EFFICACY OF NON-WORD REPETITION AND PHONEME ELISION TREATMENT FOR ADULTS WHO STUTTER: AN INSIGHT INTO PHONOLOGICAL WORKING MEMORY

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JULY, 2024

CERTIFICATE

This is to certify that this Dissertation entitled "**Efficacy of Non-word Repetition and Phoneme Elision Treatment for Adults who Stutter: An Insight into Phonological Working Memory**" is a bonafide work submitted in part fulfilment for the degree of Master of Science (Speech-Language Pathology) student with Registration Number P01II22S023027. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru

July, 2024

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July, 2024

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DECLARATION

This is to certify that this Dissertation entitled "**Efficacy of Non-word Repetition and Phoneme Elision Treatment for Adults who Stutter: An Insight into Phonological Working Memory**" is a result of my study under the guidance of Dr. Anjana B Ram, Assistant Professor in Speech Pathology, Department of Speech-Language Pathology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru	Registration No.
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Dedicated to Sunitha Shetty, my Mother and my best friend.

It is your soft strength and resilience that have guided every decision in my life.

If I was to get another chance at this life, I would pray to be your daughter again.

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Chapter I

Introduction

Stuttering is described as a communication disorder marked by involuntary disruptions in the flow or rhythm of speaking. These disruptions are often described as sound prolongations, silent blocks, and syllable repetitions, which may be brief or may last for many seconds (Yairi& Ambrose, 2005). The nature of stuttering has been extensively studied from early childhood till adolescence (Yairi & Ambrose, 2005; Bloodstein & Bernstein Ratner, 2007). Many factors such as language, emotions/temperament, and speech motor control have been found to be significant, making stuttering a multifactorial disorder (e.g., De Nil, 1999; Smith, 1999; Yairi & Ambrose, 2005; Guitar, 2006; Walden et al., 2012).

In the linguistic domain, many theories have tried to explain the significance of phonological encoding deficits as a cause of stuttering. Phonological encoding is described as the process of retrieving sound segments in a word prior to speech-motor programming and execution (Levelt, 1989). Theories that support phonological encoding as a cause of stuttering include the Fault line Hypothesis (Wingate, 1988), Neuropsycholinguistic Theory (Perkins et al, 1991), Covert Repair Hypothesis (Postma & Kolk, 1993) and the EXPLAN model (Howell & AuYeong, 2002).

There is equivocal research evidence suggesting that phonological encoding is compromised in Persons who Stutter (Bosshardt & Fransen, 1996; Ludlow et al, 1997; Burger & Wijnen, 1999; Weber-Fox et al., 2004; Hakim & Ratner, 2004; Sasisekaran et al., 2006; Hennesy et al, 2008). Research also suggests that phonological representation may be insufficient in children who stutter. Phonological processing abilities increase as typically fluent children develop; however, children who stutter do not show the same increase within the same time frame. (Byrd et al, 2007). Also, in adults who stutter, phonological processing is uniquely compromised due to increased cognitive demands (Bajaj, 2007; Jones et al, 2012; Sasisekaran & Weisberg, 2014). The above evidence warrants a better understanding and research paradigms to unveil the nature of phonological deficits in persons who stutter.

A few paradigms within the research literature are used to evaluate phonological encoding, such as phonological priming (Wijnen & Boer, 1996) and phonological processing tasks. Phonological processing is considered to be an umbrella term which includes phonological working memory and phonological awareness skills.

Non-word repetition

One of the most researched ways of testing phonological working memory is non-word repetition tasks (Ludlow et al., 1997; Gupta, 2003; Hakim & Ratner, 2004;) Non-word repetition task includes repetition of words that follow the phonotactic structure of an individual's language but hold no semantic meaning. During non-word repetition, individuals must rely on the storage component of the phonological loop for the storage, retrieval, and encoding of phonetic information without being influenced by prior lexical knowledge (Gathercole et al, 1994)

Phoneme Elision

Another part of phonological working memory is phonological awareness. Tasks to evaluate phonological awareness include sound matching, phoneme blending, phoneme segmentation, rapid automized naming and phoneme elision tasks. Phoneme elision is described as the deletion of one or more constituent phonemes in the verbal expression of the target word (Wagner et al, 1999)

Need of the study

With a large body of evidence suggesting that stuttering deficits lie in part at least with the difficulties in phonological encoding, treatment consideration should also focus on improving these phonological deficits. Byrd et al. (2015) suggest that the difficulties in establishing and maintaining fluency in adults who stutter may be due to phonological working memory deficits. Sasisekaran & Weisberg's (2014) study also suggests that adults who stutter may have reduced retention and practice effects. As the word length increases, non-word production and phoneme elision difficulties also increase in adults who stutter. This calls for a protocol or specific tasks to target phonological working memory alongside traditional fluency therapy (which focus largely on stuttering modification, fluency reshaping and cognitive-emotional counselling).

In an exploratory study in 2015, Amini et al conducted a phonological working memory intervention for four children who stutter aged 5-6 years. The intervention included a non-word repetition task conducted over 18 sessions. The results showed that all participants had a statistically significant reduction in the percentage of syllables stuttered after the intervention

Following this, Tahmasebi & colleagues (2019) checked for the efficacy of phonological processing treatment in children who stutter. They selected 6 children in the age range of 3 to 6 years who stutter. The authors conducted 13 sessions, with each session divided into two parts: the first part focused on non-word repetition (CV, CVC, and CVCC), and the second part focused on phonological awareness tasks (such as syllable knowledge, intra-syllabic unit awareness, and phoneme awareness). They found a significant difference in post-treatment stuttering severity. However, the difference was not as significant for pre-treatment and follow-up (1 week) scores.

The above studies are the only ones focusing on treating phonological working memory for persons who stutter. However, it is focused on children who stutter. The current study aims to expand on Tahmasebi et al. (2019) findings on adults who stutter. Consequently, the effect of phonological working memory treatment on the percentage of dysfluencies will be assessed.

Aim

To investigate the effect of phonological working memory on the percentage of dysfluencies in Adults who Stutter

Objectives

- To compute the periodic changes in the percentage of dysfluencies on Day 5, Day 10, and Day 15 of the treatment protocol
- To compare the percentage of dysfluencies pre-treatment and on follow-up after 1 week

Null Hypotheses

- **For Objective 1:** There is no significant difference in the percentage of dysfluencies in adults who stutter on Day 5, Day 10, and Day 15 of the treatment protocol.
- **For Objective 2:** There is no significant difference in the percentage of dysfluencies in adults who stutter between the pre-treatment period and the follow-up after 1 week.

