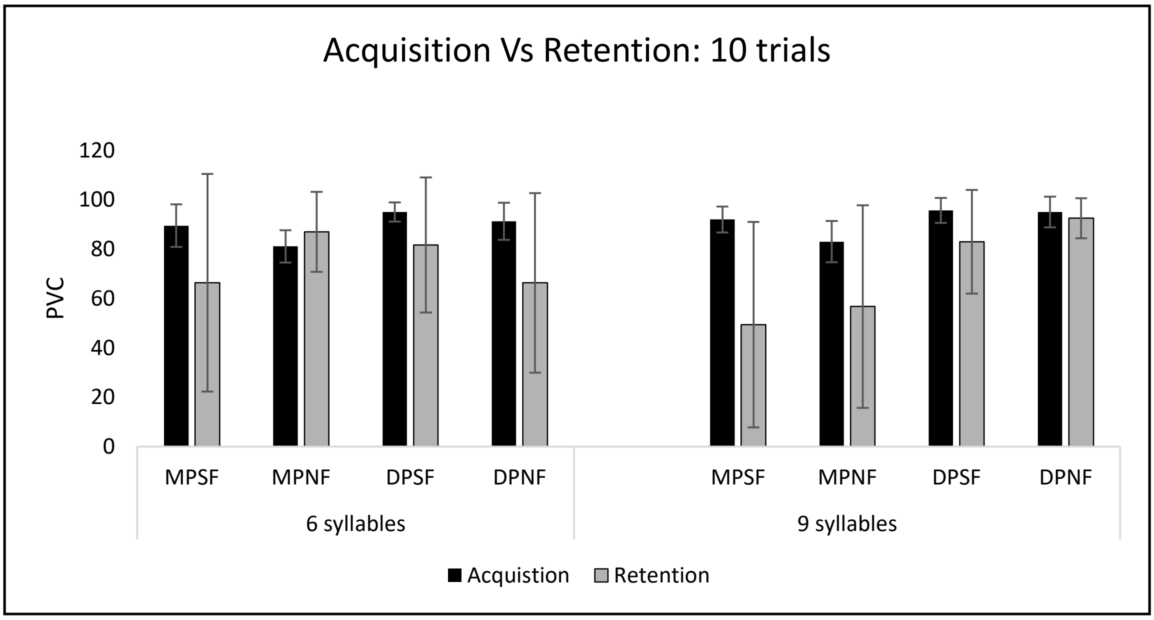
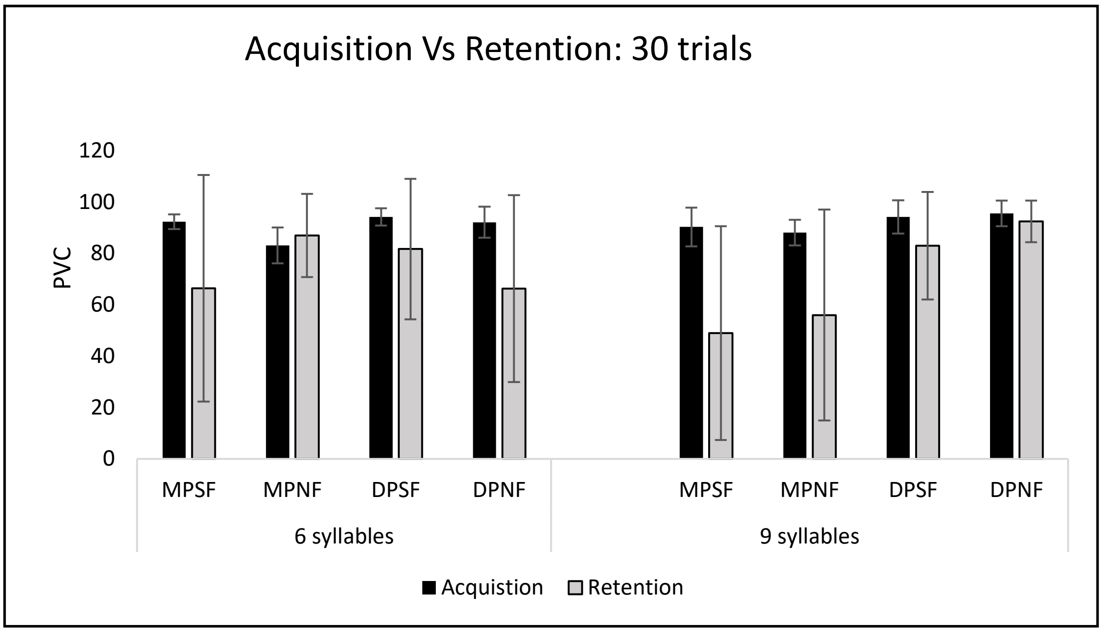


Figure 6

Comparison of Mean PVC between the Last 10 Trials of Acquisition with Retention Phases across Syllable Lengths



D) Substitution errors

The Wilcoxon signed ranks test was conducted to compare the substitution error type of the same subject during the acquisition and retention phases. Significant differences were observed in the MPNF group (Z=2.21, p=0.02) for 6 syllable sequence for 10 and 30 trails (Z=2.21, p=0.01) and in the DPNF group (Z=1.96, p=0.05) for 6 syllable sequence for both 10 and 30 trials. Only 30 trials revealed a difference in the 9-syllable sequence (Z=2.19, p=0.02). Here, MPNF produced less substitution errors in retention compared to acquisition phase.

