ACQUISITION AND RETENTION OF NONWORDS IN ADULTS WITH AND WITHOUT STUTTERING

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CERTIFICATE

This is to certify that this dissertation entitled "**Acquisition and Retention of Nonwords in adults with and without stuttering**" is a bonafide work submitted in partial fulfillment for the degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 18SLP036. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify this Master's dissertation entitled"**Acquisition and Retention of Nonwords in adults with and without stuttering"** is the result of my study under the guidance of Dr.Swapna. N, Associate Professor of Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru and has not been submitted to any other university for the award of any Diploma or Degree.

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Chapter I

Introduction

Fluent speaking involves complex and dynamic interactions among multiple neural systems governing linguistic, cognitive, emotional motor, and sensory activity of speaking. Several researchers have adopted a complex view that a mixture of all these domains is involved in stuttering, a neuro developmental disorder that emerges in early childhood (Smith & Kelly, 2001). The significant characteristics of stuttering (i.e., sound repetitions, prolongations, and blocks) ultimately represent breakdowns within the exactly regular and coordinated articulatory movements needed for fluent speech. Consequently, there have been considerable experimental efforts dedicated to understanding the characteristics of speech motor skills in adults who stutter (AWS). Variations and instability in the relative timing, speed, and coordination of articulatory movements of AWS have been found even throughout their production of noticeably fluent speech. Several reports of the stuttering neural related deficient impaired the speech motor preparation and execution, and auditory and sensor-motor integration to speech fluency breakdowns. Therefore several researchers sight stuttering as a motor deficit disorder (Braun, 1997).

The planning and execution of motor movements are usually referred to as motor control and improvement in the spatial and temporal accuracy of movements concerning practice is referred to as motor skill learning. The process in which a person learns to coordinate and combine posture, locomotion, and muscle activations, enabling him/her to participate in a range of motor behaviours that are inhibited by a range of task requirements, is referred to as motor skill acquisition (e.g., athletic context) (Newell, 1991).While learning a skill, an individual makes use of various techniques to achieve similar outcomes in movement. Therefore, while learning an individual can display certain variations in his/her body/limbs' spatial orientation, as well as in the timing and sequencing of movements. A strategy for learning motor skills is practiced in which the skills are strengthened by practice. Changes in results that come with practice are normally much stronger and quicker at the beginning and gradually decrease as practice progresses.

According to Willingham (1998), motor skill acquisition is defined as “the process by which single or multiple movements are performed without any effort or with minimum effort through repeated practice and interactions with the environment”. There are several stages involved in motor learning and several researchers in the literature of speech motor have spotlighted on practice which is defined as “the improvement in the performance of given task within a single session” and retention which is defined as “the performance of the practiced or already learned task between the sessions without any practice in the intervening duration between sessions in normal individuals and those with different disorders including stuttering”(Behrman, Cauraugh, & Light, 2000; Smith-Bandstra, Luc, & Saint-Cyr, 2006; Namasivayam&Van Lieshout, 2008; Olander, Smith & Zelaznik, 2010).

The essential and important components of motor learning are practice and repetition of the given motor tasks. According to the motor skill approach, “speech is a motor skill not acquired by birth, rather is acquired with certain practice over time and usually characterized by perfectly self-organized higher-order functions, adaptive, energy-effective and determined coordination patterns". The relationship between the motor practice and motor learning is complex since learning occurs not only because of practice effects but also because of other external variables like massed versus distributed practice and internal variables like memory and attention, which also influences learning. However, practice over a certain period can reduce the amount of physical and mental constraints needed to achieve the given task. Meanwhile, the formation of new memories will also take place to maintain the already learned skill. Therefore motor practice and motor learning are measured using different parameters.

Commonly, practice effects are measured by obtaining the behavioral changes between time using performance curves of speech response time, the accuracy of speech, and speed of the movement. Learning effects are measured using the amount of retention and amount of interference (Bauerly & De Nil, 2011). A few studies have also shown that during the time of practice any motor learning can occur, however, after a certain interval of time, the practice effect influences the storage and stabilization of previously learned skill (Robertson, 2004; Press Casement, Pascual-Leone, & Robertson, 2005).

The retention of the previously learned motor skill will give a clear idea about the effect of practice and how it triggers the learning and storage in the memory. It takes longer duration to hold the learned information in the memory during the retention of the motor skills. The most common way to measure the retention is through the difference of the performance at the practice level and the beginning of the retention. Many researchers have found the retention at different time intervals, for example, interval period of five hours (Press et al., 2005), the period of 24 hours including sleeping (Sickgold & walker, 2004), two days (Adams, Page & Jog, 2002), to as long as four weeks (Duff, Beglinger, Schultz, Moser, et al., 2007). This construction and stabilization of motor memories have been proposed to be correlated to the reshaping of neural responses making the more stable and more efficient representation of the dynamic plan with the purpose of resistant to deprivation (Jog, Kubota, Connolly, &Hillegaart,&Graybiel, 1999; Fischer, Hallschmid, Elsner, & Born, 2002; Stickgold& Walker, 2007).

The motor learning is mainly affected by an important variable called the feedback (Newell, 1976; Schmidt, 1988). The feedback will drive the environmental information from the sensory-perceptual system and the motor control system. By using this information, the individual can guide their action for accurate target productions. Through different schedules of feedback, the effectiveness of the learning can also be evaluated. Feedback acting as a significant role in enhancing the learning, evaluating the effectiveness of learning, and sometimes hinders the learning (Magill, 1994).

Nonwords have been commonly used to assess the motor learning by several researchers (Smits-Bandstra et al., 2006; Namasivayam &Van Lieshout, 2008; Smith, Sadagopan, Walsh, & Weber-Fox, 2010; Sasisekaran & Weisberg, 2014). The motor component of nonwords does not merely rely on the expression of the phonemes by moving various articulators in the words but also includes transferring acoustic energy and its representation to a sequence of motor commands in the synchronized manner, thus requiring organization and coordination of various articulators, such as the lips, tongue, jaw, and palate and also requires phonological ability to recognize that particular phoneme and sequence in the correct order and store in the phonological memory for retention. Several difficulties often posed by nonsense syllables in terms of timing and execution of speech movements relative to word structures that are already in existence.

Nonword research includes the activation and decoding of the phonemic units which form the nonwords, previously learned or unlearned motor movements or functional synergies correlated with the segments(Smits-Bandstra et al., 2006; Namasivayam &Van Lieshout, 2008; Tilsen& Goldstein, 2012). Particularly, in a task such as the coupling or phasing between the individual gestures (or inter-gestural coupling) in the nonword both between and across syllable boundaries has to be learned (Namasivayam&Van Lieshout, 2008). Hence the current study uses nonwords to assess the motor learning abilities of the adults with (AWS) and without stuttering (ANS) with practice and under the presence and absence of the feedback.

Studies in the stuttering literature described that AWS has some speech clumsiness with some amount of inadequacy in the acquisition of motor learning (Van Lieshout, Hulstijn,&Peters, 2004). A few researchers also reported that AWS has deficits in the motor learning of both the speech as well as non-motor tasks. The motor skills have been commonly measured using variables like response time and movement speed, kinematic measures, etc. (Smith&Kleinow, 2000; Namasivayam& Van Lieshout, 2008).

Van Lieshout, Hulstijn, and Peters(1996) studied the reaction time and word duration in AWS by varying the syllable length 1-2-3 in a picture-naming task to measure. Their results revealed that AWS had slower reaction time and longer word duration compared to the normals. From their results, they suggested that AWS might use altered motor control patterns to compensate for the condensed verbal motor skill, which could indicate the occurrence of sensori-motor integration deficits.

Ludlow, Siren, and Zikria (1997) observed that AWS was slower than the usually fluent adults to acquire the correct production of two and four-syllable nonsense words, and stated that although both groups influenced practice, they still had some differences. This significantly lower practice effect on AWS indicated they might also have poor phonological encoding skills.

Smits-Bandstra et al., (2006) investigated the learning in AWS and typically fluent adults of novel finger-tapping and nonsense syllable sequences. In this research, they studied the initial practice period (about 30 repetitions) followed by the transfer of the newly acquired skills (to unpracticed novel sequences) and maintenance (after a 40-min rest period). They measured performance accuracy, sequence duration, and reaction time as the outcomes. The results of their study indicated that though maintaining the accuracy levels of finger tapping and syllable sequence productions of AWS resembled that of the typical adults, the groups varied on several task conditions and variables. Retention data for the finger tapping following practice task showed that AWS was slower than the typically fluent adults and portrayed a lesser degree of transfer and retention abilities. Group differences with the practice were, however, not evident for the speech task either for segment duration or reaction time. The groups were also comparable in accuracy for both speech and non-speech tasks.

Namasivayam and Van Lieshout (2008) investigated the speech motor practice and learning changes in AWS and typically fluent adults. In this study they used nonwords at two different rates; normal and fast across three test sessions (T1, T2 on the same day, T3 on the second day). The results indicated that practice effect (within a given day), in terms of reduced variability of coordination patterns and increase in the strength of frequency coupling between gestures, was present to a greater degree in typical adults (relative to AWS) in the fast and normal speech rates respectively. They also reported significant improvement in the strength of inter-gestural frequency coupling for typical adults compared to AWS at normal speech rates, which indicated that motor learning of sequences may be limited in AWS even at normal habitual speech rates. A retention effect was compared and (T1 vs.T3) found that the AWS showed lesser variability in T3 compared to T1, while the ANS did not show similar changes. The results indicated that AWS might have inadequate speech motor skills as evidenced by the variations in the motor practice and learning changes in the variables linked to stability and strength of movement coordination.

Smith, Sadagopan, Walsh, and Weber-Fox (2010) and studied the effects of the practice of speech movements in a Nonword repetition task of AWSby varying the length and complexity of the nonwords. Speech accuracy, lip aperture variability, and speech duration were measured as the outcome of motor learning. They also reported differences in the kinematic measures from the early and fifth trial. Their results indicated that AWS had higher movement variability with an increase in the nonword length and complexity. Also, practice effects in terms of increase in coordination from the early to the later trials within the session were seen in AWS while the controls were at the ceiling levels. Speech accuracy did not show any group differences.

Bauerly and De Nil (2011) studied practice and retention in 12 AWS and 12 controls the nonword repetition task of 11 syllables. The nonword was given to the participants. On Day 1 participant were required to repeat an 11-syllable nonword for 100 times (divided into 10 blocks) on Day 1 and after 24 hours participants were required to repeat the nonword for50 times (divided into 5 blocks). Variables such as accuracy, response preparation time, and sequence duration were measured on Day1 as a measure of practice and the same variables were measured on Day2 as a measure of retention. The expected interaction of group and practice was not evident for accuracy, reaction time, and sequence duration in AWS on both Day 1 and Day2. The AWS did show significantly slower sequence duration both during practice as well as retention, which was interpreted as a motor skill limitation.

Sasisekaran and Weisberg (2014) investigated the short term practice and retention of nonwords in ten AWS and age-matched controls using a nonword repetition task by changing the length (3,4,5 syllable, phonotactic constraint [PC VS NPC], on 3 syllables) and complexity (simple and complex) of the nonwords. They found the effects of type and complexity of the nonwords in terms of both behavioral (speech accuracy) and the kinematic measures (lip aperture variability and speech duration) within and across the sessions (i.e.) two sessions with one hour gap between the sessions. In the first session, they used 19-22 blocks of nonwords in random order, and in the second session, they used 10 blocks of nonwords in random order. The behavioral analysis revealed that the AWS showed a large number of speech errors than normals for the 6 syllable, 3-NPC nonwords, and for the complex nonwords. Also, only a fewer number of AWS were able to reach the criterion of 4 – 5 accurate productions necessary for the kinematic analysis, predominantly for the 4-, 6-, and 3-NPC nonwords. Their findings imply that AWS experienced difficulties in the correct production of nonwords of increasing length, PC, and complexity, which indicated complications in phoneme programming and/or speech-motor processes. Moreover, in the retention session, the two groups showed no differences in the speech accuracy, which suggested that the ability to hold the designed programmed information in the memory, at least for one hour, maybe similar between the groups. The kinematics analysis revealed no significant differences in the movement coordination between the AWS and control groups for simple vs. complex nonwords. AWS showed reduced to practice and retention effects on inter-articulatory coordination even for short and simple nonwords where the groups were equivalent in speech errors.

Need for the study

A look into the literature revealed that AWS had some deficits in the acquisition of motor skills, both speech and nonspeech. Nonword learning has been studied in AWS by a few researchers using different stimuli and different outcome measures. Depending on the type of stimuli, complexity of the task, the amount of practice and the measures of outcomes, the results of these studies are variable and contradictory in nature, but it provides an understanding of the fact that motor learning is a complex process and it is affected by many internal and external variables.

Nonwords have been used to assess the motor learning abilities of AWS owing to its complexity. Nonword learning requires the establishment and programming of phonemic segments and assembling previously known or unknown motor gestures that accompany these segments. It also requires attention and phonological ability to recognize the phonemes and sequence them in the correct order and store in the phonological working memory for retention. Also, practicing nonwords for a certain period (acquisition) helps in effective learning and provides a way for the stabilization of previously learned nonwords by holding them in the memory for longer durations (retention).

However, most of the studies in the past on stuttering have found limitations in speech motor learning using shorter Nonwords. It is important to study the manipulation and influence of longer Nonwordson motor learning. It is known that the longer syllable length loads the linguistic and speech motor system and thereby shows characteristic variations in kinematic measures of AWS (Maner, Smith,& Grayson, 2000; Smith &Kleinow, 2000). Increasing the length of the stimuli (i.e., the more complex nonwords) and thereby measuring and comparing its behavioral and kinematic attributes in AWS and ANS would facilitate understanding of the nature of speech motor skill inadequacy in both acquisition and retention phase. Variations induced by changes in syllable length could potentially reduce the ceiling effects in the speech motor performance.

It is also important to examine the influence of nonwords on motor learning in different languages. It is known that nonword learning involves perception, storage, recall, and reproduction of phonological sequences. Those same abilities play a role in learning words and morphemes. Performance on NWR tasks tends to be affected by the specific phonological and phonotactic structure of the language a child is learning. For example, Spanish and English differ in the number of available sounds for constructing contrasting phonotactic structures (Hammond, 2001). Phonotactic rules govern the possible number of syllables, consonant clusters, stress patterns, and phoneme sequences, and these rules influence the likely arrangement of phonemes in words(Shriberg& Kent, 1982). Morphosyntactic structure may also mediate linguistic tasks and influence performance on NWR across languages (Vitevitch&Stamer, 2006). Nonword learning in different languages provides a way to explore the role of language proficiency, usage, and experience of phonological short-term memory. Because different languages have different phonotactic systems, different lexical and syntactic systems, the demands on their short-term memory and attentional systems may be different. Varying levels of fluency and proficiency of different languages may have different relationships to Nonword learning in terms of perception, storage, recall, and production of the phonemes with different phonological constraints.

The acquisition of nonwords can be made more challenging by fixing certain target duration of the nonwords by decreasing or increasing the actual duration (i.e. at a faster rate or slower rate). Though studies have used nonwords with different lengths, phonotactic constraint and complexity, there are limited studies which have used a nonword learning task with a fixed duration in AWS. Investigating the learning relative to the durational aspects is essential since this is the variable that is manipulated during the fluency management in AWS, i.e. they are expected to speak slowly to reduce the disfluencies and hence they learn a new set of motor skills.

Further while learning a new motor skill, feedback also acting a significant role in enhancing and evaluating the new motor skill in an accurate manner by providing information concerning what they produced and how they produced. However, there are no such studies that have compared the effect of feedback on speech motor performance using a Nonword learning task in AWS. Further, to date, only a few researchers have investigated the motor learning skill in AWS using a combination of behavioral measures (like reaction time, speech accuracy) and kinematic measures (like movement variability, spatial-temporal index, and speech duration).

It would be interesting to compare the motor learning abilities with and without short term practice and feedback during the acquisition of longer nonwords with fixed target duration and its retention in AWS and measuring the speech accuracy, which is a behavioral measure and speech duration, which is an objective measure. This will provide an insight into the speech motor difficulties in AWS.

These findings will also have implications in fluency intervention. It will throw light on the effectiveness of practice and feedback during an intervention. The findings will also help to draw inferences on whether retention abilities (holding the encoded information in memory) in AWSare affected or not, which could reflect on the motor learning difficulties. Further, this study will throw light on the acquisition and retention of the durational aspects. Keeping this in view, the present study was planned.