Chapter II

Review of literature

Stuttering is a unique and complex disorder of multifactorial etiology. Many researchers have debated the cause of stuttering, thus probing into psychological, physiological, socio-emotional, and linguistic aspects. Within the linguistic domain, phonological encoding is implicated to be one of the causes of stuttering.

Phonological Encoding

According to Levelt (1989), phonological encoding involves the processes of retrieving or constructing a phonetic or articulatory plan for each lemma or word and the entire utterance. This process includes three main components: generating word segments, integrating sound segments with word frames, and assigning syllable stress. Phonological encoding serves as a bridge between lexical processing and motor speech production (Levelt, 1989; Levelt et al., 1999) and occurs before the activation of the speech-motor system. In the WEAVER++ model (Levelt et al., 2001), phonological encoding is described as the retrieval and just-in-time reassembly of phonological codes (phonemes or syllables) to construct phonological words efficiently. Consequently, phonological encoding is integral to the language formulation process, making it difficult to separate from other language processes.

Theories of phonological encoding in stuttering

Fault Line Hypothesis. Wingate (1988) was one of the first to explain the linguistic nature of stuttering deficits with his Fault Line Hypothesis. The hypothesis proposes that stuttering stems from challenges at the intersection or "fault line" between linguistic planning and motor execution in speech production. The "fault line" refers to the critical juncture where phonological planning meets motor execution. Problems at this juncture, such as delays or errors in encoding, can cause speech disruptions characteristic of stuttering. According to the hypothesis, stuttering events are more likely to occur on certain types of words and sounds, particularly those that require more complex phonological encoding and motor execution.

Neuropsycholinguistic theory. This theory given by Perkins, Kent and Curlee (1991) posits that stuttering results from a dyssynchrony between linguistic and paralinguistic components of speech, processed by different neural systems converging on a common output system. Their theory addresses the role of phonological encoding in the process of speech production. For speech to be fluent, segmental (phonetic) and suprasegmental (prosodic) information must be integrated into a unified motor pattern. Disfluency, including stuttering, arises when there is a lack of synchrony in this integration. The theory highlights the need for both the paralinguistic (signal) and linguistic (symbol) systems to function efficiently and in sync. Delays in phonological encoding, such as slow or inefficient segment generation, can result in disfluency and potentially stuttering, especially under high time pressure and when the speaker is unaware of the disruption. The theory integrates genetic predispositions, brain injuries, and competition for neural resources as factors influencing stuttering.

Covert Repair Hypothesis. Postma and Kolk's hypothesis (Kolk, 1991; Postma, 1991; Postma & Kolk, 1993) accounts for the variety and frequency of disfluencies observed during stuttering. They proposed that individuals who stutter exhibit an impaired speech-planning process with an unusually high number of errors. A fluent speaker may be able to correct this faulty phonetic plan within one or two attempts. However, an individual who stutters will require multiple such attempts, leading to the disruptions which is seen in their overt speech.

The covert repair hypothesis suggests that disfluencies result from covert repairs made to internal speech errors. Internal speech errors encompass a range of irregularities, including semantic, syntactic, lexical, and (sub)phonemic issues, as illustrated in Table 2.1. The core concept is that errors can be internally detected before articulation by a monitoring system. When an error is detected, the monitor edits the current articulatory plan to correct it. If the correction is successful, the error does not appear in the spoken output; thus, it is termed a covert self-repair. However, covert repairing has a significant drawback; it can disrupt ongoing speech, manifesting as various types of disfluencies. Covert self-repairing involves three steps. First, an error is detected through internal monitoring. Second, the speech production process is interrupted. Finally, the articulatory plan is revised and executed again. The last two steps are vital to the occurrence and type of disfluency. The observed disfluency depends on the nature of the covert repair process, including the interruption point, which is influenced by the type and magnitude of the internal error.

Table 2.1:

Disfluencies and their pre-supposed underlying internal error and covert self-repair

Internal error	**Covert repair**	**Disfluency**
Restart strategy		
Semantic/syntactic error	Restart phrase	[1] Phrase repetition
Lexical error	Restart previous word	[2] Word repetition
Phonemic error	Restart interrupted syllable from beginning	[3] Blocking
Phonemic error	Restart interrupted syllable from beginning	[4] Prolongation

Phonemic error	Restart interrupted syllable from beginning	[5] (Sub)syllabic repetition
Postponement strategy		
Semantic/syntactic/ lexical error	Hold execution, reformulate	[6] Silent pause (>200 msec)
Phonemic error	Prolong current sound until proper continuation found	[7] Prolongation of syllable noninitial sounds (drawls)
Phonemic error	Hold execution next sound until proper continuation found	[8] Blocking in the midst of a syllable (broken words)

Note. Source: Adapted from Postma & Kolk (1993)

According to the hypothesis underlying these disfluencies, speakers always start a syllable over again from the beginning after identifying an internal (phonemic) defect (retrace repair strategy). The percentage of the current syllable that is articulated before the interruption determines the type of disfluency that is observed. If articulatory positioning has started but no audible sound is produced, blocking happens on the first sound. Prolongation results from the production of an audible sound, as long as the phoneme is continuous. The amount of the phoneme that is completed at the time of interruption determines whether a prolongation or repetition occurs. Restarting from the beginning of the syllable produces a larger repetition if more sounds of the syllable are articulated before the interruption. The postponement repair strategy, on the other hand, causes non-initial disfluencies inside a syllable (drawls and broken syllables), where the sound is produced by halting or breaking the sound mid-syllable without reverting. Silent and filled pauses are likewise caused by this tactic (see Table 2.1). Furthermore, rather than the retrace technique, this repair mechanism can cause some blocks and prolongations. According to the covert repair hypothesis, stutterers are capable of monitoring their speech adequately. Their inability to generate the articulatory plan through phonological encoding is the root cause of their fluency issues. Similar to common speech errors like phoneme reversals, deletions, or substitutions, this impairment leaves the articulatory plan vulnerable to phonemic and phonetic distortions. These deviations greatly impair speech fluency by providing several opportunities for covert self-repair. In other words, stutterers have high rates of disfluency because of internal errors they make in their articulatory plans frequently and internal corrections they make as a result.

EXPLAN model. Howell & Au Yeong's (2002) model suggests that stuttering results from a temporal asynchrony between linguistic planning (PLAN) and motor execution (EX) of subsequent syllables. The model asserts that fluent speech depends on precise timing and coordination between these stages. Disfluencies happen when the execution phase starts before the planning phase is finished, causing the speaker to pause or repeat sounds until the planning catches up with the execution.