Descriptive statistics for the above is shown as figure 7 and 8 across 10 and 30 trials

Figure 7

Comparison of Mean Substitution Errors between Last 10 Trials of Acquisition with Retention Phases for Practice and Feedback Conditions across Syllable Lengths

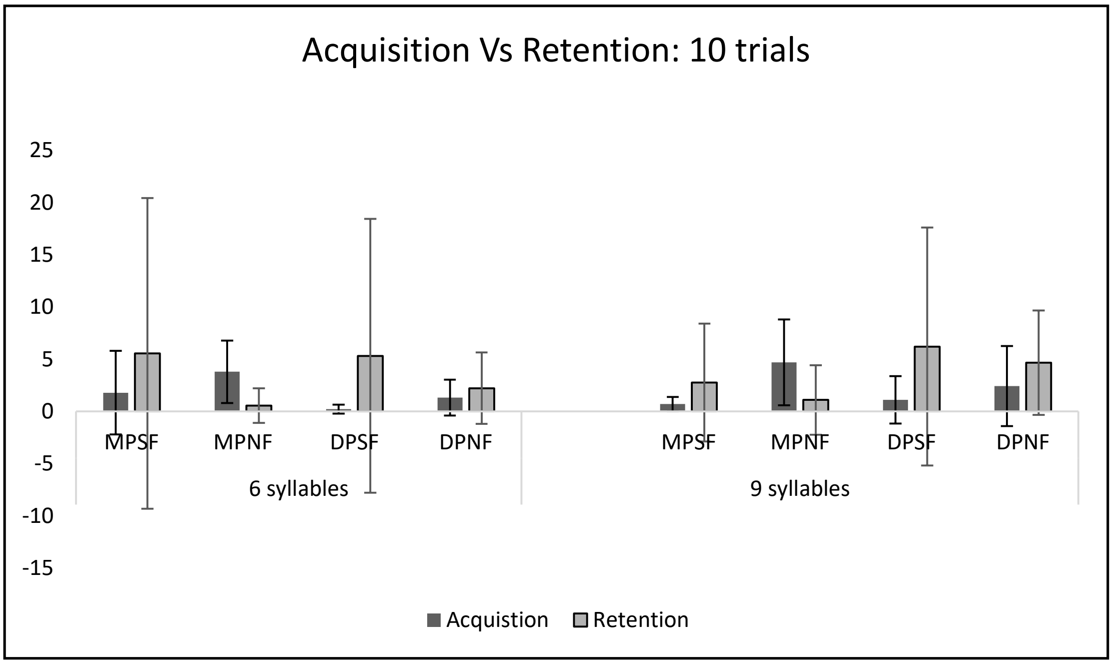
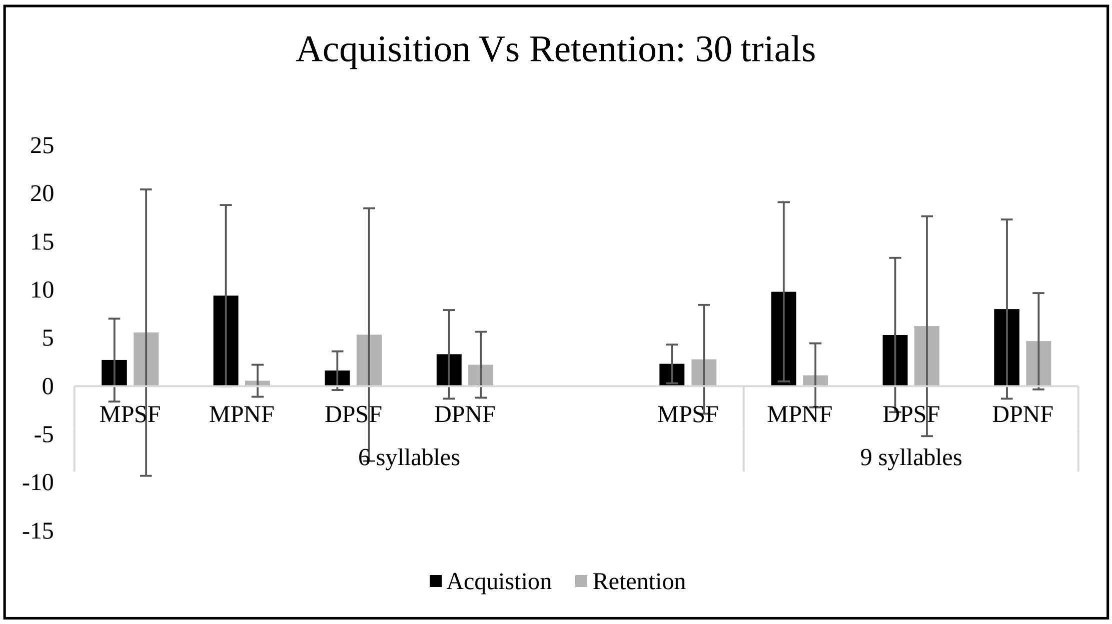