Aim

The current study aimed to investigate the nonword acquisition and its retention in Adults with stuttering (AWS) and Adults with no stuttering (ANS). The specific objectives were

- To investigate changes if any, in the speech accuracy and speech duration with short term practice during the acquisition of nonwords in AWS and ANS.
- To investigate changes if any, in the speech accuracy and speech duration with feedback during the acquisition of nonwords in AWS and ANS.
- To compare the speech accuracy and speech duration between both the groups with and without short term practice and feedback.

- To investigate changes if any, in the speech accuracy and speech duration between the acquisition and retention phase of nonwords within and across both the groups.

The null hypotheses were as follows:

- There will be no statistically significant differences in speech accuracy and speech duration with short term practice during the acquisition of nonwords in AWS and ANS.
- There will be no statistically significant differences in speech accuracy and speech duration with feedback during the acquisition of nonwords in AWS and ANS.
- There will be no statistically significant differences in the comparison in the speech accuracy and speech duration between both the groups with and without short term practice and feedback.
- There will be no statistically significant differences in the speech accuracy and speech duration between the acquisition and retention phase of nonwords within and across both the groups.

Chapter II

Review of Literature

Motor learning is a process that takes place internally with a certain amount of practice or experience to make the outcome without a minimum amount of effort or with a negligible amount of effort. It involves learning new skills or relearning the lost skills and the internal process may involve many physiologic changes in the nervous system."Continued exposure and practice of the speech production lead to an organization or establishment of a new set of motor skills thereby causing enduring changes in the central nervous system" (Schmidt & Lee, 2008). Often the terms 'performance' and 'learning' aroused synonymously, however, there is a distinction between these two terms.

According to Magill (1994), performance could be a behaviour which might be determined and refers to the act of execution of motor ability. Performance is not indicative of the permanent acquisition of motor ability. Learning could be a behaviour that cannot be determined, however, it is directly supported by a person's performance. Learning leads to the permanent acquisition of selected motor abilities.

The motor learning process consists of three stages. In the Practice phase, a particular target motor task is performed for a certain number of times under controlled experimental conditions. Throughout this process, movements are generated by involving significant amounts of attention agencies such as the consistency of attention states (divided versus focused) and motor memory retrieval, and the locus of attention (internal versus external) and motor performance along with a strong dependency on the sensory input. Once a considerable amount of practice is done, learners become less dependent. If there is a substantial amount of practice, the learners are less reliant. Once a significant amount of practice is done, the learner becomes less dependent on the sensory feedback and therefore uses less reserve of attention to perform the movement with high automaticity (Schmidt & Lee, 2005).In the retention phase, the practiced motor movements of the acquisition stage are examined for its consistency, following a rest period. A process called ‘memory consolidation’ happens throughout this phase, whereby temporary/unstable motor memory representations of the practice phase reaches a permanent/stable state with time (Robertson, 2004).In the transfer phase, the learner develops a capability to regulate the learned motor skill and executes the same for novel however for comparable tasks (e.g., Practice effect of typing on a typewriting machine is checked for its transfer on a personal laptop). A transfer phase will be considered to be successful once a high consistency within the attributes of the practice phase is utilized on a non-practiced target item.

In the context of motor learning, it is also essential to differentiate performance during practice and performance during retention and/or transfer. Performance, in general, refers to any observable behavior. Specifically, performance refers to the execution of a specific motor skill in a veryspecific environment (Moreno-Briseno, Diaz, Campus-Romo, &Fernandez-Ruiz, 2010).Performance through practice is also regarded as the learning phase of acquisition. It may be possible to calculate the ability of a person to develop a motor skill through evaluating his/her success during the practice regime; nevertheless, it will not include knowledge regarding an individual's motor learning capability. Observing a person hitting a baseball, for example, would imply observing the person's performance of the ability to hit a ball, but it does not provide information on whether the person has learned to hit the ball correctly or not. The performance of a motor function is affected to a large degree by output factors during the practice regime. This involves variables such as the individual's alertness, the practice climate, and the exercise-driven exhaustion (Magill & Hall, 2004).In summary, three significant performance aspects during practice are: (1) motor skill improvement is measured during practice, (2) the impact of motor skill output during practice is transient (i.e., it does not lead inability learning), and (3) performance is influenced by practice variables.

Performance throughout retention/transfer determines the extent of learning. Learning would demonstrate that there is a permanent change in an individual's performance as a result of practice, and is not affected by the performance variables. Analyzing learning through retention as a result of practice examines the persistence of enhanced performance. Determining performance by transition assessment explores the degree to which practice on one competence generalizes to certain abilities (e.g., practicing the tennis forehand shot and determining how the backhand shot is improving).In brief, the concept 'motor learning' means: (1) learning is stable, (2) learning is specifically defined, (3) learning is not impacted by performance factors, and (4) learning is also evaluated by memory and/or transfer checking.

2.1Three Stages of Learning

A learner is typically thought of as transitioning through relatively distinct learning processes when they practice a motor skill. Fitts (1964) and Fitts and Posner (1967) reported three phases which proved useful for explaining the process of motor learning. These stages are called the cognitive phase, the associative phase, and the autonomous phase.

2.1.1 Cognitive Stage

The learner's intention in this initial stage of motor learning is to develop an overall understanding of the skill. In attempting to understand what needs to be done as well as the nature of the skill, the learner spends an adequate amount of cognitive resources. During this stage, significantly more cognitive resources are needed, as the novel learner is initially unsure of what needs to be done**.** The cognitive knowledge of the needs for the production of movement is extremely high. The performance is extremely dependent on environmental conditions throughout this stage, the movements are gross and a large number of errors are observed. Although the learner is aware that the movements are incorrect, he/she is not sure how to correct the movements. In the form of visual, verbal instructions, demonstrations, and guidance, the learner relies mostly on feedback. They focus, also, on trial and error to direct his learning. Performance improvements are highest at this point as the learner actively tests the success-enhancing techniques. Learners have a propensity to get quickly discouraged if performance is not reached quickly.

2.1.2 Associative Stage

The learner reaches the associative stage of motor learning until the basic movement sequence is reached. The performance is much less variable throughout the whole stage and is much more consistent. Less cognitive resources are required, and the learner relies on proprioceptive feedback rather than visual or auditory feedback. Errors are reduced, and movements are rectified further. Even if this skill is not flawless, the learner has the potential to discover his/her mistakes in the transfer. The cognitive demand for production of motion decreases. Throughout this stage, some elements of the movement are consciously controlled, while some are performed automatically. The learner starts focusing on perfecting the abilities. This stage will last from a few days up to months.

2.1.3Autonomous Stage

The learner needs to enter the autonomous learning stage after an intensive practicing period. This stage reflects the maximum level of skill and not all learners arrive at this stage. The production here is becoming good and stable. The movements are involuntary and need neither cognitive effort nor attention**.** The movements are effortless, and most of the time free of errors. The accomplishment of this learning level typically requires years of practice. During the movements, the learner develops an ability to detect his / her errors and tends to correct those errors. The ability must be practiced regularly to sustain the skill at this level.

To sum up, motor learning cannot be divided exclusively into these three steps, since the motor learning cycle is constant over time. Those motor development phases, though, better characterize the development flight of relatively new or novel motor ability. The learner learns little by little and associates, rather than abruptly, from one stage to another. Therefore, the main aim of learning is to continually adjust the fundamental abilities or knowledge to adapt to a specific task. As a result, learning-related changes are not invariably apparent and should be inferred from other measures;

while some variables, such as attention and memory, can influence performance and learning.

Attention is a complex cognitive function that incorporates a wide range of components like sustained, focussed, and divided attention as well as the speed of information processing (Sohlberg&Mateer, 2001). These cognitive components involve a diffuse set of circuitries and structures that include but are not limited to the anterior frontal and temporal brain regions (Sohlberg&Mateer, 2001).Attention is very much important in the initial stages of novel task learning thelearner attempts to understand the requirements for learning and attempts to understand how effectively he can learn the first few trials. Attention is required for the monitoring of feedback or reinforcement to determine success at performing a task as well as to integrate incoming sensory information with old memories (Baddeley, 2003).

In general, the learning of a new ability is correlated with a decrease in the need for effortful performance management, contributing to automatic growth. Automaticity by definition was accomplished when other continuing tasks minimally affect the performance of a primary task. The individual to engage in more than one cognitive task simultaneously requires a high level of working memory. Working memory is important for generating new images through the synthesis of incoming sensory input and old experiences during the early stages of motor learning. The capacity to remember the knowledge right away is restricted in working memory. Thus, it is time-limited, but can be preserved if it is activated by repetition or long-term memory transfer. The maximum space of working memory is often considered to be five to nine items.

Baddeley (2003) suggested the working memory model and claimed that working memory is a set of processes that supports regulate cognition by connecting subcomponents such as the visuospatial sketchpad, the phonological loop, and the episodic buffer to long-term memory. Without these three systems working memory cannot function as a single entity. There is a main executive focus manager (core executive) and two subsystems specializing in managing and storing small quantities of knowledge in very different areas: the phonological loop (or circuit) and the visuospatial sketch (visual sketchpad central executive acts as the information flow regulator, processing, and storing that information. The phonological loop stores and manipulates speech-based data and has two subcomponents: the phonological store, which absorbs input both explicitly (auditory presentation) and indirectly (visual presentation), and the reverberation of the subvocal rehearsal process, which takes place serially in real-time, and serves to suppress the phonological store 's natural decay. The visual sketchpad conducts encoding and management of graphic and spatial data. Moreover, a new aspect, the episodic buffer, a store accountable for the storage of content, both verbal and visual elements and long-term memory, was used in a study of the proposed system by Baddeley(2003), in a single episodic representation of multidimensional codes.

In particular, the cognitive mechanisms involving the short-term retention or conservation of phonemes in a given language are known collectively as phonological working memories. Phonological working memory supports a wide range of linguistic activities such as new word learning and vocabulary creation, the maintenance of knowledge during the learning and processing of sentences, and the processing of sentences in the discourse level (Adams & Gathercole, 1995).

2.2 Measures of Motor Practice

Outcomes in practice are also assessed by measuring behavioral improvements over time using overall performance curves; while motor learning requires adjustments in internal processes and therefore needs to be concluded from the usage of indicators such as maintenance and interruption assessments. Practice and repetition of a given pattern of movement are crucial factors in motor learning. Practice consequences are thought to reflect non-permanent output shifts (Schmidt, 2004), and may be used to forecast learning (Schmidt & Lee, 2005). The reaction period and series length are the two common measures used to assess behavioral adjustments through motor activity. Reaction time is a calculation of the time from the unanticipated stimulus to the beginning of the reaction to it (Schmidt, Banstra, De Nil, & Saint-scyr,2006). Sequence duration is the interval from response initiation to response completion.

2.3 Measures of Motor Learning

The interaction between motor practice and motor performance is complicated and the results of performance can hardly be distinguished by experience alone. There are growing variables that affect the learning results explicitly or implicitly which are not apparent inside a class. For example, environmental variables that may impact the learning process include differences. For instance, environmental variables that may affect the learning process include differences in practice schedule (massed versus distributed practice), or the type of feedback (intrinsic versus extrinsic). Other variables like memory, attention, and effort, internal states of an individual, are unperceivable that additionally play an important role within the learning process. For instance, practice leads to a decrease in the reliance on attention resources, as a task is performed with less physical and mental effort. At the same time, new memories are forming for that particular task and therefore the learner is developing the capacity to maintain the skill in memory. Measures that have wanted to capture some of these internal processes associated with learning are a test of retention and test of interference. Retention refers to continuity in the performance of an acquired or obtained motor skill, whereas transfer refers to the ability to successfully perform the task as a result of another task being performed (Schmidt & Lee, 2005).

2.3.1.Test of Retention

Retention evaluation is mainly used to determine the retention of information that happens during the learning process. When a memory that is originally converted to an unstable state (prone to interference) is transformed over time into a more 'stable' state (less prone to interference) (Robertson, 2004), memory consolidation occurs. Research has found that mastering a motor ability takes place immediately during practice; moreover, the time between practice sessions simultaneously allows the memory to recover(Kami, Meyer, Jezzard, Adams, Turner, & Ungerleider, 1998; Robertson, 2004; Press Casement, Pascual-Leone, & Robertson, 2005). Consolidation of a motor skill is also studied after a retention period by looking at the performance. Measuring retention is most generally achieved by taking the differential score or "amount" of failure of ability over a retention period. It is calculated by measuring the difference in performance levels at the end of a period of practice and the start of the retention interval. Researchers have reported intervals of consolidation within ranges ranging from a total of five hours of wakefulness (Press et al., 2005) to 24 hours without sleep (Walker & Stickgold, 2004) up to four weeks (Duff et al., 2007). This development and consolidation of motor memories were suggested to be related to the reshaping of neural responses to constitute a more consistent and effective representation and more effective representation of the movement plan that is resistant to degradation (Jog et al.,1999; Fischer et al., 2002; Stickgold& Walker, 2007).

2.3.2. Tests of Interference:

The relational interference influence is a feature of schooling, where interruption through instruction becomes beneficial for ability growth. In reality, higher levels of intervention lead to worse performance than lower rates, thereby achieving better performance retention and transition effects (Magill & Hall, 1990)**.** Typically, the amount of attention paid for completing a specific motor activity is used to assess the degree to which skill is mastered in training (Logan & Etherton, 1994). It is presumed that a well-practiced task requires less cognitive resources than transitions of skill into a high automatic state. Hence, automaticity is characterized as the phenomenon of gradually achieving skilled output during extended practice with less dependence on attention and other cognitive processes (Schmidt & Lee, 2004; Fitts, 1964).

Shiffrin and Schneider (1977) proposed that easy, repeated training could improve stimulus-response mapping contributing to an automated process. Others indicated that the automatic mechanism is more complex, requiring reconstruction of tasks such as chunking (Graybiel, 1998) or memory retrieval (Logan, 1988). The focus may be directed to many other performance indicators or another task when the ability is more automatic. For this reason, experiments with dual tasks are used to estimate the amount of learning that has taken place in scientific research (Curran & Keele, 1993; Logan & Etherton, 1994; Hazeltine & Ivry, 2002).

2.4 Cognitive Effort and Motor Learning

With practice, the amount of effort needed for performing a given task should decrease. As a consequence, the ability can be deemed fairly "effortless" when it needs little cognitive training and a minimal amount of execution of the muscle (Starkweather, 1987; Ingham, Warner, Byre, & Cotton, 2006). Compared to dual tasks, scales of effort are especially useful when assessing the amount of learning on basic, repetitive motor tasks where output has reached a ceiling or floor during a relatively short practice session. In this case, the test of measures can be used as a method to eliminate individual learning discrepancies when performance levels indicate no improvement across the subjects.

2.5 Theories of Motor Learning

Within the context of motor learning, theories serve to explain the exact process of motor learning. Two important theories have had a significant impact on understanding motor learning and are discussed below.

2.5.1 Closed-loop Theory

Adams (1971) promoted the closed-loop motor learning principle. He established this hypothesis through a set of studies involving slow functioning tasks with levers. Adams indicated that the performance and learning concepts related to such studies might even apply to other motor movements. This hypothesis emphasized the significance of feedback for performing a motor function and indicated that motor learning should continue by the progressive refining of perceptual-motor feedback loops (hence the interpretation of the term closed loop). The initial gestures are rough when performing a novel motor function, and are not successful in producing the desired outcome. Even in more practice trials, the perceptual feedback correlated with motor movements includes details about the exact location of the limbs in space, and how the gestures were able to accomplish the aim of the motor target. This knowledge is referred to as the "perceptual trace" via perceptual feedback. The perceptual trace, for each subsequent practice examination, directs the individual to generate motor gestures that represent the appropriate motor target (also known as the right trace). Eventually, the individual achieves the appropriate motor target by a combination of movements controlled by the perceptual traces. The key premise of the closed-loop theory is that input directs a person to more effectively execute tasks. If individuals are asked directly regarding their performance learning new tasks they tend to do well than people who don't get this feedback. Therefore the basic role of feedback is to lead the experienced learner through concurrent practice to achieve the intended motor goal.

2.5.2 Schema Theory

Though there are many theories for motor control and learning, e.g., the theory of dynamic systems (Kelso, Saltzman, &Tuller, 1986; Kelso, 1995), Bayesian decision theory (Wolpert & Flanagan, 2001), the Schema theory is relevant because it has been widely used in the current literature. This theory is one that facilitates and helps us to understand motor learning. Schmidt (1975) developed this theory of motor learning which mainly gives us a clear idea about how the sequence of coordinated discrete motor movements is generated and controlled throughout the process of motor learning. This theory assumes that the execution of coordinated movement involves units of action called motor programs.