Phonological encoding comprises two important components: phonological working memory and phonological awareness.

Phonological working memory

Working memory (WM), also referred to as short-term memory (STM), is a type of buffer that is restricted in both time and capacity. It is used to briefly store information for processing, recoding, and possible transfer to long-term storage. It is divided into distinct sketchpads for visual and auditory input, as well as a central executive controller (Baddeley, 2003). Working memory is defined as a multicomponent neurocognitive system in Baddeley's model that is in charge of temporarily storing and retrieving information. A phonological loop, an episodic buffer, a visuospatial sketchpad, and a central executive are all part of this system. Working memory's central executive is its fundamental component. It serves as a supervisory system that focuses attention, controls thought processes and plans out the tasks of the other parts. It manages activities like inhibiting distractions, directing attention, and switching between tasks. The central executive does not keep information on its own and has limited capacity. According to Baddeley (2003) and Bajaj (2007), the phonological loop is in charge of the short-term retention and practice of linguistic information for comprehension. The phonological storage and the articulatory rehearsal process are its two subcomponents. For less than two seconds, the phonological storage module can store speech acoustics as data. Sub-vocal rehearsal, or the phenomena of silently practicing verbal information, is made possible by the articulatory rehearsal process and results in the retention of verbal information in the phonological loop for longer than two seconds. Visual and spatial data are processed and stored by the visuospatial sketchpad. It is in charge of storing and modifying spatial layouts and images. Ultimately, the episodic buffer creates a cohesive sequence or episode by combining data from the long-term memory, the visuospatial sketchpad, and the phonological loop. It is a kind of temporary storage that unifies data from several sources to show events or experiences in an integrated manner. Complex cognitive activities are made easier by this component, which enables the integration of linguistic, spatial, and visual information with long-term memory.

During speech planning, phonological encoding includes retrieval of phonological information from storage to build articulatory plans, which ultimately rely on phonological loop operations (Levelt, 1989). Baddeley (2003) further summarised that phonological storage and retrieval are affected by factors such as articulatory suppression, phonological similarity, and word length.

Non-word repetition

One of the most researched ways of testing phonological working memory is non-word repetition tasks (Ludlow et al, 1997; Gupta, 2003; Hakim & Ratner, 2004) Non-word repetition task includes repetition of words that follow the phonotactic structure of an individual's language but hold no semantic meaning. During non-word repetition, individuals must rely on the storage component of the phonological loop for the storage, retrieval and encoding of phonetic information without being influenced by prior lexical knowledge (Gathercole et al, 1994)

The earliest study of non-word repetition on individuals who stutter was done by Ludlow, Siren & Zikria in 1997. In their study, Ludlow et al hypothesised that the efficiency of speech language processing in adults who stutter (AWS) may be dependent on their ability to learn new phonological sequences such as non-words. Five adults who stutter (and seven controls) were selected for the study. They were presented with two 4-syllable non-words and were asked to repeat the non-words multiple times. The authors found that as the number of trials increased production accuracy improved both in AWS and Adults who do not stutter (AWNS), however, the percentage of consonants correct was still lower for AWS. This difference supported the view that Individuals who Stutter have inefficient phonological encoding skills.

In another study by Hakim & Ratner (2004), non-word repetition abilities were tested for eight children who stutter in the age range of 4 to 8 years and 8 controls. They used non-words of 3 syllable, 4 syllable and 5 syllable lengths from the Children's Test of Non-word Repetition (Gathercole, 1994). Results of this study showed that more omission and substitution errors were produced by CWS and a significant difference in errors was seen at 3 syllable length for CWS. The authors suggested that this study gives evidence for the hypothesized link between stuttering as a phonological processing deficit during speech production.

Bakhtiar et al (2007) aimed to examine phonological encoding in young children who stutter (CWS) during a nonword repetition task and to test the covert repair hypothesis (CRH) and phonological skills of native Persian children. The study was conducted among 12 CWS and 12 children who do not stutter (CWNS) between the ages of 5.1 and 7.10 at the rehabilitation clinics in Tehran. A list of 40 bisyllabic and trisyllabic nonwords was used in a nonword repetition task to collect information about the following dependent variables: (a) reaction times (RTs), (b) the number of phonological errors (PEs) and (c) nonword length. The findings showed no discernible difference between the groups, while the CWS performed slightly worse than the CWNS. Additionally, there were significant variations in phonological errors between bisyllabic and trisyllabic nonwords, but not for reaction times. It was discovered that even with an increase in syllable length, CWS might not have a severe issue with phonological retrieval of the novel phonological setting.

In a study conducted in 2006, Anderson and colleagues evaluated the nonword repetition abilities of 24 children, ages 3 to 5 years old, 12 of whom stutter (CWS) and 12 of whom do not (CWNS). Children's Test of Nonword Repetition (CNRep; Gathercole et al., 1994) was the instrument they employed for the non-word repetition task. When it came to two- and three-syllable nonwords, the results showed that CWS produced significantly fewer correct repetitions and significantly more phoneme errors on the three-syllable non-words than CWNS. Nonword repetition and expressive phonology test performance also showed a significant correlation for CWS but not for CWNS. Additionally, there was no discernible change in fluency as nonword length increased according to the results. In summary, the results corroborate earlier studies that found disparities in nonword repetition skills between CWS and CWNS, and that these differences could not be explained by CWS's poor language performance or stuttering during nonword output.

Anderson and Wagovich (2010) sought to explore possible connections between language processing speed and two cognitive domains: phonological working memory and attention. Participants ranged in age from 3 years 6 months to 5 years 2 months, with 9 children who stutter (CWS) and 14 children who do not stutter (CWNS). The children finished a nonword repetition test using CNRep (Gathercole, 1996) to evaluate phonological working memory and an automated picture naming task to gauge linguistic processing speed. The children's attentional skills were assessed through the completion of a temperament behavior questionnaire by the parents. The nonword repetition test was where CWS significantly underperformed, while picture naming speed and attention were not different between the groups, according to the results. The results, after adjusting for age, showed that: (a) picture naming speed and nonword repetition for CWS only exhibited a significant negative relationship; (b) attention and picture naming speed did not significantly correlate for either group; and (c) nonword repetition and focused attentional skills did significantly correlate for CWNS only. The significance of taking into account the fundamental abilities associated with lexical elements of language production in assessing the task performances of CWS and CWNS is underscored by these findings.