Figure 8

Comparison of Mean Substitution Errors between 30 Trials of Acquisition with Retention Phases for Practice and Feedback Conditions across Syllable Lengths



E) Omission Errors

Wilcoxon signed ranks analysis revealed significant differences between acquisition and retention trials for the MPNF group (z = 2.52, *p* = 0.01) and DPSF group (z = 2.67, *p*= 0.01) for 6 syllable and (z = 2.52, *p* = 0.01) for 9 syllable sequence for 30 trials only. In all the observed differences, omission errors reduced from acquisition to retention trials indicating efficient speech motor learning in these practice conditions. Speech motor learning with respect to omissions were marginally consistent in distributed practice than massed practice.

Figure 9

Mean of Omission Error Between Acquisition and Retention Phases for practice and feedback conditions across Syllable Lengths for the 10 Trials

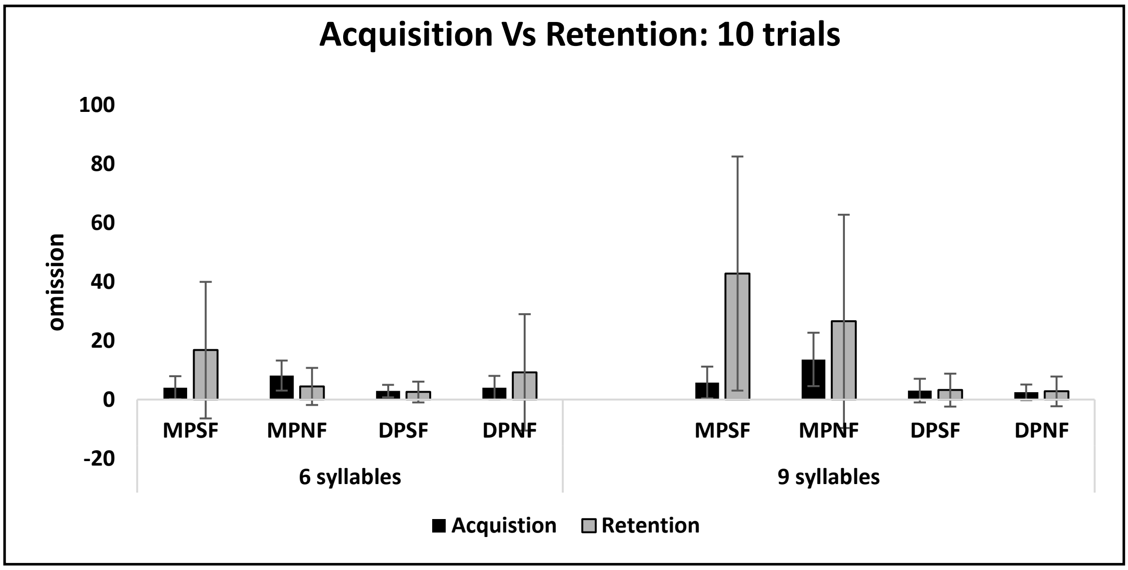
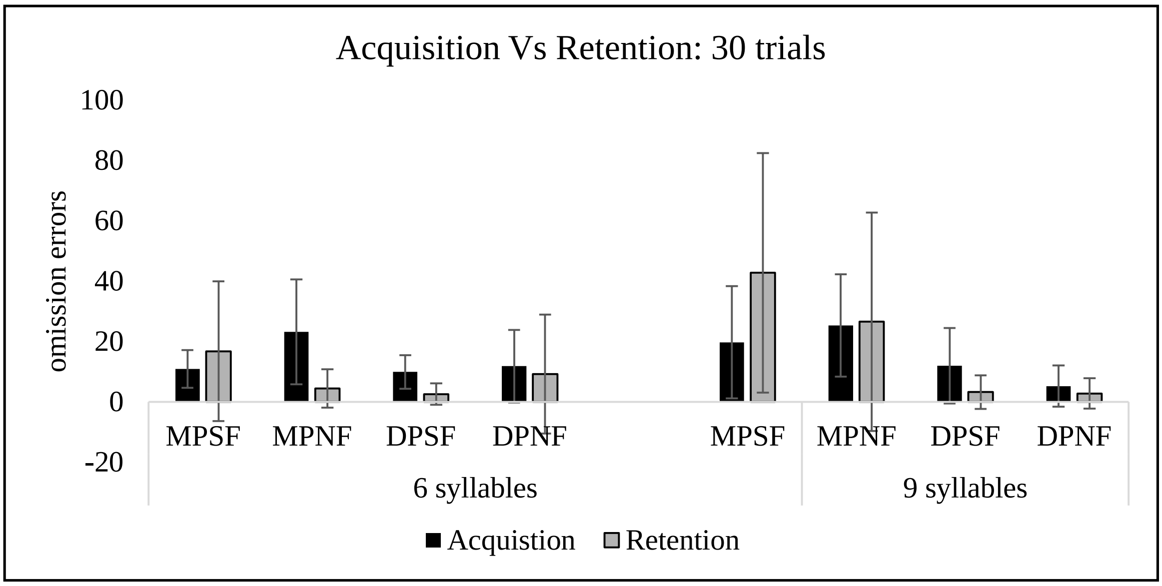