A motor program is the set of movement commands that can be organized before the initiation of the activity (Keele, 1968; Schmidt, 2003) that are theoretical representations of a particular memory encoded sequence of behavior. The program must be provided with the basic criteria that determine precisely how the action will be performed according to the task objectives (Schmidt& Lee, 2005). Mainly, he discusses the motor learning process via two memory states: recall memory and recognition memory. Recall memory is responsible for the production of movements and recognition memory is responsible for the evaluation of movement.

Recall memory does not play a part in movements with slow positioning; rather it merely recalls the condition by controlling the movements in small bursts. He conceptualized the notion of a generalized motor program; an organized coordinated movement schedule that encompasses both invariant features and variant features. The components which remain the same concerning the general process being implemented are referred to as based feature, while the system components that may be changed, such as time and force, are referred to as variant features. Individuals will not produce individual single movements; rather they produce a general motor program to produce the sequence of the movements by a set of organized motor movements. A general motor program depends on the following information retained in short-term memory during the learning process: 1) Information about the initial circumstances preceding action (variances in the direction of the lip or body size/weight), 2) Parameters for the general motor system (force, time), 3) Increased movement feedback, sensory feedback how the movement felt, looked, smelled, etc.(Schmidt & Lee, 2005). The recall and recognition schemas are interrelated and represented by these above-mentioned sources. When recall schema creation happens, the learning cycle starts with a variety of activities. The various components are modified and discarded in the working memory, but few components remain in the working memory to construct the recall scheme and the identification scheme. The schema of recognition fits the same, as the schema of recall. So this depends on the interaction knowledge between the original circumstances, the environmental factors, and the sensory effects. An individual may use an acquired recognition scheme to predict the sensory consequences even before the movement begins. These sensory consequences form just the basis for assessing the movement. Augmented feedback thus plays a key role in the creation of schemas. Schema theory is used to facilitate an interpretation of certain essential motor learning concepts and is especially helpful in explaining the processes involved with sequence skill learning.

According to Newell in 1991, “The planning and execution of motor movements are usually referred to as motor control and increasing the spatial and temporal accuracy of movements with practice is referred to as motor skill learning. The process in which a performer learns to control and integrate posture, locomotion and muscle activations that allow the individual to engage in a variety of motor behaviors that are constrained by a range of task requirements is referred to as motor skill acquisition” (e.g. athletic context). While learning a skill, changes may be observed that reflect strategies that an individual uses to achieve specific movement outcomes. A learner may exhibit a transformation in his or her body and body limbs' spatial awareness as well as a change in the timing and sequencing of movements. A pattern for obtaining motor skills is followed, in which learning accumulates with practice. Changes in a performance that go hand in hand with experience are typically somewhat greater and faster at first and then gradually diminished as the practice continues.

2.6 Speech Motor Learning

Speech production is one of the motor skills acquired early in life and also it follows the stages of motor learning which is initially preceded by an acquisition phase followed by retention and transfer phases. Experience and practice are the two important factors considered to influence speech motor learning (Magill & Anderson, 2010). It is also known that sensory information (auditory and somatosensory) is continuously accessed to tune up the articulatory movements thereby enhancing the process of speech motor learning (Smith & Sussman, 1969).

In the review article of ‘principles of motor learning’, Maas, Robin, Hula, Freedman, Wulf, Ballard, and Schmidt (2008)discussed many factors that relatively facilitate either acquisition or retention/transfer phase of speech and nonspeech motor learning. He recorded conditions related to other activities such as raising the amount of practice, massive distribution of activities; blocked practice, constant target practice, and internal focus of attention are essential aspects to improving motor skill acquisition. They also explained the role of feedback conditions, Knowledge of Performance (KP), immediate and high-frequency feedback in increasing the skill acquisition.

The above-discussed practice and feedback variables are not much beneficial when a movement sequence has to be established and transferred to certain inexperienced new target items in the long term. Therefore, factors such as distributed and variable practice, random practice schedule with an external focus of attention were established to have a reasonably enhanced motoric retention and transfer. Concerning the feedback variables, low feedback frequency, and delayed / summary feedback focusing on the Knowledge of Results (KR) have been stated as useful for motor learning retention and transfer phases. Although practice and feedback factors supported the non-speech motor skill acquisition, a few preliminary studies show the potential to explain the attainment of proficiency in speech motor skill. It was observed that random but not the blocked practice is more helpful in the speech motor retention (Shea & Morgan, 1979; Adams & Page, 2000; Kaipa&Kaipa, 2018). Certain evidence also pointed out for interaction of practice and task-related factors (Adams, Page & Jog, 2000).

Adams, Page, and Jog (2000) accounted that summary feedback received after every 5th trial combined with a random practice schedule showed greater retention for a slow speech target compared to summary feedback provided after every trial tied with blocked motor practice. Although ‘principles of motor learning’ do influence the task mastery and retention of the trained items in a long term, it is the inherent ability and limitation of an individual which would mostly affect the motor skill learning.

Newell reported in 1983 that speech-motor control is commonly characterized as the neuronal activities that activate and regulate muscle contractions to generate voice. Walsh, Mettel & Smith reported in 2015 that fluent speech production requires complex and dynamic cooperation between multiple neural systems that regulate the cognitive, linguistic, emotional, motor, and perceptive aspects of speech production. The well-organized functioning of the speech-motor system through these neural networks is affected in a sub-group of speech disorders referred to as motor-speech disorders (MSDs) (Darley, Aronson, & Brown, 1975; Duffy, 2005). MSDs may be due to disturbances at high levels of neural (cerebral) activity or lower levels such as the point of neuromuscular junctions and are known to have poor speech motor learning skills.MSDS involves both inherited and developed aspects of dysarthria and speech apraxia. Literature suggests many individuals with MSDs may lose the capacity to learn motor skills. Many characteristic features can be seen in an individual with poor motor abilities. The individuals with motor skill deficits may show improvement in task performance with a certain amount of practice throughout the period but normal individuals with intact motor skills will show ceiling effects within the practice session of the motor tasks. Also during practice sessions, individuals with motor learning deficits show a noticeable amount of errors, reduced reaction time, poor stability, and high dependence on sensory feedback systems, poor automaticity, and high task interference. Even in a greater number of practice trials, they may show limitations in acquiring motor skills (Poldrack, 2005; Halsband& Lange, 2006; Ackerman, 2007).

Another communication disorder in which speech motor skills are affected is stuttering. The following subsection provides an introduction to the disorder of stuttering, its characteristics as well as its incidence and prevalence followed by a discussion on the motor, neurobiological, genetic, and environmental factors that are thought to play a crucial role in the cause of the disorder.

2.7. Stuttering

The most frequently cited and well-accepted definition of stuttering is by Wingate in 1964. According to him, stuttering means disruption in the fluency of verbal expression, which is characterized by involuntary, audible or silent repetitions or prolongations in the utterances of short speech elements, namely sounds, syllables, and words of one syllable. These disruptions occur frequently or are marked in character and are not readily controllable. Sometimes the disruptions are accompanied by accessory activities involving the speech apparatus, related or unrelated body structures, or stereotyped speech utterances. These activities give the appearance of a speech-related struggle. Also, there are not infrequent indications or reports of the presence of an emotional state, ranging from a general condition of excitement or tension to more specific emotions of a negative nature such as fear, embarrassment, irritation, or the like. Wingate further stated that the immediate source of stuttering could be some incoordination expressed in the peripheral speech mechanism: the ultimate cause, however, is presently unknown and may be complex or compound.

Yairi and Ambrose (2005) defined stuttering as being characterized by a disruption in the flow and the rhythm of speech, though the individual knows exactly what she/he wants to say. These disruptions during the speech production process are perceived as sound prolongations, syllables repetitions, and silent blocks which can be for a brief duration or lasts for several seconds. The speech behaviors of the individual with stuttering are referred to as the core behaviors (Riper,1982). These behaviors are considered to be involuntary and out of control. Repetitions are considered to be one of the basic core behaviors of stuttering. Individuals with stuttering can simply exhibit a sound, syllable, or part of word repetition. It appears as though the speaker is stuck on a sound and continues to repeat it until the following sound can be produced. Prolongation is another core behavior that occurs when the sound or the air flows continues, but the movement of articulators stops. These prolongations can vary between half a second to several minutes. The presence of prolongations and repetitions are considered to be the core behavior of stuttering. Blocks occur when there is a sudden stop of flow of air or voice and the movement of the articulators as well. This can occur at any level of articulatory subsystems. There is certain evidence that supports the fact that the blocks occur due to inappropriate activity at the level of the laryngeal system. Persons with stuttering (PWS) differ from each other in terms of the nature and frequency of the core behaviors they present. These core behaviors also vary in different situations and individuals.

Stuttering is also characterized by the presence of a gap in the ongoing flow of speech which can be silent (duration of silence greater than 250ms) or a filled pause with extraneous sounds. Hesitations, interjections, broken words, phrase revisions, incomplete phrases, dysrhythmic phonation (prolongations and broken words), and tense pauses are the other disfluencies found in the speech of PWS.

There is considerable overlap in the type of disfluencies produced by individuals with stuttering with a lesser severity of stuttering in comparison with the disfluencies found in the speech of fluent speakers. Therefore to identify the core behaviors better and thus identify the individuals with stuttering, an attempt was made by Yairi and Ambrose (2005) to classify stuttering behavior into stuttering like disfluencies (SLDs) which include monosyllabic repetitions and part word repetitions, prolongation and blocks/articulatory fixations and other disfluencies (ODs) which include polysyllabic word repetitions, phrase repetitions, interjections, and revisions. Results of numerous empirical studies indicate that instances of stuttering or stuttering-like disfluencies (SLD) are more frequent in the speech samples of children diagnosed as stuttering compared to children considered as a fluent speaker (Yairi, 1983; Yairi& Ambrose, 2004). The frequency of occurrence of SLDs in comparison with ODs contributes towards the diagnosis of stuttering.

In addition to these disfluencies, PWS also exhibit secondary behaviors. They react to their core behaviors by trying to end these quickly or avoid them. Such behaviors develop into very well-established patterns. Secondary behaviors could be either escape behaviors or avoidance behaviors (Guitar, 2006).

Chu, Sakai, and Mori (2014) attempted to integrate the various notions of stuttering described in the literature and stated that the understanding of stuttering involves not only a characteristic set of measurable behaviors but also certain subjective experiences and perceptions that take on increasingly greater significance as a child grows and his or her stuttering evolves. This perspective is reflected in the International Classification of Functioning, Disability, and Health developed by the World Health Organization (WHO, 2001), which recognizes that complex disorders, such as stuttering, involve not only physical impairment in structure or function but also limitations on an individual's activities and restrictions on his or her participation in life.

Stuttering is, in most cases, is of developmental origin and usually manifests itself during infancy and is called developmental stuttering. When stuttering is of non-developmental origin, it is termed as acquired stuttering (Van Borsel, 2014), which could be drug-induced, psychogenic, and neurogenic.

2.7.1. Incidence and Prevalence of Stuttering

Yairi and Ambrose (1999) noted that 65% of pre-school children start stuttering before 2.5 years of age and 85% do so before 3.5 years of age. Andrews (1984) and Yairi, Ambrose, Paden, and Throneburg (1996) recorded that the prevalence of childhood stuttering was 5 percent but decreased to 1 percent in adulthood. Yairi and Ambrose (2013) published more than 40 prevalence studies worldwide in an extensive overview of the stuttering epidemiology and reported that the prevalence ranged from 0.3 to 5.6 percent. The recent reports concerning the incidence and prevalence of stuttering by Yairi and Ambrose (2013) revealed that the life span incidence and prevalence of stuttering were 8% and 0.72% respectively in the world. Further research has also revealed that stuttering is more common in males and tends to run in families.

In India to date, only a few studies have indirectly documented the incidence and prevalence of stuttering, where the prevalence of stuttering was reported from psychiatric, genetic, and communication disorders studies. An early pilot study of the incidence of speech disability among Indian school children in New Delhi, from kindergarten to seventh grade, identified a prevalence of 1.2 percent for stuttering (Hegarty, 1968). An epidemiological study of psychiatric disorders in children and adolescents reported a prevalence of 1.5 percent stuttering among 4-16 year-olds in the urban, slum, and rural areas of Bangalore, Karnataka (Srinath, Girimaji & Guruji, 2005).

2.7.2. Causes of Stuttering

Many researchers have devoted their interest to understand and find the exact causes of stuttering. This section explains a few causes of stuttering.

2.7.2.1 Neurological Causes: Speech development is the outcome of a dynamic relationship, affecting multiple cortical and subcortical brain systems, including cognitive, mechanical, auditory, and somatosensory processes.Several points of evidence support that stuttering is mainly due to deficits in the Neurophysiologic process or pathways. Several studies reported remarkable brain differences between people who stutter and normally fluent speakers. Also, there have been several significant theoretical points of view regarding stuttering as a function of abnormal brain physiology. These have hypothesized that stuttering occurs secondary to a lack of cerebral dominance, or excessive right hemisphere activation, or from a hypertensive brainstem reflex responses. Also, there may be differences in people who stutter concerning brain anatomy such as various deficiencies in white and or gray matter, and concerning brain blood flow (Yari & Seery, 2011).

2.7.2.2. Genetic Causes: Evidence has been promoting a neurological explanation for stuttering ever since the 1930s. Within the last two decades, however, promising findings from behavioral genetic studies have provided evidence that genetic factors may be important in the expression of stuttering. There are a lot of studies on families, twins, and adopted children which supports the genetic inheritance and abnormality as a cause for stuttering. Gupta (2003) reported that 32% of the patients with stuttering had relatives who stuttered. Felsenfeld, Kirk, Zhu, Statham, Neale, and Martin (2000) found that 17 of 38 monozygotic twins and 8 of 53 dizygotic twins were concordant for the presence of stuttering. The findings of the study conducted by the Illinois Stuttering Research Program suggested that genes from three different combinations of chromosomes; numbers 2 and 9;7 and 12;7 and 18 may result in stuttering. Additionally, there were sex differences concerning specific chromosomes, showing the strongest linkage signal on chromosome 13 for males and 21 for females (Suresh, Ambrose & Roe 2006).

2.7.2.3 Environmental Causes: Evidence indicates that developmental stuttering stems from an association between genetic predisposition and environmental and/or self-imposed system requirements (Bloodstein, 1975; Yairi& Ambrose, 2005; Karrass, Walden, Conture, Graham, Arnold. Hartfield, & Schwenk, 2006; Guitar, 2006). Guitar

(2006) described several stresses in the environment. Bloodstein and Bernstein-Ratner (2008) stated that parents may unintentionally cause stuttering by enforcing high parental standards of speech or language at home, such as using sophisticated language or comparing with a sibling who is more advanced in speech-language development. The University of Iowa (Darley &Johnson, 1955) performed several stuttering and non-stuttering parent research and found that parents of children with stuttering were more likely to place higher behavioral expectations on their children than parents of children with no stuttering. For example, they expected their children to walk and talk earlier. However, the behaviors of both parental classes overlapped considerably. The investigations by Zenner, Ritterman, Bowen, and Gronhovd (1978) have shown that parents of CWS appear to be more critical or nervous than parents of CWNS. Others, however, noticed no major variations between the two parent groups (Goodstein&Dahlstrom, 1956).

Many studies show that communicative experiences between parents and their children can be related to a loss of fluency (Hahim & Ratner, 2004). For example, Meyers and Freeman (1985) found fast speaking rates for parents harmed the occurrence of stuttering in young CWS.

2.7.3. Speech Motor Characteristics in Stuttering

Earlier studies on stuttering mostly addressed the psychological and behavioral issues in stuttering. Recent studies have focussed on the issues of speech motor planning and programming in adults with stuttering (AWS). Riper (1982) defined stuttering as a disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound in a word, hinting at deficits in speech motor control due to errors in speech motor programming. Few experiments suggest that AWS has trouble initiating and regulating speech gestures, together with deficiencies in temporal regulation and synchronization across various speech subsystems (respiration, phonation, and articulatory) (Max & Gracco, 2005).

Ultimately, the stuttering characteristics (i.e., sound repetitions, prolongations, and blocks) represent breakdowns within the exact regular and coordinated speech production movements needed for fluent speech. Consequently, considerable experimental attempts have been made to clarify the speech motor characteristics of AWS. Variations and instability in the relative timing, speed, and coordination of AWS articulatory movements have been found even during the duration of their noticeably fluent speech production. Some reports of the stuttering relate to impaired speech motor planning and execution, and auditory and sensory-motor interaction to speech fluency breakdowns.