Namasivayam & Van Lieshout (2008) looked into the possibility of motor practice and learning differences between persons who stutter (PWS) and persons who do not (PNS). Over the course of three test sessions—Test sessions 1 and 2 taking place on the same day, and Test session 3 taking place on a different day at least a week later—five PWS and five PNS repeated a set of non-words at regular and quick rates. The findings demonstrated that, although PWS and PNS might be comparable in terms of performance factors such as movement amplitude and length, they are different in terms of movement stability and coordination pattern strength in practice and learning. These results corroborate statements on speech-motor skill deficits in PWS.

Smith et al (2010) examined how phonological complexity affects the speech motor systems of adults who stutter by evaluating 17 adults who stutter and 17 adults who do not stutter on a nonword repetition task. The nonwords differed in their length and complexity. While both groups showed similar accuracy in repeating nonwords, significant differences emerged in the kinematic data. Adults who stutter displayed much less consistent inter-articulator coordination over repeated attempts. These differences in coordination consistency became more evident as the nonwords increased in length and complexity. Notably, unlike their fluent counterparts, adults who stutter demonstrated within-session practice effects, with improved coordination consistency in later productions. Although adults who stutter produced the nonwords more slowly, both groups showed faster production rates in later trials, indicating a practice effect. These findings indicate that despite similar behavioral accuracy, adults who stutter exhibit distinct differences in speech-motor dynamics compared to fluent adults. This supports a multifactorial, dynamic model of stuttering, suggesting that linguistic complexity and utterance length contribute to the likelihood of speech-motor system disruptions.

In her follow-up study, Sasisekaran & Weisberg (2014) studied the effect of short-term practice on retention of non-words. They used 8 non-words of different lengths, 3-, 4- and 6-syllable. Both AWS and AWNS were tested for two sessions with a one-hour gap in between. The first session was for practice, and the second session was tested for retention. As the syllable length increased, adults who stutter demonstrated a noticeably decreased likelihood of accurate responses. The kinematic profile showed practice effects for AWS with 3-syllable non-words but not for 4 and 6-syllable non-words. However, AWNS showed a marked decrease in movement variability. This suggests that AWS has reduced practice and retention as compared to AWNS.

Choopanian et al (2019) did a cross-sectional descriptive-correlational study to examine the non-word repetition ability between adults who stutter and adults who do not stutter. The participants included 20 adults with stuttering (18-30 years old) and 30 age-matched peers as the control group. Researchers examined the phonological processing of participants in terms of reaction time and word/non-word repetition accuracy. The study found that phonological processing in adults who stutter differs from those with speech fluency, but this difference is non-significant. Results indicated that adults with stuttering exhibit slower phonological processing, highlighting the need for therapists to consider this during evaluation and treatment.

Sugathan & Maruthy (2020) examined the relationship between phonological working memory (PWM) and speech-motor control in school-aged children who stutter and those who do not by using nonword repetition and identification tasks. Participants ranged in age from 7 to 12 years old and included 17 children who stutter (CWS) and 17 age- and gender-matched children who do not stutter (CWNS). Participants repeated sets of nonwords with two, three, and four syllables (12 per set) in the nonword repetition task. In the nonword identification test, participants had to silently choose one of three nonwords (12 per 2-, 3-, and 4-syllable length) as the target nonword. The number of trials conducted, the average number of accurate repetitions, the number of accurate repetitions on the first trial, and the number of fluent repetitions throughout the study were all compared. The amount of nonwords that both groups correctly detected was also examined. The initial output of nonwords by CWS was substantially less accurate, and it took them significantly longer to repeat the nonwords accurately. Furthermore, CWS performed substantially worse than CWNS in the nonword identification task when it came to accurately identifying the target nonword. The results imply that dysfluent speech in CWS may be caused by an unstable speech-motor control system in addition to deficits in phonological working memory ability.

Phoneme elision

Another part of phonological encoding is phonological awareness. Tasks to evaluate phonological awareness include sound matching, phoneme blending, phoneme segmentation, rapid automized naming, and phoneme elision tasks. Phoneme elision is described as the deletion of one or more constituent phonemes in the verbal expression of a target word (Wagner et al, 1999)

Byrd et al. (2012) investigated the phonological working memory abilities of individuals who stutter and those who do not using a nonword repetition and phoneme elision task for 48 nonwords, including 2-, 3-, 4-, and 7-syllable nonwords. They reported that the seven-syllable non-word repetition was the basis for the differences between the two groups. In order to correctly generate the seven-syllable non-words, AWS needed to attempt them multiple times and were less accurate. However, when the non-word length increased, both groups' performance on the phoneme elision test significantly declined. The authors hypothesized that whereas AWS outperform stuttering children in phonological encoding, these gains are not comparable with adults who do not stutter.

Sasisekaran & Byrd (2013) carried out similar tasks of non-word repetition and phoneme elision for school-aged children who stutter and do not stutter. These kids were split up into two age groups: younger (8–11.5 years old) and older (11.6–15 years old). For two-syllable non-words, children who stutter exhibited a considerably lower percentage of accurate phonemes compared to control groups. Younger children who stutter demonstrated a lower accuracy rate in the phoneme elision test than older children who stutter. The controls did not exhibit the same decline.

Byrd et al. (2015) added a non-vocal condition in an attempt to broaden their understanding of the phonological working memory in adults who stutter (AWS). They selected 12 non-words each for 4 and 7-syllable categories. Both vocal and non-vocal conditions were employed across two tasks: non-word repetition and phoneme elision. The vocal task included vocal phoneme elision and nonword repetition spoken aloud. The non-vocal condition involved selecting the target non-word from a set of three auditorily presented non-words, and the non-vocal phoneme elision condition involved selecting the target non-word from a set of three auditorily presented non-words with the correct phoneme elision. Significant group differences were noted by the authors in the phoneme elision task in both the vocal and non-vocal conditions. While AWS were less accurate in their early productions, AWNS needed fewer trials to generate the 7-syllable non-word with phoneme elision. Adults who stutter also produced fewer precise seven-syllable non-words than AWNS during the non-word repetition task.

Baddeley et al. (2002) suggest that more time for subvocal rehearsal is beneficial for individuals who stutter when repeating shorter syllable non-words. Consequently, there is a greater chance that the non-word repetition will be more accurate. However, findings indicating adults with stuttering do worse on non-word repetition as syllable length increases suggest that these adults may have deficits in their phonological working memory systems and subvocal rehearsal, especially in terms of retaining auditory information (Bosshardt, 1990; Byrd et al., 2012; Ludlow et al., 1997).