Figure 10

Mean of Omission Error Between Acquisition and Retention Phases for practice and feedback conditions across Syllable Lengths for the 30 Trials



Wilcoxon signed ranks test was carried out in order to compare the **distortion type** of error of same subject, between acquisition and retention phase. Significant difference was seen in MPNF group (Z=2.04, *p*=0.04) for 9 syllable sequence for 30 trails only. Wilcoxon signed ranks test was carried out in order to compare the addition type of error of same subject, between acquisition and retention phase. Significant difference was seen in MPNF group (Z=2.2, *p*=0.02) for 9 syllable sequence for 30 trails only.

CHAPTER 5

DISCUSSION

The research presented is novel in a few different ways. First, this is the one among the first experimental studies to investigate the effect of practice distribution (massed vs distributed) together with feedback condition (with and without summery feedback) in learning a novel speech task such as non-sense Kannada syllable sequences with varying syllable lengths. Secondly, this study also measures the spatial (PCC, PVC, SODA) and temporal (absolute duration) aspects of speech motor learning. Therefore, this study has together investigated the interactions between different practice conditions with feedbacks coupled with varying syllable length on typical Kannada adults.

Duration

Investigation of the speech motor learning of nonsense Kannada word sequences during the *Acquisition phase* as a function of Practice Distribution (Massed versus Distributed) and Feedback Condition (with and without summary feedback) for absolute duration was significant only in 30 trials across the syllable lengths. The target kept for 6 syllables was 0.65 seconds, whereas for the 9 syllables, a duration of 1 second was targeted. The *immediate performance* or acquisition was better in the massed practice trials compared to distributed practiced trials. Also, the immediate performance was better when distributed practice was coupled with summary feedback. This indicated that both massed and distributed practice trials could be used to improve the acquisition of a new speech motor task. However, it was also observed that for shorter syllables, type of practice and feedback conditions might not play a significant role during motoric acquisition. But the same cannot be generalized to longer syllable lengths where consistent differences were observed for practice conditions where massed practice outperformed distribute practice and summary feedback always improved the speech motoric acquisition. All these findings are possibly hinting at an interaction between practice condition, feedback and syllable lengths. We *reject the null hypothesis* as differences in acquisition of nonsense syllables were observed between the groups.

With regard to the *Retention phase* differences were clear for 6 syllable lengths compared to 9 syllable conditions. This hints that as the syllable length increases, retaining the target is regardless of practice condition as well as on feedback. With regard to 6 syllable lengths, the group with the distributed practice maintained the target absolute duration (0.65 seconds) compared to massed practice group. This supports the contention of Maas et al (2008) that distributed practice helps in efficient retention of learned targets during the acquisition phase. Further studies are required to understand the effects of syllable lengths on retention as the current study findings did not reveal consistent results across the syllable lengths undertaken.

When compared between *acquisition and retention phases,* massed practice groups had taken longer duration than the target, particularly in 6 syllable conditions. This trend was also observed for 9 syllables for MPNF but did not reach statistical significance. Together, these findings indicates that *massed practice trials* did not help in retaining the durational targets learnt during the acquisition phase. It also has to be noted that these trends were significant particularly for 6 syllable lengths and not for 9 syllable lengths. In continuation of the findings, MPSF, DPSF and DPNF all maintained the learnt durational targets as the acquisition phase did not differ with the retention phase. Therefore, augmenting the massed practice with *summary feedback* and any form of distributed practice (with or without summary feedback) was observed to be consistent in their maintenance of durational targets. Efficient learning of durational targets in the massed practice is supported by Lee Silverman Voice Therapy (LSVT) treatment protocols applied on Parkinson's disease patients which is most commonly presented in the form of massed practice sessions across several studies (Ramig et al., 2001; Spielman et al., 2007). However, key press input tasks employed in non-speech motor studies have supported the use of distributed practise because the taught key patterns were effectively retained after 9 months in the distributed practise group (Baddeley and Longman, 1978; Kwon et al., 2015; Shea et al., 1979).