The Speech Motor Skills (SMS) approach stated by Van Lieshout and colleagues (Peters, Hulstijn,& Van Lieshout, 1999) views stuttering as an inadequacy in the speech control mechanism, wherein AWS exhibits complexity in preparing, planning and performing a complex set of speech motor actions, which is mainly influenced by important domains such as cognitive-linguistic and, emotional domains. This further speculates that AWS is at the lower end of the normal continuum of speech processing abilities (Van Lieshout, 1995), whereas adults with no stuttering (ANS) are at the upper end. The innate limitations in the speech motor control system of AWS could be observed only when the task complexity is increased and their performance is not limited to simple motoric tasks. The theory assumes that among several sequences of events that lead to speech production (cognitive, linguistic, and emotion domains), speech motor control is the weak link that is easily susceptible to breakdown. Stuttering, according to SMS approach, is not considered as difficulty in cognitive or linguistic processing, but an influence of these factors on speech motor control that produces perceptual dysfluencies. The SMS approach concludes that speech motor function is the relationship that is more likely to be adversely affected in the category of speech production experiences. Therefore, the disorder of stuttering is postulated to possess some of the characteristic features that resemble speech motor skill limitations like lack of automaticity and flexibility, slower execution speed, and more prone to articulatory breakdown, especially during task interferences. Therefore, several researchers view stuttering as a motor deficit disorder (Braun,1997).

The Schema theory (Schmidt, 1975; 2003; Schmidt & Lee, 2005) also accounted for the speech motor skill limitations observed in PWS. This theory assumes that stuttering is a deficit at the level of motor planning due to the inaccurate representation of abstract motor programs that constitute the Generalized motor programs (GMPs). These hypothesized inaccurate GMPs would make a PWS execute the speech movements with difficulty and results in faulty sound production. Also, as the recognition schema is aberrant, the continuous evaluation of speech based on the expected sensory consequences could be problematic and hence the knowledge of translating a set of motor commands acquired for a specific situation does not get updated to handle novel speech tasks or situations.

Provided that motor expression dysfunction involves defects in motor function, treatment modalities concentrating on dimensions of motor learning/relearning may also help treat AWS-related speech deficits. That is, a new set of speaking strategies that need to be learned by an AWS include producing smooth articulations, using continuous phonation, and not reducing the overall speaking rate (Ludlow, Siren,&Zikira, 1997). As relapse is most common in AWS, this hints for a possible limitation in retaining and transferring the newly learned strategies of speaking to handle speaking situations for a long duration of time (Craig & Hancock, 1995).

2.7.4. Speech Motor Deficits in AWS

During speech production, stuttering is indicated by repeated hesitations, interruptions, prolongations, and phonemic repetitions. To generate a word, the phonological and phonetic encoding processes take place followed by the articulatory motor phase. Stuttering may arise if any of this is incomplete.

Prescott in 1988 investigated the event-related potential indices of speech motor programming in AWSand ANS.CNVs (Contingent Negative Variation) were recorded before spoken words, which varied according to the number of syllables, whether the words were the same or different on each trial and the degree of repetition within the word.The effects of these response parameters on the slow potential behavior reported over the speech motor region were apparent both before and during the response, indicating that both speech pre-programming and ongoing programmed control represented the slow potentials. Differences between groups only became apparent before the answer, particularly when words were familiar and therefore likely to be entirely pre-programmed. This suggests that AWS have difficulty in setting up the parameters of the response, rather than in ongoing programmed control.

In 2017, Ning, Peng Liu, and Yang studied the processes of AWS in speech preparation. The trial included fifteen AWS and fifteen proficient-talk adults (AFS). The event-related potentials (ERPs) were reported in the paradigm for the fore-period. The warning signal (S1) was a color square, and either a white square (the Go stimulus asking participants to identify the color of S1) or a white circle (the NoGo signal preventing participants from speaking) was the corresponding imperative stimulus (S2). There were three variations between the AWS and AFS. Next, the mean amplitude of the parietal positivity of the ERP variable elicited by S1 (S1-P3) was smaller in AWS than in AFS, which meant that AWS may have deficits in investing phonological programming in working memory. Second, the topographical change from the early phase to the late phase of dependent negative variance emerged sooner for AWS than for AFS, indicating that in AWS the cycle of motor planning is promoted. Second, the NoGo impact in the parietal positivity of the ERP portion produced by S2 (S2-P3) was greater for AFS than for AWS, suggesting that AWS has trouble inhibiting planned speech. These findings make a complete description of the AWS mechanisms of speech planning and reaction inhibition.

2.7.5Neural Basis for Speech Motor Deficits in AWS

Usually, the cerebellum is known to be a motor organ associated with motor learning and novel activities. Petacchi, Laird, Fox, and Bower observed strong stimulation of the cerebellum in functional imaging experiments in purely auditory tasks in 2005 and suggested that the cerebellum may play a role in sensory auditory processing.

De Nil, Kroll, Houle, and Lafaille (2003) reported that there is evidence of higher overall cerebellum activity and irregular right lateralization in AWS compared with ANS during silent and oral reading. This stimulation further enhances the fluency shaping therapy and in the long run. This elevated activity in AWS compared with pre- and post-treatment controls could be attributable to improved sensory or motor regulation, decreased automaticity in sequences of articulatory action, including when reading silently.

Using Functional magnetic resonance imaging(fMRI), De Nil and Bosshardt (2001) found a more widespread activation pattern in AWS compared to controls during both a single, sentence generation task as well as a dual, word rhyming and word categorization task. They suggested AWS may have an inability to automatize speech-motor processes effectively as these results are similar to the activation pattern observed during the early practice stages in ANS (Rauch, Whalen, Curran, McInerney, Heckers, & Savage, 1998; Foerde, et al., 2005; Poldrack, Sabb & Foerde 2005)

Further, another analysis by Allen, Buxton, Wong & Courchesnein (1997) claimed that cerebellar activity can also be correlated with selected attention mechanisms, and previous care in PWS can result in improved concentration and control during speech output and thus less efficiency in articulatory movement execution. The raise in cerebellar activity from pre- to post-treatment followed by a decline in stimulation would be associated with this theory as speech training would gradually minimize automaticity and improve self-monitoring and concentration commitment during speech and this would then decline as the fluency skills learned become more developed and automatic over time.

Supplementary motor region (SMA) is implicated in the voluntary regulation of acquired motor patterns, and the anterior cingulate gyrus is implicated in the volitional monitoring of emotional processes (Jürgens, 2002). A few functional imaging studies in AWS provide evidence of the active participation of unusual neural activation patterns of the angular cingulate cortex (AAC) during the speech, with relatively increased activation of AAC in AWS during the silent and oral reading.AAC also offers contact between the limbic system and the sensorimotor cortex and is specifically important to AWS and participates in response planning and anticipatory reactions, especially with complex stimuli and multiple response selection (Kroll & Scott-Sulsky, 2010; De Nil, 2004)

Using functional and diffusion imaging, Watkins, Smith, Davis, and Howell in 2007 examined brain structure and function in the motor and language areas in a group of young people who stutter. During speech output, independent of fluency or auditory input, AWS demonstrated longitudinal and under activation in the ventral premotor, Rolandic opercular and sensorimotor cortex, and Heschl's gyrus on the left, overactivity compared to controls in the anterior insula, cerebellum, and midbrain.

Also, there is a diffusion tensor imaging (DTI) evidence of decreased fractional anisotropy (FA) in the white matter underlying the left rolandic operculum (LRO) which corresponds to the left sensorimotor representation of the larynx and tongue. Analysis of this diffusion data revealed that the integrity of the white matter underlying the underactive areas in the ventral premotor cortex was reduced in AWS. In this area, white matter tracts via connections with the posterior superior temporal and inferior parietal cortex provide a substratum for the integration of articulatory preparation and sensory input, and a substratum for the execution of articulatory movements through connections with the primary motor cortex. They concluded that stuttering is a condition predominantly correlated with dysfunction of the cortical and subcortical neural networks promoting the collection, activation, and execution of the motor sequences required for fluent speech development. This discovery of decreased FA in white matter that underlies the LRO also supports the finding of atypical gyral morphology in AWS in the same region. Studies assessing the short and long term effects of treatment changes in neural activity have highlighted potential differences in the motor learning abilities in PWS. In an fMRI study (von Kriegstein, Dogan, et al., 2008), activity in the caudate nucleus correlated with stuttering severity during a speaking task at pre-treatment. That is, those who stuttered more severely showed more activity in the caudate nucleus. The caudate nucleus is observed to play a role in the later stages of sequence skill learning, particularly when maintenance of speed is required (Lehéricy, Benali, Van de Moortele, Pélégrini-Issac, Waechter, Ugurbil, & Doyon, 2005). This correlation was absent following participation in a 3-week intensive fluency therapy program, where they learned techniques such as syllable prolongation and soft voice onset. However, there was no significant correlation between fluency gains due to therapy and an increase in activity in the caudate nucleus, as would be expected considering the role the caudate nucleus plays in sequential motor learning (Jueptner, Frith, Brooks, Frackowiak, & Passingham, 1997).

The De Nil (1998) PET experiments, and De Nil, Kroll, Lafaille, and Houle(2003)Post-treatment research, showed an average rise in neuronal activity with a propensity towards stronger activity in the left hemisphere relative to the activation in the right hemisphere during pre-treatment study. However, related activations have been identified between AWS and ANS when subtracting an oral reading function from a process of verb production. In other words, the neural function responsible for the mechanisms of higher-order thinking was identical across classes, offering help for dysfunction at the stage of motor preparation or execution.

De Nil et al. (2008) have reported an increase in longitudinal stimulation of the pre- and post-central gyrus, superior temporal gyrus, insula, and cerebellum, with right hemisphere stimulation occurring in the putamen, frontal gyrus, and anterior cingulate during education, and spontaneous speaking after treatment. Post-treatment testing demonstrated a reduction in overall activity for a behavior shift in activity from the right to the left hemisphere.

Although Neumann, Euler, Von Gudenberg, Giraud, Lanfermann, and Gall(2003) also found a shift from the right to the left hemisphere following fluency treatment, the hyperactivation before treatment became even more widespread after treatment. At a two-year follow-up scan, neurological activity was shown to shift back to the right hemisphere and remained more widespread than before therapy. These results suggest that some of the neurological differences that set AWS apart from ANS disappear when AWS gain more control over their fluent speech (De Nil, Kroll, LaFaille, & Houle, 2003). However, AWS' overactivation in cerebral activity compared to controls (De Nil &Bosshardt, 2001; De Nil et al., 2003; Neumann et al., 2003), along with an increase in cerebellar activity (De Nil et al., 2003) at post-treatment scans may reflect a failure to learn a fluency skill to a level in which automatization is achieved. This explanation is plausible considering the learning-related activation patterns generally observed in ANS in which a larger extent of activity is observed as the skill is introduced following by an overall decrease in activity as the skill becomes learned (Rauch et al., 1998; Poldrack, Sabb, &Foerde, 2005).

Results from neuroimaging studies provide converging evidence that AWS possesses an inadequacy or insufficiency in their motor learning ability. The primary area of interest was in the allocation of attentional resources, linguistic ability or speech motor control, and evidence of deficient motor learning abilities compared to ANS. The extent to which such differences relate specifically to motor learning capacities is indirect and indistinct. Therefore, studies specifically designed to assess motor practice and learning-related differences in motor performance between AWS and ANS are indispensable.

2.8 Sequence Skill Learning

The schema theory also accounts for the effect of motor practice on temporal aspects of speech production. It explains that after a certain amount of practice, a learned movement sequence is produced with lesser time to recall, plan, and execute the same (Schmidt, 1975). The theory also accounts for the effects of motor practice on speech movement variability. Schmidt (1988) describes that with practice the variability for a given movement sequence reduces.

Schema theory assumes that when practicing a pre-specified set of increasing units through repetition, they can be together and controlled as a single, larger unit (Schmidt, 1988; Keele, 1968). To sequence multiple units and produce as a single unit, the involvement of many movements in rapid succession is required. Schmidt (1988) described this response as having many parts that are not initiated separately, a process called chunking (Miller, 1956). The concept of “chunking” has been extensively researched and incorporated into several other models of motor programs and learning (Graybiel, 1998; Sakai, Hikosaka, & Nakamura, 2004). Learning of a sequential skill is then reflected by a decrease in the time it takes to recall, plan and execute a motor sequence (Schmidt, 1975; Ericsoon, Chase, & Faloun, 1980). Schmidt in 1988 described the changes in behaviour from sequence skill learning using the principles of variability. In this case, with practice, variability within a sequence is measured lesser than the variability between a sequence. Sequencing of actions is used in various everyday tasks from sequencing movements in typing to playing a musical instrument to sequencing sounds in speech. In research, a commonly used sequence skill paradigm includes finger-tapping to a specified number sequence (Karni et al., 1995; Doyon et al., 2002; Doyon & Ungerleider, 2002). Speech production in adults involves serial order processing of planned units (phonemes, syllables, and words) that when strung together form meaningful sequences (Dell, Burger & Svec, 1997; Levelt, 2001).

Nonwords have also been commonly used to assess motor learning by several researchers (Smits-Bandstra et al., 2006; Namasivayam&Van Lieshout, 2008; Smith, Sadagopan, Walsh, & Weber-Fox, 2010; Sasisekaran & Weisberg, 2014). The motor component of nonwords does not merely relate to the articulation of the phonemes in the word but also includes transferring an acoustic representation to a sequence of motor commands in the real-time, thus requiring coordination of multiple articulators, such as the lips, tongue, jaw, and palate and also requires phonological ability to recognize that particular phoneme and sequence in the correct order and store in the phonological memory for retention. Also, the nonsense sequence has some challenges in terms of the timing and execution of speech gestures compared to already existing word patterns. The learning of nonwords requires activation and encoding of the phoneme segments that constitute the nonwords, previously known or unknown motor gestures or functional synergies affiliated with the segments (Smits-Bandstra, De Nil, & Saint-Cyr, 2006; Nam, 2007; Tilsen & Goldstein, 2012). Particularly, in such a task, the coupling or phasing between the individual gestures (or inter-gestural coupling) in the nonword both between and across syllable boundaries has to be learned (Nam, 2007). The sequence skill learning paradigms used in the laboratory are the closest representation of the motor processes involved in the act of speaking. Hence the current study uses the nonwords to assess the motor learning abilities of the adults with (AWS) and without stuttering (ANS) with practice and under the presence and absence of the feedback.

2.8.1 *Studies Investigating Sequence Skill Learning in AWS*

Webster (1986) found that PWS did not show improvements in accuracy compared to PNS when practicing a 4-element finger tapping sequence task that did not include any repeated elements (e.g., 2-1-4-3). Similar to nonspeech motor task, reduced performance gains in AWS compared to ANS were observed when practicing speech motor tasks. Cross and Luper (1979) found PWS to be slower at initiating phonation when cued by a tone. Adams and Hayden (1976) found AWS to be slower at terminating phonation, a difference that continued the following practice.

Ludlow, Siren, and Zikria (1997) studied the ability to repeat the nonwords and the changes in the percent correct consonants with the practice for five AWS and five typically fluent adults in two, 4-syllable nonsense words. They found that there was slow learning by AWS to learn the correct production of two, four-syllable nonsense words than the typically fluent adults with repeated practice. They reported that both groups had some effect of practice but still they had some variations. This less effect of practice on AWS indicated that they might have poor phonological encoding skills. Their findings were suggested to have impaired speech and language processes. Cooper and Allen (1977) also found impairments in the rate of learning in AWS compared to ANS during a repetition task of reading aloud paragraphs and sentences.

Smits-Bandstra et al. (2006) studied the learning of novel finger tapping and nonsense syllable sequences in AWS and ANS. In this study, they investigated the initial practice period (about 30 repetitions) followed by the transfer (to unpractised novel sequences) and retention (following a 40-min rest period) of the newly learned skills. The outcome of the current study was the performance accuracy, sequence duration, and reaction time. The productions of AWS resembled with ANS in maintaining the accuracy levels of finger tapping and syllable sequence production. These two different groups differed on the other different task variables and conditions.AWS was slower than ANS in the retention data for finger tapping following a practice. They also portrayed a lesser degree of transfer and retention abilities.

Namasivayam and Van Lieshout (2008) investigated the speech motor practice and learning changes in AWS and typically fluent adults using kinematic measures. In this study they used bisyllabic nonwords at two different rates; normal and fast across three test sessions (T1, T2 on the same day, T3 on the second day). The results revealed practice effect (within a given day), in terms of reduced variability of coordination patterns, which was present to a greater degree in typical adults (relative to AWS) in the fast and normal speech rates respectively. They also reported significant improvement in the strength of inter-gestural frequency coupling for typical adults compared to AWS at normal speech rates, which indicated that motor learning of sequences may be limited in AWS even at normal habitual speech rates. A comparison of retention effect (T1 vs.T3) revealed that the AWS showed lesser variability in T3 compared to T1, while the ANS did not show similar changes. According to Namasivayam and Van Lieshout (2008), the indication of an increase in strength of inter-gestural frequency coupling, in the ANS was considered to represent a more stable relationship between speech gestures and also indicative of a learned movement pattern, a characteristic not present to the same extent in AWS. There was a weak practice effect in AWS which continuously improved with motor memory consolidation across habitual and fast speaking rates. The results indicated that AWS might have inadequate speech motor skills as evidenced by the variations in the motor practice and learning changes in the variables linked to stability and strength of movement coordination.