Phonological encoding treatment for stuttering

Amini et al. (2015) did an exploratory study to evaluate the effectiveness of phonological working memory intervention in reducing stuttering severity in four children (ages 5-6) who stutter. The children participated in a non-word repetition intervention conducted over 18 sessions in six weeks, using a single-subject research design (AB model). Data analysis showed that all participants experienced a statistically significant reduction in the percentage of syllables stuttered after the intervention. The findings suggest that phonological working memory intervention effectively reduced stuttering severity in the participating children, providing preliminary evidence for using a psycholinguistic approach to treating stuttering in children.

As a follow-up, Tahmasebi et al. (2019) investigated the effect of phonological processing on the stuttering severity of preschool children. They conducted a quasi-experimental study with a before-and-after clinical trial design, selecting six children for the study. These children participated in a 13-session treatment protocol focused on phonological processing, which included nonword repetition tasks to target phonological working memory and phonological awareness therapy. To evaluate phonological working memory, 30 nonwords were used, and the Persian Test of Language Development was employed to assess phonological awareness. The severity of stuttering was measured before and after treatment, with parents rating severity daily using the Guitar protocol and reporting their scores to the therapist. The study results showed a significant reduction in stuttering severity from pre- to post-treatment (P=0.027), though the reduction was not significant in the follow-up phase (P=0.236). Parents' ratings during treatment indicated a significant decrease in stuttering severity (P=0.0001). The authors concluded that weaknesses in phonological awareness and phonological working memory affect stuttering severity and that addressing these aspects can significantly reduce stuttering severity and improve speech fluency.

Chapter III

Method

The study aimed to investigate the effect of phonological working memory on the percentage of dysfluencies in Adults who Stutter

Participants:

A total of 10 adults who stutter were selected for the study through convenience sampling. Adults selected were in the age range of 18-39 years (mean average age of 22.1 years), with 9 males and 1 female participant. All participants were native speakers of Kannada. They were subjected to phonological working memory treatment for three weeks or 15 sessions (Monday to Friday) of 40 minutes each. Therapy sessions were conducted online, considering the participants' convenience. The phonological working memory treatment included two tasks: The non-word repetition task and the Phoneme Elision task.

The inclusionary criteria for the participants were

- Participants not enrolled in any traditional fluency treatment during the period of the study
- Participants with no cognitive, physical, or sensory deficits
- Participants with no significant history of articulation deficits.

Ethical Standards used in the study

- All participants were briefed about the study's aim, method, and duration.
- An informed verbal and written (via Google Forms) consent was taken before the initiation of the study

Pre-test Evaluation

All participants underwent a pre-test evaluation to check for the percentage of dysfluencies. Stuttering-like dysfluencies such as sound/syllable repetitions, prolongations, and blocks were evaluated. A 3% or greater than 3% of stuttering-like dysfunctions (SLD) was taken as indicative of stuttering based on Yairi & Ambrose's study (1999). A 5-minute conversation sample was audio and video recorded. The researcher then assessed this sample to measure the percentage of dysfluencies. Additionally, as part of the pre-test evaluation, participants were given a list of 15 non-words (5 non-words each in 4-syllable, 5-syllable, and 7-syllable categories) and asked to perform a non-word repetition task to determine a baseline (see Table 3.1)

Table 3.1

Participant details and pre-test evaluation scores

Participant no.	Age	Percentage of Total Dysfluencies	Percentage of Stuttering-like Dysfluencies	Baseline Non-word Repetition
1	23	12.1	B- 10.51 P- 0 R- 1.59	13
2	19	10.69	B- 6.65 P- 3.56 R- 0.475	15
3	24	9.16	B- 1.78 P- 2.29 R- 5.09	14
4	22	5.45	B- 3.82 P- 0.73 R- 0.91	12
5	20	6.41	B- 2.56 P- 3.85 R- 3.85	10
6	27	6.5	B- 5.29 P- 0.42 R- 0.835	11
7	23	5.5	B- 3.9 P- 0.26 R- 1.3	12
8	22	11.88	B- 8.35 P- 1.619 R- 1.93	11
9	19	6.1	B- 4.35 P- 0 R- 1.74	13
10	22	8.72	B- 7.26 P- 0 R- 1.45	15

Note. In the table B- Blocks; P- Prolongations; R- Syllable Repetitions

The study was conducted in three phases:

Phase 1: Development of stimuli

A list of 75 real words was collected from Kittel's Online Kannada English dictionary. These words were categorized based on syllable length into three groups (n= 20 for each syllable length): 4-syllable, 5-syllable, and 7-syllable words. Non-words were developed by transposing the syllables in a word such that none of the individual syllables resembled a true word in Kannada to avoid any advantage based on the participant's knowledge of vocabulary. Other rules applied during the non-word development included maintaining all the consonants from the real word, not including consonant clusters, and ensuring that the non-words followed the phonotactic rules of the Kannada language.

Phase 2: Validation

The non-words thus formed were given to five native speakers of Kannada to judge for word likeness. Non-words were judged on a scale of 0 to 3, with '0' denoting the least degree of word likeness (least similar to a true word) and 3 denoting the most (100%). Non-words with a score of '1' or '0' were selected for the study. An additional 30 words (n=10 for each syllable length) were used to replace the words that would be judged as '2' or '3'. Thus, 56 words were selected, and 4 additional words were replaced.

Following this, all 75 non-words were audio recorded in a female speaker's voice on PRAAT 6.3.16 version. These non-words were then subjected to loudness calibration on Adobe Audition 3.0 software. They were then presented to 3 listeners auditorily to judge for comprehensibility. Words that were incomprehensible were replaced. Thus, 7 non-words were replaced and underwent another listener judgment.

In this way, 75 non-words were selected, of which 15 non-words (n=5 each in 4-syllable, 5-syllable, and 7-syllable categories) were used for baseline pre-test evaluation (see Appendix I). The remaining 60 non-words (n=20 each in 4-syllable, 5-syllable, and 7-syllable categories) were used during the sessions (see Appendix II).

Phase 3: Administration

Each session was divided into two parts:

Task 1: Non-word repetition

In the first half of the individual therapy session, the participant practiced non-word repetition.

The researcher played the audio-recorded non-word for the participant and asked the participant to repeat the non-word. Each non-word was practiced five times before moving to the next non-word. The non-word list was randomized for every participant.