The summary feedback delivered in this study was delayed in nature as the investigator consumed time to input the durational targets into Microsoft excel software to show the durational changes for every 5 trials in the summary feedback group.

2. Percentage Consonant Correct (PCC)

Investigation of the speech motor learning of nonsense Kannada word sequences during the ***Acquisition phase*** as a function of practice distribution (Massed versus Distributed) and feedback condition (With and without summary feedback) for PCC did not show any significant differences across syllable lengths and trials analyzed. Across all the practice and feedback conditions, the PCC measure reached the highest performance levels and hence there was no further scope of improvement in the acquisition phase.

In the ***retention phase, statistical*** significance was seen only in 9 syllables wherein distributed practice with summary feedback (DPSF) outperformed massed practice with summary feedback (MPSF). Similarly, when no feedback was provided, DPNF outperformed the MPNF group in the PCC measure.

When compared between *acquisition and retention phases*, massed practice groups showed poor retention of consonants than distributed practice groups, it was interesting to observe that poor retention was seen in MPSF group which was provided with summary feedback. We anticipated that summary feedback would aid in the efficient learning of the consonants practised, but a surprising result was seen, especially when massed practise and summary feedback were combined. Summary feedback during massed practice might be interfering with efficient learning of nonsense syllable and therefore further studies are warranted to measure an interaction between the two.

3. Percentage PVC

Overall comparisons (across syllable lengths and trials considered) revealed that there was high accuracy in the production of vowels in distributed practise group compared to massed practise group. Augmenting the summary feedback for massed practice trials improvised the immediate performance. Interestingly, regardless of feedback, distributed practice groups were comparable in their overall accuracy in the production of vowels. Among all the practise and feedback groups, the immediate performance of *DPSF* group was higher than any other group compared. It could be opined that *distributed practice (with and without summary feedback)* holistically improved the acquisition of vowel targets in this study.

In ***retention phase*** no trends were observed while retaining the vowel targets for 6 syllable lengths. Additionally, similar to PCC, PVC trends were consistent across groups only in 9 syllable sequences. Here again the distributed practice group outperformed in the retention of vowel targets compared to massed practice groups. This could be attributed to the better memory consolidation that occurs during the repeated rehearsals after the training periods (Robertson et al., 2004).

Finally, when both acquisition and retention phases were compared for PVC across syllable length conditions, poor accuracy of vowel production was consistent in the massed practice groups, particularly when the syllable length was increased. At shorter syllable lengths there was an interaction between massed practice with summary feedback which led to poor vowel accuracy. Also, at shorter lengths, distributed practice required summary feedback to maintain the target vowel accuracy.

4. Substitution Errors

We can infer that in the acquisition phase, substitution-type errors persisted until the end of trials in massed practice groups. Augmenting the summary feedback for massed practice trials improved the immediate performance since MPSF had a lesser substitution type of error compared to MPNF. MPNF had more substitution errors than the other groups, and it could be said that distributed practice (with and without summary feedback) improved learning in this study as a whole, while massed practice did not help reduce substitution errors across trials.

In the retention phase, no significant difference was seen across 6 and 9 syllables. This indicated that none of the practice distribution and feedback helped to change the substitution errors. Finally, when both acquisition and retention phases were compared for substitution type of errors across syllable length conditions, significant differences were seen only in MPNF and DPNF groups in 6 syllables for both 10 and 30 trials. Substitution-type errors were corrected by participants in MPNF group in retention phase across syllables but this was not observed in DPNF group.

5. Omission Errors

In the ***acquisition phase***, across the syllable lengths differences were seen between massed and distributed practice. Massed practice group showed more omission errors compared to distributed groups. This was much more pronounced as the *syllable length* increased. This was maintained even during the retention phase where omission errors were still present in the massed practice group, particularly in the 9 syllable length condition. Feedback had no influence as errors did not reduce even in MPSF group. Comparison of both acquisition and retention phases for omission type of error across syllable length showed improvisations in reducing the omission only in shorter syllable lengths but errors persisted for longer syllable (9 syllable lengths), and this was particularly true for massed practice irrespective of feedback conditions. But in DPSF group, even for 9 syllables error were reduced in retention phase. We can infer that massed practiced condition will perform better only for shorter syllables sequence. As per schema theory, we hypothesize that, improved self-rehearsals that occur in distributed practice during the rest periods (gap between the days), may have stabilized the recognition schema and when the target was recalled this stabilized programmes might have reduced the overall errors in their non-sense syllable production.