Smith, Sadagopan, Walsh, and Weber-Fox (2010) studied the effects of the practice of speech movements in a nonword repetition task of AWS by varying the length and complexity of the Nonwords. The variables such as speech accuracy, lip aperture variability, and movement duration were measured as the outcome of motor learning. They also reported the differences in the kinematic measures from the early and fifth trial. Their results indicated that AWS had higher movement variability with an increase in the nonword length and complexity. Also, AWS showed practice effects in terms of increase in coordination from the early to the later trials within the session while the controls were at the ceiling levels. No group differences were seen in speech accuracy. This indicated the presence of practice effect in AWS. AWS showed longer movement duration compared to age, gender-matched typical adults and a within-session effect of practice were noticed wherein the duration of the last few trials were shorter compared to the earlier trials. These findings suggest that AWS shows a practice effect for interarticulatory coordinative stability (LAVAR) and movement duration. Few studies have also shown changes in the movement duration as a factor of treatment. McClean, Kroll, and Loftus (1990) showed that PWS who underwent intensive stuttering therapy showed longer jaw movement duration and higher peak velocities compared to the control group that did not receive any treatment.

Bauerly and De Nil (2011) studied practice and retention in 12 AWS and 12 controls. Participants were required to repeat an 11-syllable nonword 100 times (divided into 10 blocks) on Day 1 and 50 times (divided into 5 blocks) on Day 2 session conducted after 24 hours. They measured accuracy, response preparation time, and sequence duration on Day 1 as a measure of practice and on Day 2 as a measure of motor learning (retention). Results failed to confirm the hypothesized poor practice and learning effects in AWS as the expected interaction of group and practice was not evident for accuracy, response anticipation time, or sequence duration on Day 1 or Day 2. The AWS did show significantly slower sequence duration both during practice as well as post-consolidation, which was interpreted as a motor skill limitation. The authors speculated that the relatively high task demands may have resulted in the observed group differences in the speech task contrary to the lack of such differences in Smits-Bandstra et al. (2006).

Sasisekaran and Weisberg (2014) investigated the short-term practice and retention of nonwords in ten AWS and age-matched controls using a nonword repetition task by changing the length (3,4,5 syllable, phonotactic constraint (PC VS NPC, on 3 syllables) and complexity (simple and complex) of the nonwords. They found the effects of type and complexity of the nonwords in terms of both behavioural (speech accuracy) and the kinematic measures (lip aperture variability and speech duration) within and across the sessions (i.e.) two sessions with the one-hour gap between the sessions. In the first session, they used 19-22 blocks of nonwords in random order, and in the second session, they used 10 blocks of nonwords in random order. The behavioural analysis revealed that the AWS showed a large number of speech errors than the normals for the 6 syllable, 3-NPC nonwords, and for the complex nonwords. Also, only a smaller number of AWS were able to reach the criterion of 4-5 accurate productions necessary for the kinematic analysis, predominantly for the 4-, 6-, and 3-NPC nonwords. Their findings imply that AWS experienced difficulties in the correct production of nonwords of increasing length, PC, and complexity, which indicates complications in phoneme programming and/or speech-motor processes. Moreover, the groups showed no differences in the speech accuracy with retention in Session 2, suggesting that the ability to hold the designed programmed information in the memory, at least for a few duration, may be similar between the groups. The kinematics analysis revealed no significant differences in the movement coordination between the AWS and control groups for simple vs. complex nonwords. The movement variability data demonstrated that AWS showed reduced to practice and retention effects on inter-articulatory coordination even for short and simple nonwords where the groups were equivalent in speech errors. These findings suggest that PWS had increased difficulty in learning nonwords that vary in syllable length and complexity. Interestingly, as behavioural differences disappeared during the retention phase in AWS, it was hypothesized that memory consolidation was intact for the learned motoric sequences at least for a shorter time duration.

In the Indian context, Namratha and Mahesh (2019) investigated the short-term effects of speech motor learning on kinematics measures of lower lip movement duration and Lip aperture variability (LAVAR) on nonsense sequences of 4 syllable bilabial sequences and 8 syllable bilabial sequences in AWS rated as mild and severe, using Electromagnetic MidsaggitalArticulography EMMA(AG501). They found that there was no significant difference in both the groups on motor retention, even after 24 hours of the consolidation period. Also, there was no statistical difference between the lower lip movement duration and LAVAR measures. They suggested that motor learning changes were similar across the stuttering severity groups and syllable length conditions which may be possibly attributed to a limitation in the speech motor learning of AWS, variations in the task complexity and period allowed for memory consolidation of learned motoric sequences.

To summarize, very few studies have analyzed speech motor learning in AWS, especially concentrating on the effect of practice on acquisition and retention. Most of the behavioural studies have examined accuracy, reaction time, and sequence duration (Smits-Bandstra et al., 2006; Bauerly& De Nil, 2011; Bauerly& De Nil, 2015), whereas some of the recent studies have examined the physiological attributes of motor learning by using speech kinematic measures (Namasivayam& Van Lieshout, 2008; Sasisekaran& Weisberg, 2014; Namratha&Mahesh, 2019). To date, only a few researchers have investigated the motor learning skill in AWS using a combination of these measures.

Further, very few studies in the past have focussed on longer nonwords. It is known that the complex syllable length loads the linguistic and speech motor system and thereby shows characteristic variations in kinematic measures of AWS (Maner, Smith & Grayson, 2000; Smith &Kleinow, 2000). Increasing the length of the stimuli would help in understanding the nature of speech motor skill inadequacy in both the acquisition and retention phases. Further, most of the studies have been carried out in the west. In the Indian scenario, such studies are limited. Languages can influence the results because of nonword difficulty increases as a function of nonword length in syllables. This has been seen across several languages including Italian (Bortolini, Arfe, Caselli, Degasperi, Deevy & Leonard 2006), Spanish (Girbau &Schwartz, 2008), Swedish (Radeborg, Barthelom, SjÖBerg, & Sahlén, 2006), Dutch (Gijsel, Bosman & Verhoeven 2006), Greek (Masoura & Gathercole, 2005), French (Klein, Watkins, Zatorre, & Milner, 2006), Portuguese (Santos, Bueno, & Gathercole, 2006), and Cantonese (Stokes, Wong, Fletcher, & Leonard., 2006). In these studies, the ability to repeat nonwords accurately increased with age and vocabulary size. These results suggest that the skills required to repeat nonwords are universal and may support language learning.

To the best of our knowledge, no studies to date have explored the combined effects of practice condition and feedback conditions in speech motor learning investigations in AWS. Hence, the current study was planned to analyze the effects of speech motor practice and feedback on acquisition vs. retention as a factor of longer syllable length conditions.

Chapter III

Methods

3.1. Research Design

The cross-sectional comparative study design was adopted to investigate the effect of practice and feedback during the acquisition of nonwords and its retention in AWS and ANS.

3.2.Participants:

Ten male adults with stuttering (AWS) in the age range of 18-35 (M= 23.5, SD= 3.31) years with native language Kannada participated in the study. They formed the clinical group. They were diagnosed as 'stuttering' by experienced speech-language pathologists based on the ratings obtained on the Stuttering Severity Instrument (SSI Version 4, Riley, 2008). To determine the severity of stuttering, the scores obtained on SSI-4 were considered. The severity was calculated based on frequency (included job task and reading task), duration of disfluencies (duration of three highest blocks), and physical concomitants exhibited by these adults. Among them, 4 had a mild degree of stuttering,3had a moderate degree and 3 had a severe degree of stuttering. Besides, they were screened for any problems in voice, articulation, and language. Oral mechanism examination and hearing screening were carried out to rule out any abnormality. The participants who had not undergone any stuttering intervention program were considered for the study. Table 3.1 depicts the demographic details of the clinical group considered for the study.

Table 3.1

Demographic details of the clinical group considered for the study

Sl. No.	**Age in years**	**Gender**	**Stuttering severity instrument-4 scores**	**Stuttering severity**
1	29.00	Male	89	Severe
2	22.00	Male	76	Severe
3	18.00	Male	22	Mild
4	24.00	Male	86	Severe
5	21.00	Male	24	Mild
6	21.00	Male	21	Mild
7	26.00	Male	55	Moderate
8	28.00	Male	46	Moderate
9	22.00	Male	30	Mild
10	24.00	Male	62	Moderate

3.3 Inclusion Criteria

- Individuals who were right-handed with no history of neurological problems, intellectual, sensory (vision and hearing), or other communication disorders were considered.
- Only those individuals with developmental stuttering and who were literate (minimum education till X grade) were included in the clinical group.

Ten age and gender-matched adults with no stuttering comprised the control group. They were matched with the clinical group for their socioeconomic status using the NIMH socioeconomic status scale developed by Venkatesan(2009). The scale has sections such as occupation, education, annual income, family income, property, and per capita income to assess the socioeconomic status of the participants. All the participants considered had Kannada as their mother tongue and were randomly recruited from both urban and semi-urban areas in Mysuru. The participants were recruited from those who reported to the Department of Clinical Services, AIISH.

To rule out the group differences in vocabulary and short term memory, semantic memory and working memory subtests from Cognitive Linguistic Assessment Protocol For Adults (CLAP) (Aruna Kamath, 2001) were administered and to screen for their phonological knowledge, subtests to assess meta-phonological skills from Reading Acquisition Profile-Kannada (RAP-K) (Prema,1997) was administered for persons in both groups. Those participants who passed the screening test in all the aspects were included in the study. Ethical guidelines were considered to select the participants, that is, the purpose and procedures of the study were explained to the participants and an informed verbal and /or written consent was also obtained.

3.4. Preparation of the Stimuli

Tennonwords with seven-syllable length were created by transposing the syllables of meaningful words. The development of the nonword list was done considering the criteria given below. It was ensured that the

1. Nonwords would not be affected by the vocabulary knowledge which was taken care of by ensuring that the individual syllables (CV or CVC) in the nonwords constructed did not correspond to a Kannada word.
2. The consonants of the original word weremaintained.
3. All the stimuli began with a consonant and ended with a vowel.
4. Nonwords did not include consonant clusters.
5. The consonants did not occur more than once within a given nonword.
6. The nonwords developed followed the phonotactic rules of the Kannada language.
7. The vowel positions were maintained.

Table 3.2 depicts the words and the corresponding nonwords generated by following the rules mentioned above.

Table 3.2

Words along with the corresponding nonwords generated

Sl. No.	**Kannada words**	**Nonwords**
1	/ʤiːvɑnɑʃɑılıgɑlu/	/viːʤɑgɑlɑıʃınɑku/
2	/binɑvɑgiruθaðe/	/vigɑbɑniduθare/
3	/nɑdɑjabe:kaðare/	/bɑlɑgɑne:dɑrɑke/
4	/horanaðejabeku/	/rohadanebakeju/
5	/kɑlupısɑlɑːgıðɜ/	/sɑlukıdɑgɑːlıpɜ/
6	/munθuvɑrıjɑlıθe/	/kunmurɑvılɑθıje/
7	/nədesuvıkejənu/	/kəsedujıneləvu/
8	/mɑːdɑbekɑːðadu/	/bɑːmɑkedɑːkɑpu/
9	/sɑrːgɑgolisuvɑ/	/gɑrɑːsɑpovikulɑ/
10	/pɑrin:ɑmɑvɑigıðɜ/	/mɑvip:ɑnɑgɑiθırɜ/

The nonwords prepared were subjected to a judgment on word-likeliness on a 4-point rating scale by five adult native speakers of Kannada, with ‘3’ denoting the highest degree (100%) of word-likeliness and ‘0’ denoting least degree (not at all similar to any meaningful Kannada word) of word-likeliness. The words rated with a point of ‘0’ were included in the final list of Nonwords. Only five nonwords were included in the experiment after the word likeliness ratings as those nonwords were marked as the least degree of word similarity compared to the other five nonwords, which were marked as the highest degree of word similarity. Two nonwords from this list were considered as sample stimuli.

The final list of words was uttered thrice by a typical native Kannada speaker to obtain the duration, which was averaged. This average duration of each nonword was multiplied by two (two times slower than the average duration of the nonwords) to fix the target duration. The nonwords were then audio recorded with PRATT software version 6.0.30by a female native speaker of Kannada with the target duration. An interstimulus interval of 5secs was used. Further, the nonwords were orthographically represented in the Microsoft PowerPoint presentation with the recorded audio samples for the fixed duration. Two words were recorded as practice stimuli for familiarization of the stimuli. The final list of words used in the experiment with their average duration and the target duration obtained by doubling has been depicted in table 3.3.

Table 3.3

A Final List of Words with their Average Duration and the Target Duration

l. No.	**Nonwords**	**Average duration(in secs)**	**Average duration multiplied by 2 (in secs)**
	Practice stimuli		
	/vigɑbɑniduθare/	1.40	2.81
	/sɑlukɪdɑgɑːlɪpɜ/	1.75	3.51
	Final stimuli		
	/viːʤɑgɑlɑɪʃnɑku/	1.95	3.91
	/vigɑbɑniduθare/	1.75	3.50
	/bɑlɑgɑne:dɑrɑke/	1.83	3.67
	/rohadanebakeju/	1.93	3.87
	/gɑrɑːsɑpovikulɑ/	1.70	3.41

3.5. Pilot Study

Following the generation of these nonwords, a pilot study was conducted on 5 participants from the control group and two participants from the experimental group to identify the problems if any, reported by the participants during the course of the experiment in terms of clarity of stimuli recorded. Further, the pilot study also helped in assessing the total duration of the experiment and identifying whether any rest period was required during the testing within each of the two trials in either of the experiments.

3.6 Procedure

The participant information form was filled in before the recording to confirm the fulfillment of inclusionary criteria. The necessary tests were administered. The data collection was carried out in two phases:

3.6.1 Acquisition phase

The participants were seated comfortably in front of the monitor and the stimuli were presented one at a time both auditorily through the loudspeakers at a comfortable listening level and visually (written nonword)through the computer monitor in a quiet listening environment with no distractions. Participants were either asked to repeat or practice the sample nonwords before recording. The participants had to utter the nonwords ten times with the target duration after listening to each nonword. The responses were recorded using Computerized Speech Lab(Pentax medical 4400), with a unidirectional microphone placed at a distance of 6cm. No prompting or cueing was provided regarding the accuracy of the product during the testing. No feedback was given during the first ten productions of each test nonword.

The speech duration analysis was carried out through the text grid of the PRAAT (version 6.1)software. The speech duration was obtained and plotted in an excel sheet of the Microsoft 7, to give feedback regarding the maintenance of duration during the production. Simultaneously, speech accuracy (percentage of correct vowels/consonants) for all the nonwords was calculated and feedback was given regarding the accuracy of production. After the feedback concerning accuracy and duration, the participants were expected to produce the nonwords again 10 times, which was recorded similarly.

Each participant was instructed in Kannada as following: “You will be given a set of five words which will be presented through a speaker and visually on the screen. Your job is to utter those given words 20 times by maintaining the fixed target duration for each of the given words. Once you complete the first set of 10 trials, you will be informed about your performance, i.e., whether you produced the given words correctly or not. If you had failed to maintain the fixed duration and /or accuracy, you should try to rectify the same in the second set of 10 trials.”

3.6.2 Retention phase

After the 24-hour consolidation period, the participants were asked to repeat the same nonwords in the absence of the target stimuli by maintaining the same target duration for three trials, which was recorded. The participants were instructed in the Kannada language as follows.“Yesterday, you uttered five words for twenty times and you were asked to maintain some fixed target duration. Now, you need to recall and utter all those five words with the same target duration three times.No feedback will be given about your results”.

3.7 Scoring and Analysis

For each nonword in both the acquisition and retention phase, the following parameters were measured:

3.7.1 Speech Accuracy

The Percentage of vowels/consonants correct (PVC/PCC) index was computed for the five 7-syllabic nonwords on the 10th and 20th trial of the acquisition phase for both the groups.PCC was also obtained for 3rd trial of the retention phase which was elicited without any stimuli and feedback for both the groups.PVC/PCC index was obtained by dividing the number of correct vowels/consonants by the total number of vowels/consonants in the sample (correct consonants + incorrect consonants), multiplied by 100. Disfluencies, including interjections, hesitations, sound or syllable repetitions, prolongations, and blocks, and self-corrects were not included in the behavioural analysis. The type and frequency of errors namely, substitution, omission, and addition errors were considered as incorrect responses.