Task 2: Phoneme elision

Using the practiced non-words, the participant was asked to carry out phoneme elision tasks in the second half of the therapy session. Five trials were provided to the participant to pronounce each non-word without the target phoneme. The participant was instructed to remove the first consonant from the first syllable of the first word, the first consonant from the second syllable of the second word, and so on, within each syllable length.

For example, in the 4-syllable non-word list, the phoneme elision task for the first non-word would be

a) 'Say Gatahara without G' which will be 'atahara';

For the second syllable, it will be

b) 'Say Tanakali without N,' which will be 'Taakali.'

As a result, phoneme location determined the elision task. Until the participant reached the end of the non-word list for that session, the cycle of locations for the eliminated phoneme continued.

Participants were exposed to varying lengths of non-words based on the week of treatment (see Table 3.2)

Table 3.2.

Schedule for the phonological working memory treatment

Week 1	Day 1 to Day 5	4 syllable Non-Word Repetition and Phoneme Elision
Week 2	Day 6 to Day 10	5 syllable Non-Word Repetition and Phoneme Elision
Week 3	Day 11 to Day 15	7 syllable Non-Word Repetition and Phoneme Elision

Post-treatment periodic Evaluation.

This included a 5-minute audio and video recorded conversation sample to check for the percentage of dysfluencies at the end of each week (Day 5, Day 10, and Day 15). Participants were also evaluated for non-word repetition skills based on the 15 non-word list provided during the pre-test evaluation to compare pre and post-treatment

Follow up.

In order to evaluate the effectiveness of treatment, a follow-up evaluation was done one week after the cessation of treatment. A 5-minute conversation sample was taken, and the percentage of dysfluencies was computed.

Chapter IV

Results & Discussion

The current study aimed to measure the effect of phonological working memory on the percentage of dysfluencies in Adults who Stutter. A baseline value for the non-word repetition skills of participants was achieved on Day 1 (pre-treatment) and compared with the values achieved on Day 15 (post-treatment). Overall, changes in the percentage of dysfluencies from Day 1 to Follow-up were tracked. The total percentage of dysfluencies was further subtyped into blocks, prolongations, and syllable repetitions. As per the objectives, changes in the percentage of dysfluencies across Day 1(Pre-treatment Baseline), Day 5, Day 10, and Day 15 (Post-treatment) were assessed. Consequently, the difference was noted on Day 1(Pre-treatment) and Day 20(Follow-up). Data thus collected was analyzed using IBM SPSS version 26. The following statistical analysis was done:

- Descriptive statistics were carried out to calculate the mean, median, and standard deviation for the percentage of dysfluencies and the percentage of different subtypes of dysfluencies.
- The Shapiro-Wilk test was done to determine the normality of the data. Non-parametric tests were used as the data presented with outliers and was not normally distributed.
- Friedman's Two-way analysis of variance was done for data pertaining to the total percentage of dysfluencies and the subtypes of dysfluencies
- The pre-treatment and post-treatment baseline phonological encoding test was subjected to Wilcoxon's signed rank test.

The results are explained as follows:

- Comparison between the scores for phonological encoding (non-word repetition) scores on Day 1(pre-treatment) and Day 15 (post-treatment)
- Comparison between the total percentage of dysfluencies for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)
- Comparison between the percentage of blocks for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)
- Comparison between the percentage of prolongation for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)
- Comparison between the percentage of syllable repetitions for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)

4.1. Comparison between the scores for phonological encoding (non-word repetition) scores on Day 1 (pre-treatment) and Day 15 (post-treatment)

The data is not normally distributed for the scores for the phonological encoding test done on Day 1 and Day 15. Hence, non-parametric tests were performed. Wilcoxon's signed rank test exhibits a statistically significant difference between phonological encoding test scores on Day 1 and Day 15 ($p < 0.05$). Descriptive statistics show a general increase in the scores between Day 1 and Day 5(Refer to Table 4.1 and Figure 4.1), proving an improvement in the phonological encoding (non-word repetition) skills.

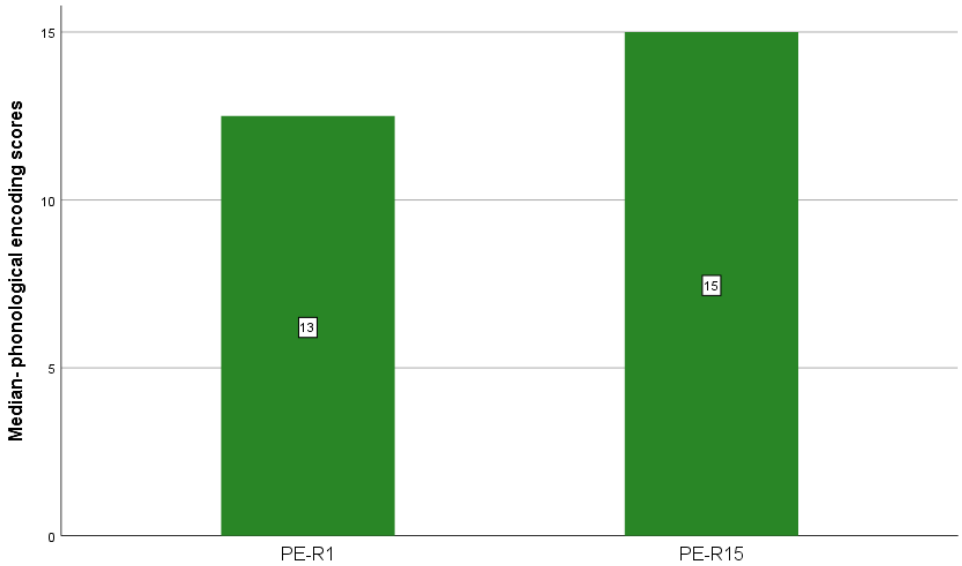
Table 4.1

Mean, median, standard deviation, and interquartile range values for phonological encoding scores (non-word repetition) on Day 1 and Day 15

Days Of Treatment	Mean	Median	Std. Deviation	IQR
Day 1	12.60	12.50	1.713	3
Day 15	14.20	15.00	1.317	1

Figure 4.1

Median values for phonological encoding scores (non-word repetition) on Day 1 and Day 15



Note: PE-R1= phonological encoding (non-word repetition) on Day 1; PE-R15= phonological encoding (non-word repetition) on Day 15

The increase in scores aligns with studies on non-word repetition for adults who stutter. Ludlow et al. (1997) showed that adults who stutter improved their production accuracy over multiple attempts of repeating two 4-syllable non-words.