6. Distortion Errors

In ***acquisition phase***, difference was seen only in 30 trials when compared across the groups i.e. between MPSF vs MPNF; MPSF vs DPSF; MPSF vs DPNF. This result also suggests that massed practice groups had more errors compared to distributed practice whereas these trends were not observed in the retention phase. Trend were not consistent for distortion errors, as distortions are not a typical error expected by an adult who have had years of experience in speech motor production.

Addition Errors

Only marginal differences were seen only in 10 trials when additional errors were compared across the groups. Only MPSF group had addition type of error and this was not seen in retention phase. Similar explanation as that of distortion holds good for addition type of errors, where a typical adult may not show additional errors even in complex production tasks such as recalling the non-sense syllables. Therefore, future studies might target only substitutions and omissions rather than distortions and additions while studying the efficiency of speech motor learning in typical participants. However, these variables could be included while investigating a disordered speech motor control (e.g., dysarthria).

CHAPTER 6

SUMMARY AND CONCLUSIONS

The aim of this study was to find the effect of massed [MPNF (masses practice with no feedback & MPSF(massed practice with summary feedback)] and distributed practice [DPNF(distributed practice with no feedback) & DPSF (distributed practice with summary feedback)] with and without summary feedback (after 5 trials) on speech motor learning in typical Kannada adults. The speech motor learning was examined in *massed practice* condition by practicing 6 and 9 syllable non sense syllable sequence for 30 times each in a day and measured its retention after 3 days. Massed practice condition had 2 groups, one of the groups received feedback in terms of absolute duration, PCC, PVC, and SODA errors (MPSF) and other group did not (MPNF). Similarly, speech motor learning was examined in distributed practice conditions by practicing both 6 and 9 syllable non sense Kannada syllable sequences, which was spread across 3 days,10 times for each day, and measured its retention after 3 days. Similar to massed practice group distributed practice group also further sub divided into 2 groups, with (DPSF) and without feedback (DPNF).

Based on few inclusion and exclusion criteria 36 participants were included in the study. Participants were provided with an auditory and a visual model of both 6 and 9 nonsense syllable targets which were developed based on the frequent Kannada words. In the acquisition phase, participants were instructed to 'repeat the target non-sense sequences shown on the computer screen as accurately as possible within a *fixed duration* of time (either 0.65 seconds or 1.06 seconds). A total of 30 trials were practiced by all the four groups included in the study. For MPSF group, all 30 trials were practiced and summary feedback of the last 2 trials (4^{th} and $5^{th)}$ in terms of 'articulatory accuracy' and 'temporal target' was provided immediately after every 5 trials in a time gap of 2 minutes.

Feedback on the *articulatory accuracy* was provided in terms of a) percentage of consonants correct (PCC) and b) percentage of vowels correct (PVC) c) type of articulatory errors (substitutions, omissions, distortions or additions). The duration of the 4^{th} and 5^{th} trial was showed as a bar graph on the computer screen as *temporal feedback*. A total of 6 summary feedbacks were given to the MPSF participants. For MPNF group, all 30 trials were practiced without any feedback on articulatory accuracy or temporal target.

For distributed practice groups (DPSF and DPNF), the acquisition phase was spread across 3 separate days, wherein only 10 trials were practiced for each day, amounting to a total of 30 trials. Feedback on articulatory and temporal accuracy was provided to the DPSF group twice a day after every 5 trials and the nature of those feedback were similar to the ones provided for the massed practice groups. However, for the DPNF group, speech motor practice was carried out for 3 separate days with 10 trials for each day and no feedbacks were delivered after every 5 trials.

Later, mean percentage consonants correct, mean percentage vowels correct, type of SODA errors (Substitution, Omission, Distortion and Addition) and mean absolute duration of the two non-sense syllable sequences were measured for practice and retention phases across the groups. Kruska Wallis, Mann Whitney U test and Wilcoxon Signed rank test were used to analyze the results using SPSS software.

Major findings of the Study and their Conclusions:

1. **Effects of Speech Motor Practice on the Acquisition of Non-Sense Kannada Syllable Sequences Across Syllable Lengths**

- Significant differences were seen in terms of absolute duration across practice and feedback conditions for shorter non-sense syllable sequences. Here, massed practice group outperformed distributed groups in 6 syllable sequences.
- The effect of speech motor practice on PCC was insignificant, as all the groups showed ceiling effects of highest performance in the production of consonants included in the non-sense syllable sequences.
- There was a significant difference for PVC. The distributed group with summary feedback produced vowels with greater accuracy than the massed group regardless of sequence length.
- There was a significant difference observed for consonant substitution errors. The performances of the distributed practice group were better than those of massed practice. Within massed practice, the group augmented with summary feedback outperformed the group without any feedback.
- There was a significant difference in omission. Massed practice groups showed high omission errors when no feedback was provided on their errors, particularly on 9-syllable non-sense sequence lengths.
- There was a significant difference found for both distortion and addition errors. However, the errors observed here were negligible compared to substitutions and additions. Massed practice groups showed more errors compare to distributed groups regardless of feedback.