3.7.3 Speech Duration

The vertical cursors were placed at the onset and offset of each nonword duration segment. The first instance of acoustic energy associated with the nonword-initial phoneme was considered as the onset for each of the nonwords and the last instance of acoustic energy associated with the nonword final phoneme was considered as the offset for each of the nonwords. The time interval between the cursors was recorded as the word duration (in ms) for every trial of 5 nonwords with the text grid feature of the PRAAT (Version 6) Software.

The speech accuracy (calculated manually) and duration (extracted through PRATT) of all participants in the acquisition phase (with and without practice and feedback) and in the retention phase for both the control and clinical groups were noted and was subjected to statistical analysis.

3.7.4 *Test-retest Reliability*

To check the test-retest reliability of the derived speech accuracy and speech duration scores, 20% of the total data in both the groups was reanalyzed by another Speech-Language Pathologist.

3.8 Statistical Analysis

The obtained speech duration and speech accuracy values for the participants of two groups along with the measures of CLAP and RAP-K were subjected to statistical analysis using SPSS (Version 20). The test-retest reliability of speech accuracy and speech duration was assessed using Cronbach's alpha measures. Normality of the sample selected for the study using the Shapiro-Wilk-test for normality. Descriptive statistics were computed to obtain the mean, median, and standard deviation for all the parameters for both the groups. The test-retest reliability of speech accuracy and speech duration was assessed using Cronbach's alpha measures. Mean speech duration scores and mean speech accuracy percentage was examined for its normality using Shapiro-Wilk's test. The analysis revealed that the data were non-normally distributed across groups. Speech accuracy scores during the acquisition phase were omitted from the analysis since both the groups had the same percentage values. As the sample size was less and the data were non-normally distributed, non-parametric inferential tests were used to analyze the data.

Mann-Whitney test was used to find the significant differences if any, inaccuracy of response as well as to compare the speech duration in both acquisition and retention phase between both the groups. Mann-Whitney test was also used to compare CLAP and RAP-K scores across groups. Friedman's test was used to compare the accuracy of speech duration between the target duration, 1st trial, the 10th trial, and the 20th trial of the acquisition phase within the group. Wilcoxon test was used to compare the accuracy of speech duration between the target duration, the 10th and 20th trials of the acquisition phase, and 3rd trial in the retention phase within the group. One sample Wilcoxon signed-rank test was used to compare the accuracy of the responses of the percentage of correct consonants and vowels within and across the group in both acquisition and retention phases. The results obtained are presented in detail in the next chapter under different sections.

Chapter IV

Results

The study aimed to analyze the behavioral and acoustic measures with and without practice and feedback on Nonword learning in Adults with Stuttering (AWS) and Adults with No Stuttering (ANS). The study was carried out in two phases, viz. the acquisition phase and retention phase. The effects of practice and feedback were examined by comparing the speech accuracy and speech duration of 1st trial, 10th trial, and 20th trial of acquisition phase (Day 1) and 3rd trial of retention phase (Day 2). The obtained speech duration and speech accuracy values for the participants of two groups along with the measures of CLAP and RAP-K were subjected to statistical analysis using SPSS (Version 20).

Descriptive statistics were carried out to compute mean, median, and standard deviation values in both groups. The test-retest reliability of speech accuracy and speech duration was assessed using Cronbach’s alpha measures. Mean speech duration scores and mean speech accuracy percentage was examined for its normality using Shapiro-Wilk’s test. The analysis revealed that the data were non-normally distributed across groups. Speech accuracy scores during the acquisition phase were omitted from the analysis since both the groups had the same percentage values. As the sample size was less and the data were non-normally distributed, non-parametric inferential tests were used to analyze the data. Mann-Whitney test was used to find the significant differences if any, in the accuracy of response as well as to compare the speech duration in both acquisition and retention phases between both the groups. Mann-Whitney test was also used to compare CLAP and RAP-K scores across groups. Friedman's test was used to compare the accuracy of speech duration between the target duration, 1st trial, the 10th trial, and the 20th trial of the acquisition phase within the group. Wilcoxon test was used to compare the accuracy of speech duration between the target duration, the 10th and 20th trials of the acquisition phase, and 3rd trial in the retention phase within the group. One sample Wilcoxon signed-rank test was used to compare the accuracy of the responses of the percentage of correct consonants and vowels within and across the group in both acquisition and retention phases. The results obtained are presented in detail below under different sections:

4.1Comparison of scores obtained on CLAP and RAP-K across groups

4.2 Test-retest reliability of the speech accuracy and speech duration scores of both groups

4.3 Comparison of speech accuracy and speech duration during the acquisition phase within and across both groups.

4.4 Comparison of speech accuracy and speech duration during the acquisition phase to assess the effect of feedback within and across both the groups

4.5 Comparison of speech accuracy and speech duration in the acquisition phase and retention phase within and across both the groups.

4.1 Comparison of Scores Obtained on CLAP and RAP-K across Groups

CLAP and RAP-K scores were statistically analyzed for both the groups. Mann-Whitney U test was used to check for the significant difference, if any in these scores, between both AWS and ANS. The mean score for CLAPwas 161.5(SD=9.8) in AWS and the mean score for CLAP was 167.0 (SD=11.5) in ANS. Mann- Whitney U test revealed no significant differences between both the groups (/z/= 1.38, $p<0.05$).The mean score for RAP-K was 409.40 (SD=42.5)in AWS and the mean score for RAP-K was 416.9 (SD=44.26) in ANS. Mann-Whitney U test again revealed no statistically significant differences between both the groups (/z/=0.38, $p<0.05$).

4.2 Test-retest Reliability

To check the test-retest reliability of the derived speech accuracy and speech duration scores, 20% of the total data in both the groups was reanalyzed by another Speech-Language Pathologist. Cronbach's alpha was used to analyze the test-retest reliability of the analyzed data of both speech duration and speech accuracy. For speech accuracy, the Cronbach's alpha of PCC and PVC was 0.76 and 0.97 for AWS respectively and the Cronbach's alpha of PCC and PVC was 0.93 and 0.92 for ANS respectively. For speech duration, the Cronbach's alpha was 0.96 and 0.97 for AWS and ANS respectively. These results indicated very good reliability for both speech accuracy measures and speech duration measures in both AWS and ANS except PCC for which, the value indicated acceptable reliability.

4.3 Comparison of Speech Accuracy and Speech Duration during the Acquisition Phase to Assess the Effect of Practice within and across Groups

During the acquisition phase, the participants were instructed to repeat nonwords with a pre-specified target duration ten times. The speech accuracy and duration were measured on the first and the tenth trial to assess the effect of practice. The mean, median and standard deviation values of the speech accuracy scores and speech duration scores of both the groups on the first and the tenth trial computed through descriptive statistics has been depicted in table 4.1.

Table 4.1

Mean, Median and SD Values of Speech Accuracy and Duration for the First and Tenth Trial in Both the Groups

Measures		**Group**	**First trial**			**Tenth trial**		
			Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Speech accuracy	PCC*	AWS	100.00	0.00	100.00	100.00	0.00	100.00
		ANS	100.00	0.00	100.00	100.00	0.00	100.00
	PVC*	AWS	100.00	0.00	100.00	100.00	0.00	100.00
		ANS	100.00	0.00	100.00	100.00	0.00	100.00
Speech duration		AWS	3.43	0.27	3.41	3.25	0.30	3.32
		ANS	3.5	0.23	3.52	3.28	0.32	3.25

*PCC-Percentage of consonants correct, PVC-Percentage of vowels correct

It was seen that the mean and median values in the acquisition phase for the percentage of consonants correct (PCC)and percentage of vowels correct (PVC) within both the groups and across both the groups were the same (mean&median = 100) and SD (0.00) for the first and the tenth trial of the utterance of nonwords. Therefore, the Mann-WhitneyU test revealed no significant differences in the speech accuracy measure between the first trial and tenth trial during the acquisition phase of nonword learning within and across both AWS and ANS.

It was found that the mean values of AWS and ANS on the first trial and the tenth trial were lesser than the mean values of the target duration that was supposed to be imitated (M=3.68). On comparison of the mean values of speech duration within both the groups, it was seen that the speech duration values were shorter on the tenth trial when compared to the first trial in both the groups.

The mean speech duration values were subjected to an independent sample test; Friedman test was done to compare the speech duration across the trials (target duration, first trial, and tenth trial) within both groups. The results of the Friedman test showed that there were significant differences in speech duration between the target duration, first trial, and tenth trial in AWS (X^2=19.04, $p<0.05$)and in ANS (X^2=14.08, $p<0.05$).

Wilcoxon signed-rank test was done to compare target duration and first trial; first trial and tenth trial; target duration and tenth trial in both groups. Results showed that there were significant differences for speech duration between target duration and first trial (/z/= 2.02, p=0.04); first trial and tenth trial (/z/= 2.02, p=0.04); target duration and tenth trial (/z/= 2.02, p=0.04) in AWS. In the ANS group, there were no significant differences for speech duration between target duration and first trial (/z/= 1.73, p=0.08); first trial and tenth trial (/z/= 1.73, p=0.08), but there was a significant difference between target duration and tenth trial (/z/= 2.02, p=0.04).

When the mean values of speech duration were compared across groups, it was seen that the ANS had higher values (nearer to the target duration compared to the AWS group. The results of the Mann-Whitney test indicated that there was no significant difference in the speech duration between AWS and ANS in the first trial (/z/= 0.10, p=0.92) and tenth trial (/z/= 0.10, p=0.92).

4.4 Comparison of Speech Accuracy and Speech Duration During the Acquisition Phase to Assess the Effect of Feedback within and across Groups

During the acquisition phase, after the tenth trial, the participants were provided with feedback about their performance on the nonword production based on the speech duration and accuracy, after which they were instructed to repeat it another ten times. The speech accuracy and duration were measured on the tenth and the twentieth trial to assess the effect of feedback. The mean, median, and standard deviation values of the speech accuracy scores and speech duration scores of both the groups on the tenth and the twentieth trial computed through descriptive statistics have been depicted in table 4.2.

Table 4.2

Mean, Median and Standard Deviation (SD) Values of Speech Accuracy and Duration for the Tenth and Twentieth Trial in Both the Groups

Measures		**Group**	**Tenth trial**			**Twentieth trial**		
			Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Speech accuracy	PCC*	AWS	100.00	0.00	100.00	100.00	0.00	100.00
		ANS	100.00	0.00	100.00	100.00	0.00	100.00
	PVC*	AWS	100.00	0.00	100.00	100.00	0.00	100.00
		ANS	100.00	0.00	100.00	100.00	0.00	100.00
Speech duration		AWS	3.25	0.28	3.24	3.20	0.12	3.23
		ANS	3.30	0.29	3.19	3.14	0.24	3.12

*PCC-Percentage of consonants correct, PVC-Percentage of vowels correct

It was seen that the mean and median values in the acquisition phase for the percentage of consonants correct (PCC)and percentage of vowels correct (PVC) in both the groups were the same (mean/median=100) and SD (0.00) for the tenth and the twentieth trial of the utterance of Nonwords. Therefore, the Mann-WhitneyU test revealed no significant differences in the speech accuracy measure within and across groups.

It was found that the mean values of AWS and ANS on the tenth trial and twentieth trial were lesser than the mean values of the target duration (M= 3.68). On comparison of the mean values of speech duration, it was seen that in both the groups, the speech duration values were slightly shorter on the twentieth trial when compared to the tenth trial.

The mean speech duration values were subjected to an independent sample test; Friedman test was done to compare the speech duration across the trials (target duration, tenth trial, and twentieth trial) within both groups. The results of the Friedman test showed that there were significant differences in speech duration between the target duration, tenth trial, and twentieth trial in AWS (X^2=19.04, $p<0.05$) and in ANS (X^2=14.08, $p<0.05$).

Wilcoxon signed-rank test was done to compare target duration and tenth trial; tenth trial and twentieth trial; target duration and twentieth trial in both groups. Results showed that there were significant differences for speech duration between target duration and tenth trial (/z/=2.02, p=0.04); tenth trial and twentieth trial (/z/=2.02, p=0.04); target duration and twentieth trial (/z/=2.02, p=0.04) in AWS. In the ANS, there were significant differences for speech duration between target duration and tenth trial (/z/=2.02, p=0.04); tenth trial and twentieth trial (/z/=1.73, p=0.05) and target duration and twentieth duration (/z/=2.20, p= 0.04).

When the mean values of speech duration were compared across groups, it was seen that the ANS had higher values (nearer to the target duration) compared to the AWS group. The results of Mann Whitney U test indicated that there were no significant differences in the speech duration across AWS and ANS in the tenth trial (/z/=0.10, p=0.92), however, there was a significant difference in the speech duration between AWS and ANS in the twentieth trial (/z/=0.73, p=0.47).

4.5 Comparison of Speech Accuracy and Speech Duration between the Acquisition Phase and Retention Phase within and across Both the Groups.

On the next consecutive day, the participants were called again and instructed to recall all the nonwords and utter them three times which were recorded. The speech accuracy of the words uttered on the third trial on Day 2 (retention phase) was compared with the twentieth trial on Day 1(acquisition phase). The mean, median, and standard deviation values of the speech accuracy scores and speech duration scores of both the groups on the twentieth trial on Day 1 and the third trial on Day 2 computed through descriptive statistics have been depicted in table 4.3.

Table 4.3

Mean, Median and Standard Deviation (SD) Values of Speech Accuracy and Duration for the Twentieth Trial of the Acquisition Phase and Third Trial of the Retention Phase in Both the Groups

Measures		**Groups**	**Acquisition phase (Twentieth trial- Day 1)**			**Retention phase (Third trial-Day 2)**		
			Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Speech accuracy	PCC	AWS	100.00	0.00	100.00	48.03	10.40	22.80
		ANS	100.00	0.00	100.00	71.94	19.76	80.80
	PVC	AWS	100.00	0.00	100.00	18.98	6.41	18.50
		ANS	100.00	0.00	100.00	82.80	23.01	97.00
Speech duration		AWS	3.14	0.31	3.12	0.88	0.34	1.11
		ANS	3.20	0.07	3.14	3.01	0.05	3.34

*PCC-Percentage of consonants correct, PVC-Percentage of vowels correct

It was seen that the mean and median values for the percentage of consonants correct (PCC)and percentage of vowels correct (PVC) in both the groups were higher (mean/median = 100) for the twentieth trial of the acquisition phase than the third trial of the retention phase. Wilcoxon rank test revealed a significant difference in the PCC (/z/= 2.20, p=0.04) and PVC measure (/z/=2.20, p=0.03) between the twentieth trial of the acquisition phase and third trial of the retention phase of Nonword learning in AWS. In the ANS group also, the p values reached a significance value for PCC (/z/=2.20, P=0.05) and PVC (/z/=2.20, p=0.05) measure between the twentieth trial of the acquisition phase and third trial of the retention phase of Nonword learning.

It was found that the mean values of AWS and ANS on the twentieth trial and the third trial were lesser than the mean values of the target duration (M= 3.68). On comparison of the mean values of speech duration, it was seen that in both the groups, the speech duration values were shorter on the third trial of the retention phase when compared to the twentieth trial of the acquisition phase.

The mean speech duration values were subjected to an independent sample test; Friedman test was done to compare the speech duration across the trials (target duration, the twentieth trial of the acquisition phase, and the third trial of the retention phase) within both the groups. The results of the Friedman test showed that there were significant differences in speech duration between the target duration, twentieth trial, and third trial in AWS (X^2=19.04, $p<0.05$) and in ANS (X^2 =14.08, $p<0.05$).

Since there were significant differences in the speech duration between the acquisition phase and retention phase for both the groups, Wilcoxon signed-rank test was done to compare target duration and twentieth trial; twentieth trial and third trial and target duration and third trial in both groups. Results showed that there were significant differences between target duration and twentieth trial (/z/=2.02, p= 0.04); twentieth trial and third trial (/z/=2.02, p=0.04)and also between target duration and third trial (/z/= 2.02, p=0.04) in AWS. In the ANS group, there were significant differences between target duration and twentieth trial (/z/=2.02, p=0.04) and between target duration and third trial (/z/=2.02, p=0.04), however, there were no significant differences in the speech duration of the twentieth trial and the third trial (/z/= 4.50, p=0.69).