However, their percentage of correct consonants remained lower than that of adults who do not stutter, demonstrating a practice effect. Similarly, Smith (2010) found that adults who stutter exhibited a practice effect within one session (5 trials) when presented with five non-words of varying length and phonemic complexity, showing a significant increase in articulatory movement consistency and decreased speech duration. Bauerly and De Nil (2011) also noted a practice effect in terms of accuracy, response anticipation time, and sequence duration when repeating a single sequence of nonsense syllables. Additionally, Sasisekaran (2013) identified a trend towards group differences in practice effects on movement duration for the non-word repetition task in nine adults who stutter.

According to Howell and AuYeong (2002), a relationship exists between linguistic planning and speech-motor abilities. They hypothesize that during speech production, if the execution phase begins before the linguistic planning is done, then we will see dysfluencies. These dysfluencies are exhibited as pauses or repetitions until the planning phase catches up with execution. The studies quoted above check for the practice effect through kinematic analysis. They prove that with repeated practice, a stabilization of speech-motor abilities is achieved. This can be inferred as the effect of improved linguistic planning. In the case of the current study, improvements were seen due to the practice of phonological encoding skills.

4.2 Comparison between the total percentage of dysfluencies for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)

Descriptive statistics were carried out to calculate the mean, median, and standard deviation of the data obtained from the percentage of dysfluencies noted on Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), and Day 20 (Follow-up). The data was then subjected to Shapiro-Wilk's test of normality. As the data had outliers, normality was not met, so non-parametric tests were used. Friedman's two-way analysis by variance was done, and the results conclude that there are statistically significant differences between the groups ($p < 0.05$). Thus, on comparing mean values as indicated in Table 4.2, the highest mean values were seen on Day 1 (pre-treatment), indicating a higher percentage of dysfluencies. The mean and median values decreased on Day 5 and continued a downward trend thereafter, indicating a decrease in the percentage of dysfluencies. The lowest mean and median values were seen on Day 20 (Follow up). The median value drops significantly on day 10, as there is a skewed distribution in the type of dysfluencies seen; that is, prolongations decrease significantly. The standard deviation is also high on Day 10 due to this variability.

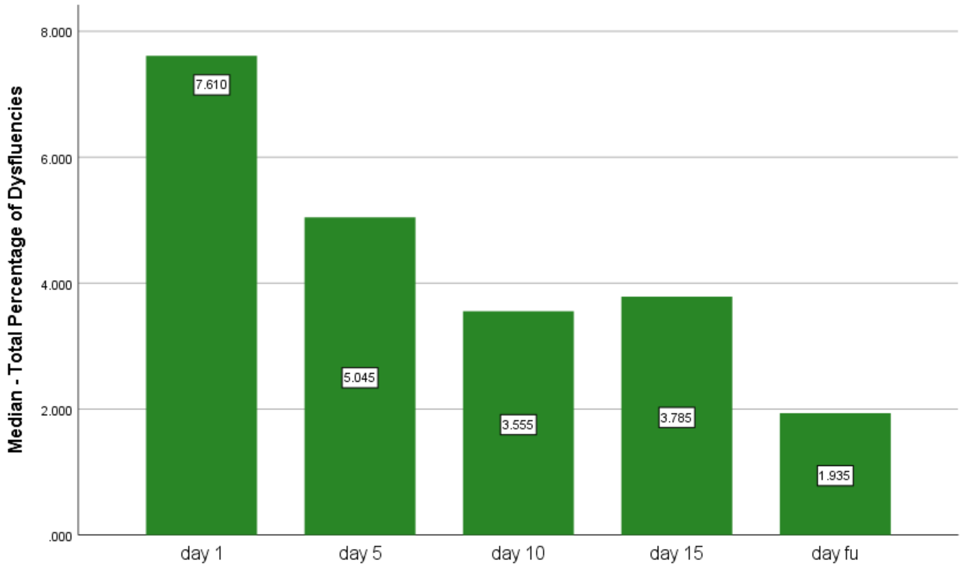
Table 4.2

Mean, median, and standard deviation for total percentage of dysfluencies on Day 1, Day 5, Day 10, Day 15, and Day 20 (follow-up) scores

Days Of Treatment	Mean	Median	Std. Deviation
Day 1	8.25100	7.61000	2.613535
Day 5	5.48600	5.04500	2.019693
Day 10	4.89300	3.55500	2.753438
Day 15	3.93800	3.78500	2.235600
Day 20	2.32300	1.93500	1.663290

Figure 4.2

Median values for the total percentage of dysfluencies on Day 1, Day 5, Day 10, Day 15, and Day 20(follow-up)



Note: Day fu= Day 20 (follow-up)

Similar to the studies by Tahmasebi et al. (2019) and Amini et al. (2015), phonological encoding treatment significantly improves the percentage of dysfluencies. However, unlike Tahmasebi et al. (2019), the treatment effects continued into the follow-up phase, resulting in a significant decrease in overall dysfluencies. The non-word repetition test measures phonological memory, while phoneme elision tasks assess real-time phonological encoding functions, making them helpful in enhancing these skills. This study's exploratory treatment aimed to improve phonological encoding through repeated practice. The reduction in dysfluencies likely results from increased efficiency in phonological encoding skills after the treatment in adults who stutter, leading to better and more accurate articulatory plans and, consequently, fewer dysfluencies (Postma & Kolk, 1993).

Within the total percentage of dysfluencies, blocks, prolongations, and syllable repetitions were taken as the subtypes and computed separately.

Comparison between the percentage of blocks for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)

The mean, median, and standard deviation of the percentage of blocks were calculated for Day 1 (pre-treatment), Day 5, Day 10, Day 15 (post-treatment), and Day 20 (follow-up). The Shapiro-Wilk test was conducted to assess normality. The presence of outliers led to a failure to meet the normality assumption, necessitating non-parametric tests. Friedman's two-way analysis of variance indicated statistically significant differences between the groups ($p < 0.05$). After applying Bonferroni's correction, significant differences were observed in the percentage of blocks between Day 1 (pre-treatment) and Day 15 (post-treatment), as well as between Day 1 (pre-treatment) and Day 20 (follow-up), leading to the rejection of the null hypothesis.
As per Table 4.3, a consistent decrease in the mean and median values from Day 1 to Day 20 is seen, suggesting a significant reduction in blocks over time, indicating the effectiveness of the treatment. The decreasing standard deviation and interquartile range from Day 1 to Day 20 reflect a reduction in variability, implying that the treatment effects are becoming more consistent among the participants. The greatest reduction and consistency in dysfluencies are seen by Day 20, showing sustained improvement during the follow-up period. The median values show a consistent decreasing trend from Day 1 to Day 20, as per Figure 4.3.