2. **Effects of Speech Motor Practice on the Retention of Non-Sense Kannada Syllable Sequences across Syllable Lengths**

- Regardless of practice conditions, significant differences were seen in maintaining the absolute duration as a factor of non-sense sequence syllable lengths. Retention of absolute duration was easier for longer syllable lengths compared to shorter lengths. Among practice conditions, distributed practice clearly maintained the practiced absolute duration in the acquisition phase.
- There was a significant difference seen in retaining the consonant accuracy as measured using PCC for 9 syllables. Here again distributed practice outperformed massed practice regardless of feedback.
- There was a significant difference observed for PVC in 9 syllables sequence. Here again the distributed practice groups outperformed in retention of vowels target compared to massed practiced group.
- Significant difference was seen in omission type of error among SODA error in 9 syllable sequence only. Massed practice regardless of feedback showed higher frequency of errors compared to distributed practice groups.

3. **Effects of Speech Motor Practice between Acquisition and Retention Phases of Non-Sense Kannada Syllable Sequences across Syllable Lengths**

- There was a significant difference in terms of absolute duration when compared between the acquisition and retention phases; massed practice groups had poor maintenance of absolute duration, which was longer than the target fixed, compared to distributed practice groups.
- A significant difference was found for the PCC massed practice group, which showed poorer speech motor learning of consonants than distributed groups.

- A significant difference was found for PVC across syllable lengths. Massed practice showed poor accuracy of vowel production compared to distributed groups, regardless of feedback.
- A significant difference was found for all SODA errors. More errors were seen in the massed practice group compared to the distributed group, regardless of feedback conditions. Higher errors were common as syllable length increased.

Study Implications

- The study's findings have contributed to a better understanding of the effects of practice distribution variables on short term retention of speech motor goals.
- The findings can be replicated across speech motor disorders (voice, fluency articulation, and motor speech disorders) to strengthen the understanding of the practice distribution and its interactions with feedback variables.

Limitations of the Study

- The study used non parametric tests and hence the interactions between the within subject and between subject factors could not be tested.
- Sample size chosen was small for each group.
- Short retention was examined in this study (3 days), and hence generalisation of the learned speech motor targets for longer retention could not be examined as an objective due to time constraints.

Future Directions

- Parametric analysis might provide insight into the interaction effects of the practice distribution and feedback conditions with syllable lengths.
- Only familiar words were used as a base while constructing the non-sense syllable sequences and therefore the effect of motor learning on non-sense syllable sequences based on unfamiliar words needs to be examined further.
- The practice distribution and feedback principles could be manipulated either individually or in combination with therapy techniques used for speech motor disorders to understand effective speech motor learning.

REFERENCES

Ackerman, P. L. (2007). New Developments in Understanding Skilled Performance. *Current Directions in Psychological Science*, *16*(5), 235–239. https://doi.org/10.1111/j.1467-8721.2007.00511.x

Baddeley, A. D., & Longman, D. J. A. (1978). The Influence of Length and Frequency of Training Session on the Rate of Learning to Type. *Ergonomics*, *21*(8), 627–635. https://doi.org/10.1080/00140137808931764

Doyon, J., Penhune, V., & Ungerleider, L. G. (2003). *Distinct contribution of the cortico-striatal and cortico-cerebellar systems to motor skill learning. Neuropsychologia*, *41(3)*, 252–262. (n.d.).

Early visual experience, learning, and neurochemical plasticity in the rat and the chick. (1977). *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, *278*(961), 307–318. https://doi.org/10.1098/rstb.1977.0044

Guadagnoli, M. A., & Kohl, R. M. (2001). Knowledge of Results for Motor Learning: Relationship Between Error Estimation and Knowledge of Results Frequency. *Journal of Motor Behavior*, *33*(2), 217–224. https://doi.org/10.1080/00222890109603152

Hapner, E. R. (2018). *Voice Therapy: Clinical Case Studies*, *Fifth Edition*. United States: Plural Publishing, Incorporated.

Kamath, A. (2001). *Cognitive linguistic assessment protocol for adults.* (Unpublished Master’s dissertation). University of Mysore, Mysore.