Since the mean scores of PVCof the twentieth trial across in AWS and ANS were the same, Mann-Whitney test results revealed no significant differences in the speech accuracy across both the groups. On the third trial of the retention phase, the mean scores of PCC and PVC were lesser for the AWS group than the ANS group. Mann Whitney test revealed a significant difference(/z/=2.61, p=0.01) for PCC across both the groups. For PVC, the Mann-Whitney test revealed a significant difference(/z/=2.61, p=0.01) for PVC across both the groups

When the mean values of speech duration of the twentieth trial were compared across groups, it was seen that the ANS group obtained higher values compared to the AWS group. Mann-Whitney test indicated that there was a significant difference (/z/=0.73, p=0.47) across groups. On the third trial, the mean values of speech duration for ANS were higher than the AWS group and Mann-Whitney test results revealed a significant difference (/z/=2.61, p=0.01) across groups.

In summary, the results indicated no statistically significant differences between both the groups on short term memory and phonological knowledge. The test-retest reliability was acceptable and towards the higher side for both speech accuracy measures and speech duration measures in both AWS and ANS.

The effect of practice was assessed between and within groups by comparing the speech accuracy and duration between the first and the tenth trial(acquisition phase). Acomparison of speech accuracy of the nonwords in the first trial and tenth trial in AWS and ANS did not show any significant differences. A ceiling effect with highly similar scores was seen in speech accuracy for both groups. There was no significant difference across the groups as well. The comparison of speech duration of the nonwords in the first trial and the tenth trial of the acquisition phase across groups did not show any significant differences. However, there were significant differences in speech duration between the target duration, tenth trial, and twentieth trial in both the groups.

The effect of feedback was assessed between and within groups by comparing the speech accuracy and duration between the tenth and the twentieth trial(acquisition phase). The comparison of speech accuracy of the nonwords in the tenth trial and twentieth trial showed statistically no significant differences within and across groups. The comparison of the speech duration of the nonwords showed no significant difference in the tenth trial and a significant difference in the twentieth trial with the feedback across AWS and ANS. There were also significant differences seen in speech duration between the target duration, tenth trial, and twentieth trial in both the groups.

The effect of motor learning was also assessed by comparing speech accuracy and duration between days 1 and 2 (acquisition vs. retention phase). The comparison of speech accuracy and speech duration of the nonwords in the twentieth trial of the acquisition phase and the third trial of the retention phase in AWS showed statistically significant differences. The results have been discussed in detail in the next chapter.

CHAPTER V

DISCUSSION

This study specifically aimed to investigate the behavioural and acoustic measures with and without practice and feedback on Nonword learning in Adults with Stuttering (AWS) and Adults with No Stuttering (ANS). The current study was done in two phases, viz. the acquisition phase and retention phase. The effect of practice was examined by comparing the speech accuracy and speech duration of the first trial and the tenth trial in the acquisition phase and the effect of feedback was examined by comparing the speech accuracy and speech duration of the tenth trial and the twentieth trial of the acquisition phase. The motor learning abilities were examined by comparing the speech accuracy and speech duration of the nonwords produced between the acquisition phase (twentieth trial) and retention phase (third trial).

To rule out the group differences in vocabulary and short-term memory, semantic memory and working memory subtests from Cognitive Linguistic Assessment Protocol For Adults (CLAP) (Aruna Kamath, 2001) were administered to screen for their phonological knowledge. The meta-phonological skills were assessed using a subtest from the Reading Acquisition Profile-Kannada (RAP-K, Prema, 1997). There was no statistical significance between both the groups on short term memory and phonological knowledge, however, the AWS group had a few difficulties in the subtest of meta-phonological skills. The test-retest reliability was high for both, speech accuracy measures and speech duration measures in both AWS and ANS, except PCC for which, the value indicated acceptable reliability. The data were statistically analyzed and the results revealed several findings of interest, which have been described below under different sections.

5.1 Effects of Practice on Speech Accuracy in the Acquisition Phase

Within and across group comparison of the accuracy of production of the five nonwords during the acquisition phase across the first and tenth trial was carried out to assess the effect of short-term practice. The measures of speech accuracy (both percentages of correct consonants and percentage of correct vowels) did not show statistically significant differences within and across both the groups, as the scores in both the groups were homogeneous and showed ceiling effect. There were no speech errors seen in AWSin both the trials. This finding indicated that the AWS did not exhibit any deficits in the phonological encoding skills and phonological working memory. The presentation mode of the stimuli could be attributed to the homogeneity in the speech accuracy scores obtained in both the groups. It should be noted that the observed dysfluencies during the acquisition phase were not included while calculating the percentage of consonants correct and the percentage of correct vowels. The null hypothesis is therefore accepted that there were no statistically significant differences in the speech accuracy with short term practice during the acquisition of Nonwords in AWS and ANS.

In the current study, the AWS and ANS obtained comparable and high scores on speech accuracy and there were no evident speech errors, which could be attributed to the auditory-visual mode of presentation, which could have lead to relatively lesser cognitive loading. The simultaneous presentation of stimuli through the auditory mode and orthographical mode might have reduced the extra demand on the working memory.

Kefalianos, Onslow, Block, Menzies & Reilley (2012) reported that in AWS, both cognitive processing and phonological processing are more prone to disruption, which is caused by heightened amounts of cognitive load in simultaneous attention-demanding tasks. Though the nonword syllable length was long (seven syllables) in the current study, compared to other studies (Bandstra et al. 2006 & Sasirekhan et al. 2014), the AWS performed the task with high accuracy.

Research in the past has revealed that AWS obtained high speech accuracy in similar nonword repetition tasks, even if anyone of the modality was employed. For instance, Smith et al., (2010) presented stimulus only though the auditory mode, and Smits-Bandstra et al. (2006) and Bauerly et al. (2011) presented the stimulus visually. Despite employing a single modality, all these studies reported no group differences in speech accuracy. The findings of the current study are in agreement with these studies. Since the present study used both auditory and visual modes of presentation, the ceiling effect was seen in the scores of percentages of correct consonants and the percentage of correct vowels. Smits-Bandstra et al. (2006) also found good speech accuracy scores in AWS and reported that both AWS and ANS were comparable on this task.

Moreover, the number of nonwords was lesser compared to other studies (Smith et al., 2010; Bauerly et al., 2011; Sasisekaran et al., 2014). Further, the participants of the current study were expected to imitate only one specific duration unlike the study by Namasivayam and Van Lieshout (2008), where they had to imitate nonwords at two different rates. All these could have led to relatively lesser cognitive loading. These may be the possible reasons for the homogeneity in speech accuracy across the first, tenth, and twentieth trial during the acquisition phase in both AWS and ANS. During the acquisition of nonwords, both the groups were efficient in an immediate repetition of all the nonwords with a high degree of speech accuracy.

Another reason for the high performance on the speech accuracy task could be the blocked schedule of practice employed in the current study. According to (Adams, Page & Jones, 2002) a blocked schedule of practice (i.e. practicing on the same skills over some time) resulted in better acquisition scores than the random practice schedule (i.e. practicing different skills over some time). Similarly, the practice of single motor skills acquires better acquisition scores than the simultaneous practice of several motor skills (multi-tasking skills). The current study followed the blocked schedule of practice over a small amount of time leading to the ceiling effects seen in speech accuracy.

However, this finding is in divergence with the study by Sasisekaran et al. in 2014, who employed both auditory and visual mode presentation. They investigated the practice and retention of nonwords in AWS by using nonwords that varied in length (3,4, 6 syllable and 3Non-Phonotactic Constraint) and complexity (Simple versus complex). The findings of this study suggested that AWS experienced difficulties in the accurate production of nonwords of increasing length, phonotactic constraint, and complexity, which reflect the difficulties in phonemic encoding and/or speech-motor processes. This disparity could be attributed to the type of stimuli used and linguistic differences. The nonwords in this were inclusive of clusters, however, clusters were not used in the nonwords employed in the current study. Also, the stimuli were presented in a random schedule for practice with multiple blocks. In the current study, the stimuli were presented in a blocked schedule for practice rather than in a random schedule. Moreover, Sasisekaran's study was done on American English speaking participants with AWS, whereas the current study was done on Kannada speaking participants. The linguistic structure and nature of Kannada and English are inherently different. There is little or no overlap in their respective written forms, syntax, morphology, phonology, and syllable structure. Kannada is an alpha-syllabary language with a simple syllabic structure, mora-timed rhythm, and emphatic stress (Savithri, Jayaram, Kedarnath, & Sanjay, 2005), English on the other hand, is an alphabetic language with stress-timed rhythm and lexical stress. Maruthy, Raj, Geetha, and Priya(2015) also reported that English is phonetically more complex compared to Kannada.

The findings of the current study are also not in agreement with the study was done by Ludlow et al., (1997) who found that to learn the precise production of two and four-syllable non-sense words, AWS was slower when compared to typically fluent adults and reported that though both groups had some effect of practice, they still had some variations. This decreased effect of practice on AWS was attributed to poor phonological encoding skills.

5.2 Effects of Practice on Speech Duration in the Acquisition Phase

The effect of short-term practice on speech duration measures showed significant differences between the first trial and the tenth trial (i.e., without practice and with practice) in the AWS Group, however, there was no significant difference in the ANS group. This indicated that in the ANS group, there was an effect of practice since they could maintain the duration as on the first trial. However, the AWS could not maintain the duration, which was longer for the first trial compared to the tenth trial. Thus, the effect of practice was not seen in the AWS group.

Additionally, both the groups failed to achieve the target duration pre-specified for each seven-syllable nonwords. There were significant differences between target duration and first trial and between target duration and tenth trial in AWS. In the ANS group, there were no significant differences for speech duration between target duration and the first trial, but there was a significant difference between target duration and tenth trial. However, the mean score of speech duration for ANS was nearer and comparable to the target duration than the mean score of speech duration for AWS. Therefore, the null hypothesis is rejected as that there was a statistically significant difference in the speech duration with short-term practice during the acquisition of Nonwords in only the AWS group.

It was also found that there were no significant differences across the groups in the first trial and tenth trial. Therefore, the null hypothesis is accepted as that there was no statistically significant difference in the speech duration with short term practice during the acquisition of Nonwords between AWS and ANS.

Besides, the mean scores of the speech duration of both groups failed to achieve the pre-specified target duration. Support can be drawn from the study done by Namasivayam and van Lieshout (2008) who indicated that AWS and ANS resemble each other on several performance variables (such as movement amplitude and duration), but they differ in terms of practice and learning on variables that relate to movement stability and strength of coordination patterns at different rates (normal habitual rates and faster rates).

Another study that is in agreement with the current study is by Smith, Sadagopan, Walsh, and Weber-Fox (2010), who studied the effects of the practice of speech movements in a Nonword repetition task of AWS by varying the length and complexity of the Nonwords. The stimuli were presented randomly with a carrier phase and about 10 trials were provided for each word during practice. The behavioral measures, kinematic measures, and speech duration were measured as the outcome of motor learning. They found that AWS had a longer duration than the ANS. Group differences were found in the coordinative consistency by increasing the length and complexity of the Nonwords. The improvements in coordination consistency in the five later productions than the five initial productions showed within-session practice effects. In initial trials, AWS produced the nonwords at a slower rate, but both groups showed increased rates of production on the later trials and that indicated a practice effect for the duration for both groups. They concluded that though the AWS performed behaviourally with the same accuracy as ANS, the Nonword repetition task revealed significant differences in the speech motor dynamics underlying fluent speech production in AWS compared to ANS. These results support a multifactorial, dynamic model of stuttering in which linguistic complexity and utterance length are factors that contribute to the probability of breakdown of the speech motor system. The study focused mainly on the phonological complexity rather than the motor practice and also no retention or transfer of learned skills were studied to explore the changes that happen due to motor practice in AWS.

The findings of the current study are also in agreement with the study done by Bauerly and De Nil (2011), who studied practice and retention in 12 AWS and 12 controls. The nonword repetition task of 11 syllable Nonword was given to the participants. On Day 1, the participants were required to repeat an 11-syllable Nonword 100 times (divided into 10 blocks) and after 24 hours, the participants were required to repeat the Nonword 50 times (divided into 5 blocks). Variables such as accuracy, response preparation time, and sequence duration were measured on Day1 as a measure of practice and the same variables were measured on Day2 as a measure of retention). The expected interaction of group and practice was not evident for accuracy, reaction time, and sequence duration in AWS on both Day 1 and Day2. The AWS did show significantly slower sequence duration both during practice as well as retention, which was interpreted as a motor skill limitation. Similar results were also reported by Smits-Bandstra et al. (2006), who suggested that the early or cognitive stage of motor learning may be particularly affected in AWS.

In the current study, the stimuli were presented in a blocked schedule for practice rather than in a random schedule. According to Schmidt (2004), practice effects are considered to represent temporary improvements in performance that are traditionally observed as an increase in speed and accuracy, resulting from a decreased reliance on sensory mechanisms to guide performance. Many types of research supported that practice or repetition of a given movement pattern is an essential component of learning. Upon practicing a motor task, an individual’s performance is often characterized by shorter response times and sequence durations as well as more accurate responses(West &Sabban, 1982; Moore & Marteniuk, 1986; Salthouse, 1986). Accordingly, the motor practice should result in an accurate response in the speech duration. Even after a certain amount of practice, AWS in the current study failed to benefit by the short term practice, as there were significant differences between target duration and first trial and between target duration and tenth trial in AWS, with the mean score of speech duration for AWS deviating from the target duration. However, the ANS group had benefited from a small amount of practice.

The finding that AWS was AWS could not maintain the duration, which was longer for the first trial compared to the tenth trial indicated that they find it difficult to automatize the learned skill. De Nil and Bosshardt (2001) suggested that AWS may have an inability to automatize speech-motor processes effectively. Moreover, the caudate nucleus is observed to play a role in the later stages of sequence skill learning, particularly when maintenance of speed is required (Lehéricy, Benali, Van de Moortele, Pélégrini-Issac, Waechter, Ugurbil, & Doyon, 2005). The current study showed that the AWS group was not as efficient as the ANS group in maintaining the duration, which indirectly supports the fact that the caudate nucleus could be impaired in its function in AWS. However, this requires further investigation.

5.3 Effect of Feedback on Speech Accuracy in the Acquisition Phase

Within and across group comparison of the accuracy of production of the five Nonwords during the acquisition phase across the tenth and the twentieth trial was carried out to assess the effect of feedback. After the 10th trial of the acquisition phase feedback about their results (i.e. whether they produced the given Nonwords correctly or incorrectly) was given to both groups. The measures of speech accuracy (both percentages of correct consonants and percentage of correct vowels) did not show statistically significant differences within and across both the groups as the scores in both the groups were homogeneous and showed ceiling effect. It may be noted that there were no speech errors seen in the first trial itself. The null hypothesis is therefore accepted that there were no statistically significant differences in speech accuracy with the feedback during the acquisition of Nonwords in AWS and ANS.

Adams, Page, and Jog (2002)reported that the use of frequent feedback schedule (i.e. feedback after every trial was associated with the better acquisition of novel motor task than intermittent or less frequent feedback (i.e. feedback after every five practice trials).On the other hand, a less frequent feedback schedule was associated with better retention of a novel motor task than a frequent feedback schedule. In the current study, it is difficult to interpret whether feedback provided affected speech accuracy, since both the groups of participants showed a ceiling effect.

Some studies have shown a positive effect of feedback in normal individuals. For example, Lowe and Buchwald (2017) investigated the influence of feedback on whole nonword accuracy, phoneme accuracy, and acoustic duration measures during a novel speech motor learning task. They also examined how acquisition and retention are affected by the frequency of feedback while learning new motor skills. Nonword productions were compared among groups by providing two different levels of low-frequency feedback (e.g., 50% vs. 20%), high-frequency feedback (100%), or no feedback (0%). The performance was compared across sessions (practice vs. short-term retention; practice vs. long-term retention) and stimulus properties (i.e., nativeness of word-initial consonant cluster). While measuring whole Nonword accuracy, regardless of the frequency of feedback received during practice, all participants, demonstrated similar degrees of improvement at short-term and long-term retention tests. But, while measuring the phoneme accuracy small differences in performance were noted between feedback groups and the results were interpreted with care in the presence of a possible ceiling effect.

5.4 Effects of Feedback on Speech Duration in the Acquisition Phase

Within and across group comparison of the speech duration of production of the five Nonwords during the acquisition phase across the tenth and the twentieth trial was carried out to assess the effect of feedback. After the 10^{th} trial of the acquisition phase feedback about their results (i.e. whether they produced the given Nonwords correctly or incorrectly) was given to both groups. The results of the current study revealed a significant difference between the tenth trial and twentieth trial (i.e. without feedback and with feedback) within both groups. This indicated that the feedback provided had a positive influence on the Nonword duration in both the groups during the acquisition phase. Therefore, the null hypothesis that there will be no statistically significant differences in the speech duration with feedback during the acquisition of nonwords in AWS and ANS was rejected.

Additionally, both the groups failed to achieve the target duration pre-specified for each seven-syllable Nonwords. It was found that the mean values of AWS and ANS on the tenth trial and twentieth trial were lesser than the mean values of the target duration. There were significant differences in speech duration between target duration and tenth trial and between target duration and twentieth trial in AWS and ANS. However, the mean score of speech duration for ANS was nearer and comparable to the target duration than the mean score of speech duration for AWS.

Across the groups, there was no significant difference in the speech duration in the tenth trial; however, there was a significant difference in the twentieth trial. This indicated that the feedback had influenced the performance of Nonword learning during the acquisition phase. Therefore, the null hypothesis that there will be no statistically significant differences in the speech duration with feedback during the acquisition of Nonwords between AWS and ANS was rejected.

Many studies discuss the effects of auditory feedback (i.e. delayed auditory feedback on fluent speech production in AWS but, to date, no studies investigated the effects of feedback (i.e. knowledge of results and knowledge of performance) on the motor learning skills in AWS. However, De Nil and Abs (1991) observed that when AWS required to make the smallest possible movements in the absence of visual feedback, they made larger oral movements than ANS. The performance of the two groups become similar when visual feedback was added. In the present study as well, there was a significant difference between groups in the twentieth trial, with ANS maintaining the speech duration nearer to the target duration with feedback. The current study is the first of its kind to report changes in acoustic duration measurements during a speech motor learning task using the knowledge of results as feedback in AWS.

The findings of the present study concerning the ANS group could be related to the study by Lowel and Buchwald (2017), who investigated the performance of novel speech motor learning tasks and the impact of feedback frequency on its performance. Improvements were seen in phoneme accuracy and whole nonword accuracy at short-term and long-term retention time points in all the participants. Also, they refined the productions of nonwords, as indicated by a decrease in nonword duration across sessions. Fifty percent of productions exhibited the largest reduction in duration between practice and long-term retention sessions.

As mentioned in the previous section, Adams, Page, and Jog (2002) reported that the use of frequent feedback schedule (i.e. feedback after every trial is associated with the better acquisition of novel motor task than intermittent or less frequent feedback (i.e. feedback after every five practice trials).On the other hand, a less frequent feedback schedule is associated with better retention of a novel motor task than a frequent feedback schedule. In this study, however, the feedback provided was not beneficial for AWS to maintain the pre-specified target duration. This could be because only one-time feedback was provided in the current study. Future studies with other types of feedback schedules can be employed to study the difference in performance in both groups.

5.5 Speech Accuracy in the Acquisition and Retention Phase

The comparison of speech accuracy between the acquisition phase and retention phase of five Nonwords within and across both the groups was carried out. The measures of speech accuracy (percentage of consonants correct and the percentage of correct vowels) showed statistical differences between the twentieth trial of the acquisition phase and third trial of the retention phase of Nonword learning in both the groups, with higher mean values for the percentage of consonants correct and percentage of vowels correct for the twentieth trial than the third trial. This indicated that the speech errors were seen more in the third trial of the retention phase compared to the twentieth trial, which reflected the fact that the effects of practice and feedback during the acquisition phase did not influence and help in the retrieval of already learned nonwords in the retention phase (day-2). Also, the number of retrieved Nonwords for AWS was lesser compared to the ANS. Thus, the null hypothesis is rejected as there is a statistical difference in the speech accuracy between the acquisition and retention of Nonword learning within and across AWS and ANS.

Support for the current findings can be drawn from the study of Byrd in 2015, who reported that certain basic memory processes (i.e., recency effect) and the processing of gist semantic information are largely intact in AWS, but recall of verbatim phonological information and subvocal rehearsal may be deficient.

Researchers suggest that multiple covert productions increase the likelihood of accuracy of the recall (Baddeley, Chincotta, Stafford, & Turk, 2002). In the current study, the consolidation time was only 24 hours. The findings of the current study indicate that AWS requires prolonged access to the stimuli as well as repeated presentation than adults who do not stutter. This was also reported by Ludlow and colleagues (1997); Namasivayamand Van Lieshout, (2008), and Smith et al. (2010).

Further, the number and length of nonwords used in the current study might have made it difficult for both the groups to recall with accuracy. Particularly more disruption was seen in AWS. Some reports indicate that the precision of the recall is influenced by the word length, and its influence is greater in AWS than in ANS, indicating that AWS' subvocal rehearsal method is not as successful in preserving the quality of the feedback (Bosshardt, 1990; Ludlow et al., 1997).

The current study is in agreement with the study done by Bauerely and De Nil (2011), who investigated the practice effects and retention of nonsense syllables in AWS.

They measured accuracy, response preparation time, and sequence duration on Day 1 as a measure of practice and on Day 2 as a measure of motor learning (retention). The results indicated and confirmed the poor practice and learning effects in AWS which was interpreted as motor skill limitation.

However, Sasisekaran et al. (2014) found that there were no group differences between ANS and AWS. They compared speech accuracy for Nonwords varying in Nonword type (length and phonetic complexity) and complexity within(acquisition) and between sessions (retention). The groups showed no differences in the speech accuracy with retention in session 2, suggesting that the ability to hold the designed programmed information in the memory, at least for one hour, maybe similar between the groups. This difference in findings could be attributed to the time available for consolidation in both the studies. In the current study, retention was assessed after 24 hours, whereas in this study, the retention was assessed after one hour.

5.6 Speech Duration in the Acquisition and Retention Phase

The comparison of speech duration between the acquisition phase and retention phase of five Nonwords within and across both the groups was carried out. The measures of speech duration showed statistical differences between the twentieth trial of the acquisition phase and the third trial of the retention phase of Nonword learning in both the groups, with higher mean values for the speech duration in the twentieth trial than the third trial. This indicated that AWS has difficulty in retrieving the learned skills (speech duration) in the acquisition period. This indicated that the effects of practice and feedback during the acquisition phase did not influence and help in the retrieval of already learned Nonwords in the retention phase (day-2). Thus, the null hypothesis is rejected as there was a statistical difference in the speech duration between the acquisition and retention of Nonword learning within and across AWS and ANS. Bauerly and De Nil (2011) also reported that the AWS did show significantly slower sequence duration both during practice as well as post-consolidation, which was interpreted as a motor skill limitation.

Support for the current study can also be drawn from the findings of Namasivayam and Van Lieshout (2008), Namasivayam and Van Lieshout (2008), who recorded a discrepancy in practical effects while producing a non-word on the first day versus the second day amongst AWS and ANS through kinematic analysis, they assessed the synchronization trends and enhanced the degree of frequency coupling between gestures. For adults who stutter to the same degree as adults who did not stutter, the inconsistency in the coordination of movements needed to generate the non-word did not diminish. Additionally, the strength of frequency coupling between the required articulatory movements has not increased in AWS in the way it did for ANS. Results also showed that, over time, adults who stutter did not hold the same degree of performance quality as ANS. Thus, the authors indicated that the motor processing of novel sound sequences demonstrated unique difficulties in AWS.

However, the results of the present study are not in agreement with the study conducted by Smits-Bandstra et al. (2006), who found no group differences with the practice in either the segment duration or the reaction time in the speech task. Using a 10-syllable sequence delivered in random order on AWS and ANS, they explored the variations in speech sequencing ability over time. Their findings indicated that ANS displayed reduced sequence durations compared to AWS over-testing, while precision for both groups was kept steady. But during the retention phase, there were no major variations and they concluded that success in the early stages of learning is slow, deliberate, and most possibly mediated by declarative or cognitive learning approaches and interpreted that the early or cognitive stage of motor learning may be especially impaired in AWS.

More and more research studies have pointed to limitations in the phonological encoding abilities and motor learning of AWS. Through this current study as well, it can be inferred that even after a certain amount of constant practice along with the provision of feedback, AWS benefited only during the acquisition period, but the practice effects and feedback had no benefit in retrieving the already learned nonwords, both in terms of maintaining accuracy and the duration. Hence, the current study supports the fact that AWS has no deficits in phonological encoding skills as evidenced through their performance in the acquisition phase, however, have limited speech motor learning skills, as evidenced through their performance on the retention tasks.

Motor learning is generally accepted to involve a relatively permanent change in behavior that is a result of practice or experience, and not a result of maturation, motivational, or training factors(Sage 1983). Speech motor learning deficits in AWS are known to be poor compared to ANS (Van Lieshout &Namashivayam, 2011). During therapy, this difficulty in speech motor learning creates difficulties, as AWS must develop a different set of speech motor sequences/patterns under structured therapeutic conditions (Ludlow et al., 1997; Neilson & Neilson, 1991; Smits-Bandstra et al., 2006). The novel speech motor patterns like reduced speaking rates, light articulatory interactions, controlled breathing mechanisms are used in fluency management (Ludlow et al., 1997). AWS most frequently relapse back with the complaints of perceptual disfluencies soon after the termination of the treatment process. Craig and Hancock (1995)stated that at least 14% to 70% of AWS shows relapse with increased perceptual dysfluencies, which is referred to as a support for the succeeding speech motor skill limitation in AWS (Kalvaram, 2001). The current study also supports the fact that increased practice and feedback can lead to better retention. Therefore, the therapy sessions need to be carried out over a longer duration with increased practice and feedback, to facilitate the retention of the newly learned speech motor skills, thereby preventing relapse.

Chapter VI

Summary and Conclusions

To the best of our knowledge, no studies to date have explored the combined effects of practice condition and feedback conditions in speech motor learning investigation in adults with stuttering. Hence, the current study was planned to analyze the effects of speech motor practice and feedback on acquisition and retention by utilizing complex syllable length conditions.

The specific aim of the study was to investigate the effects of short term practice and feedback in the motor learning on AWS and ANS using seven-syllable Nonwords. The specific objectives of the current study were a) To investigate changes if any, in the speech accuracy and speech duration with short term practice during the acquisition of nonwords in AWS and ANS, b) To investigate changes if any, in the speech accuracy and speech duration with feedback during the acquisition of nonwords in AWS and ANS, c) To compare the speech accuracy and speech duration between both the groups with and without short term practice and feedback and d) To investigate changes if any, in the speech accuracy and speech duration between the acquisition and retention phase of nonwords within and across both the groups.

The study was carried out in two phases, viz. the acquisition phase (day 1) and retention phase (day2). The effects of short term practice and feedback were measured by using speech accuracy (percentage of correct consonants and percentage of correct vowels) and speech duration measures. The study included 10 Kannada speaking male AWS with a mean age of 23.5 years. They were diagnosed as ‘stuttering’ by experienced speech-language pathologists based on the ratings obtained on the Stuttering Severity

Instrument (SSI Version 4, Riley, 2008). Among them four had a mild degree of stuttering, three had a moderate degree and three had a severe degree of stuttering.

Ten age and gender-matched adults with no stuttering comprised the control group. They were matched with the clinical group for their socioeconomic status using the NIMH socioeconomic status scale developed by Venkatesan(2009). Also, they were screened for any problems in voice, articulation, and language. Oral mechanism examination and hearing screening were carried out to rule out any abnormality. To rule out the group differences in vocabulary and short term memory, semantic memory and working memory subtests from Cognitive Linguistic Assessment Protocol For Adults (CLAP) (Aruna Kamath, 2001) were administered and to screen for their phonological knowledge, subtests to assess meta phonological skills from Reading Acquisition Profile-Kannada (RAP-K, Prema,1997) was administered for persons in both groups. Those participants who passed the screening tests were included in the study.

In the acquisition phase using CSL pentax4000, responses were obtained for 20 trials for each of the five seven-syllable length Nonwords, constructed as a part of the study. The nonwords were audio-recorded with PRAAT software version 6.0.30 by a female native speaker of Kannada with a target duration, that was obtained by multiplying the original duration of each word by two. An interstimulus interval of 5secs was used between the nonwords. Further, the nonwords were orthographically represented in the Microsoft PowerPoint presentation with the recorded audio samples for the fixed duration, which were provided to the participants. The participants had to utter the nonwords ten times by maintaining the target duration. The responses were recorded using CSL Pentax 4000, with a unidirectional microphone placed at a distance of 6cm.

The speech duration analysis was carried out through the text grid of the PRAAT software. The speech duration was obtained and plotted in an excel sheet of the Microsoft 7 to give feedback regarding the maintenance of duration during the production. Simultaneously, speech accuracy (percentage of correct vowels/consonants) for all the nonwords was calculated and feedback was given regarding the accuracy of production. After the feedback concerning accuracy and duration, the participants were expected to produce the nonwords again 10 times, which was recorded similarly.

During the retention phase, the participants were asked to repeat the same nonwords in the absence of the target stimuli after 24 hours by maintaining the same target duration for three trials, which was recorded. The same procedure as in the acquisition phase was used to calculate the speech accuracy and speech duration.

The calculated scores were averaged and compared across the trials (First, tenth and twentieth trial) in the acquisition phase and (3rd trial) in the retention phase within and across AWS and ANS. The speech duration and speech accuracy values for the participants of two groups along with the measures of CLAP and RAP-K were subjected to statistical analysis using SPSS (Version 20). The test-retest reliability of speech accuracy and speech duration was assessed using Cronbach’s alpha measures. As the data were non-normally distributed, a non-parametric test was used to find the statistical differences across the groups. Mann-Whitney test was used to find the significant differences if any, in the accuracy of response as well as to compare the speech duration in both acquisition and retention phases between both the groups. Mann-Whitney test was also used to compare CLAP and RAP-K scores across groups. Friedman's test was used to compare the accuracy of speech duration between the target duration, 1st trial, the

10thtrial, and the 20th trial of the acquisition phase within the group. Wilcoxon test was used to compare the accuracy of speech duration between the target duration, 10th, and 20th trial of the acquisition phase and 3rd trial in the retention phase within the group. One sample Wilcoxon signed-rank test was used to compare the accuracy of the responses of the percentage of correct consonants and vowels within and across the group in both acquisition and retention phases.

There were no statistically significant differences between both the groups on short term memory and phonological knowledge. The test-retest reliability was acceptable and towards the higher side for both speech accuracy measures and speech duration measures in both AWS and ANS. The effect of practice was assessed between and within groups by comparing the speech accuracy and duration between the first and the tenth trial (acquisition phase). The comparison of speech accuracy of the nonwords in the first trial and tenth trial in AWS and ANS did not show any significant differences. A ceiling effect with highly similar scores was seen in speech accuracy for both groups. There was no significant difference across the groups as well. The comparison of speech duration of the nonwords in the first trial and the tenth trial of the acquisition phase across groups did not show any significant differences. However, there were significant differences in speech duration between the target duration, tenth trial, and twentieth trial in both the groups.

The effect of feedback was assessed between and within groups by comparing the speech accuracy and duration between the tenth and the twentieth trial (acquisition phase). The comparison of speech accuracy of the nonwords in the tenth trial and twentieth trial showed statistically no significant differences within and across groups.

The comparison of the speech duration of the nonwords showed no significant difference in the tenth trial and a significant difference in the twentieth trial with the feedback across AWS and ANS. There were also significant differences seen in speech duration between the target duration, tenth trial, and twentieth trial in both the groups.

The effect of motor learning was also assessed by comparing speech accuracy and duration between days 1 and 2. The comparison of speech accuracy and speech duration of the nonwords in the twentieth trial of the acquisition phase and the third trial of the retention phase in AWS showed statistically significant differences.

The results indicated that the AWS and ANS benefit with practice, though the effects of practice were seen to a greater extent in the ANS. The effect of feedback was restricted to the first few trials, as AWS could not maintain the duration until the twentieth trial. Moreover, the retention was deficient in AWS as they exhibited greater speech errors and could not maintain the speech duration as well. The performance in the acquisition phase was better than the retention phase, as the effect of practice and feedback was not evident in the recall of the nonwords. These results indicated that AWS had deficient speech motor learning skills as reflected through the poor scores on speech accuracy and speech duration. The amount of practice or time might have been insufficient to induce learning-related changes in speech motor physiology for these nonwords, which support the need for further investigation of the effects of long term practice on the learning of novel phonemic strings in AWS.

The study has implications in the management of persons with stuttering. The study provides an insight into the need for extended practice and feedback during the management to facilitate retention of the newly learned speech motor skills. The long-term practice with enhanced visual feedback could facilitate motor learning. However, caution has to be exercised while generalizing the results of the study, as the sample size was small. Kinematic measures could also have been incorporated as that would have provided a holistic picture of performance on such tasks. The severity of stuttering was not controlled, which could have influenced the results of the study. Future studies can be undertaken with a larger sample size to analyze the effects of specific types of practice and feedback schedules. Nonwords with variation in phonological complexity might further deepen our understanding of motor learning deficits in AWS. The differential effect of age, gender, and severity of stuttering on speech motor learning could also be explored.

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