Kaipa, R., & Mariam Kaipa, R. (2018). Role of Constant, Random and Blocked Practice in an Electromyography-Based Oral Motor Learning Task. *Journal of Motor Behavior*, *50*(6), 599–613. https://doi.org/10.1080/00222895.2017.1383226

Kwon, Y. H., Kwon, J. W., & Lee, M. H. (2015). Effectiveness of motor sequential learning according to practice schedules in healthy adults; distributed practice versus massed practice. *Journal of Physical Therapy Science*, *27*(3), 769–772. https://doi.org/10.1589/jpts.27.769

Lee, T. D., & Genovese, E. D. (1989). Distribution of Practice in Motor Skill Acquisition: Different Effects for Discrete and Continuous Tasks. *Research Quarterly for Exercise and Sport*, *60*(1), 59–65. https://doi.org/10.1080/ 02701367. 1989.10607414

Maas, E., Robin, D. A., Austermann Hula, S. N., Freedman, S. E., Wulf, G., Ballard, K. J., & Schmidt, R. A. (2008). Principles of Motor Learning in Treatment of Motor Speech Disorders. *American Journal of Speech-Language Pathology*, *17*(3), 277–298. https://doi.org/10.1044/1058-0360(2008/025)

Park, J.-H., Shea, C. H., & Wright, D. L. (2000). Reduced-Frequency Concurrent and Terminal Feedback: A Test of the Guidance Hypothesis. *Journal of Motor Behavior*, *32*(3), 287–296. https://doi.org/10.1080/00222890009601379

Ramig, L. O. (2001). Intensive voice treatment (LSVT(R)) for patients with Parkinson's disease: A 2 year follow up. *Journal of Neurology, Neurosurgery & Psychiatry*, *71*(4), 493–498. https://doi.org/10.1136/jnnp.71.4.493

Ranganatha, M. R (1982) *"Morphophonemic analysis of Kannada language :Relative frequency of phonemes and morphemes in Kannada. Central Institute of Indian Languages,*. (n.d.).

Schmidt, R. A. (2003). Motor Schema Theory after 27 Years: Reflections and Implications for a New Theory. *Research Quarterly for Exercise and Sport*, *74*(4), 366–375. https://doi.org/10.1080/02701367.2003.10609106

Schmidt, R. A., & Lee, T. D. (2005). *Motor control and learning: A behavioral emphasis, 4th ed.* (n.d.).

Shea, C. H., Lai, Q., Black, C., & Park, J.-H. (2000). Spacing practice sessions across days benefits the learning of motor skills. *Human Movement Science*, *19*(5), 737–760. https://doi.org/10.1016/S0167-9457(00)00021-X

Shea, J. B., & Morgan, R. L. (1979). Contextual interference effects on the acquisition, retention, and transfer of a motor skill. *Journal of Experimental Psychology: Human Learning and Memory*, *5*(2), 179–187. https://doi.org/10.1037/0278-7393.5.2.179

Spielman, J., Ramig, L. O., Mahler, L., Halpern, A., & Gavin, W. J. (2007). Effects of an Extended Version of the Lee Silverman Voice Treatment on Voice and Speech in Parkinson’s Disease. *American Journal of Speech-Language Pathology*, *16*(2), 95–107. https://doi.org/10.1044/1058-0360(2007/014)

Steinhauer, K., & Grayhack, J. P. (2000). The role of knowledge of results in performance and learning of a voice motor task. *Journal of Voice*, *14*(2), 137–145. https://doi.org/10.1016/S0892-1997(00)80020-X

Swinnen, S. P., Lee, T. D., Verschueren, S., Serrien, D. J., & Bogaerds, H. (1997). Interlimb coordination: Learning and transfer under different feedback conditions. *Human Movement Science*, *16*(6), 749–785. https://doi.org/10.1016/S0167-9457(97)00020-1 van Leeuwen, P., de Groot, S., Happee, R., & de Winter, J. (2011). Effects of Concurrent Continuous Visual Feedback on Learning the Lane Keeping Task. *Proceedings of the 6th International Driving Symposium on Human Factors in Driver Assessment, Training, and Vehicle Design : Driving Assessment 2011*, 482–488. https://doi.org/10.17077/drivingassessment.1436

Vander Linden, D. W., Cauraugh, J. H., & Greene, T. A. (1993). The Effect of Frequency of Kinetic Feedback on Learning an Isometric Force Production Task in Nondisabled Subjects. *Physical Therapy*, *73*(2), 79–87. https://doi.org/10.1093/ ptj/73.2.79

Winstein, C. J., & Schmidt, R. A. (1990). Reduced frequency of knowledge of results enhances motor skill learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *16*(4), 677–691. https://doi.org/10.1037/0278-7393.16.4.677

Winston, A. S. (1990). Robert Sessions Woodworth and the "Columbia Bible": How the Psychological Experiment Was Redefined. *The American Journal of Psychology*, *103*(3), 391. https://doi.org/10.2307/1423217