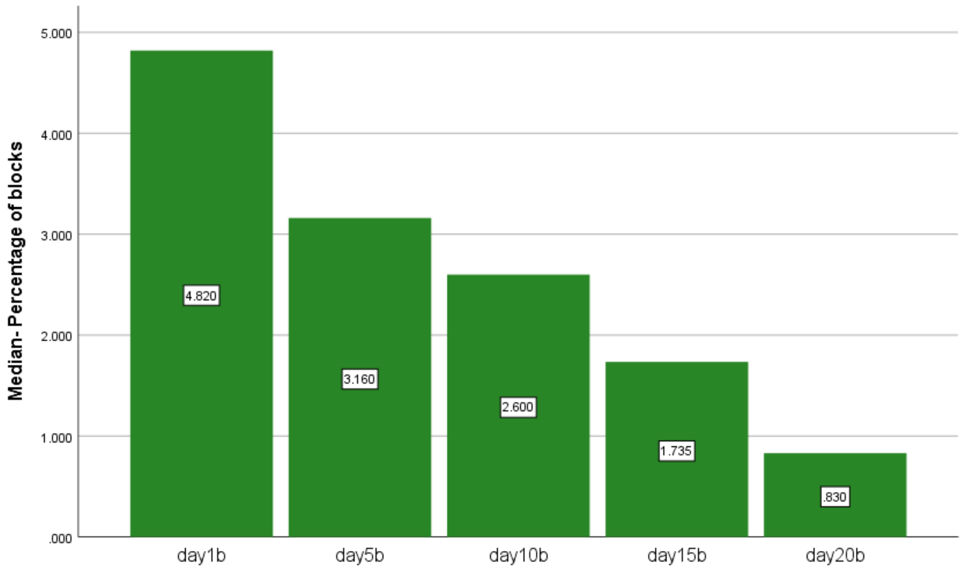
Table 4.3.

Mean, median, standard deviation and interquartile range for the percentage of blocks on Day 1, Day 5, Day 10, Day 15, and Day 20 (follow-up) scores

Days Of Treatment	Mean	Median	Std. Deviation	IQR
Day 1	5.447	4.820	2.725	4.028
Day 5	3.255	3.160	1.961	2.964
Day 10	2.862	2.600	2.253	3.247
Day 15	2.246	1.735	2.192	1.195
Day 20	1.302	0.830	1.538	1.512

Figure 4.3.

Median values for the total percentage of dysfluencies on Day 1, Day 5, Day 10, Day 15, and Day 20(follow-up)



Note: b indicates Blocks

Comparison between the percentage of prolongations for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)

Friedman's test was carried out since the data for the percentage of prolongations was not normally distributed. Since the p-value was less than 0.05, there was a statistically significant difference between the different days of treatment. After applying Bonferroni's correction, a significant difference was seen in the percentage of prolongations between Day 1 and Day 10. This is explained as the median values (see Table 4.4) after day 10 (day 15 and day 20) show zero values, indicating that improvement was seen by Day 10 of the treatment. A decreasing trend is seen in the percentage of prolongations based on median values as per Figure 4.4.

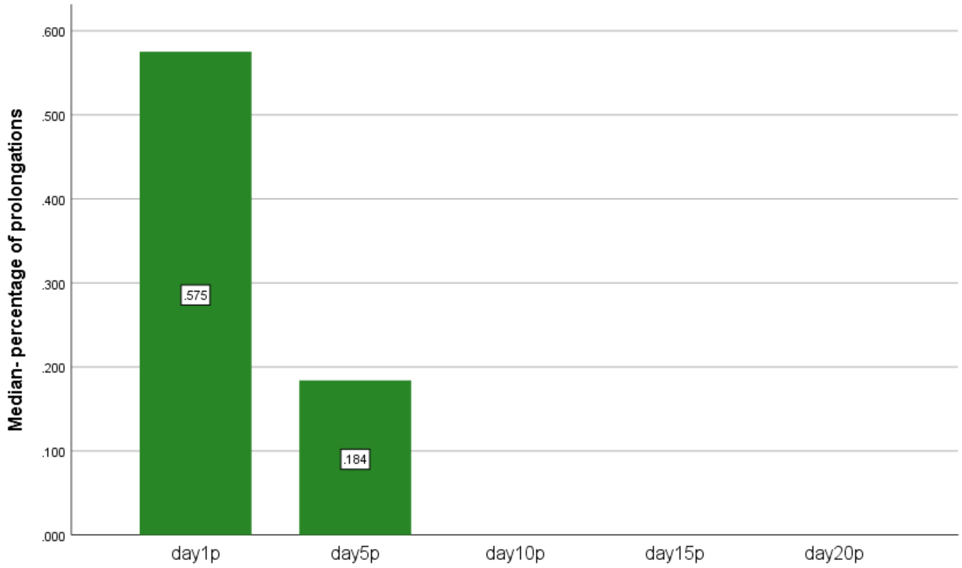
Table 4.4

Mean, median, standard deviation, and interquartile range for percentage of prolongations on Day 1, Day 5, Day 10, Day 15, and Day 20 (follow-up) scores

Days Of Treatment	Mean	Median	Std. Deviation	IQR
Day 1	1.273	0.575	1.488	2.608
Day 5	0.569	0.184	0.674	1.318
Day 10	0.496	0.000	0.911	1.075
Day 15	0.431	0.000	0.688	1.143
Day 20	0.403	0.000	0.852	0.470

Figure 4.4

Median values for the total percentage of prolongations on Day 1, Day 5, Day 10, Day 15, and Day 20(follow-up)



Note: p indicates Prolongations

Comparison between the percentage of syllable repetitions for Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), Day 20(Follow up)

Since the data does not follow normal distribution for the percentage of syllable repetitions, a non-parametric test was done. Friedman's test showed statistically significant differences (p across the different days of the treatment ($p < 0.05$). The adjusted significance value shows a significant difference between day 20 (follow-up) and day 1(pre-treatment). This is due to the differences in the central tendencies (mean and median) and variabilities (standard deviation) across different days of treatment as per Table 4.5. However, the percentage of syllable repetitions decreased on day 20 (follow-up) as compared to Day 1(pre-treatment), as seen in Figure 4.5.

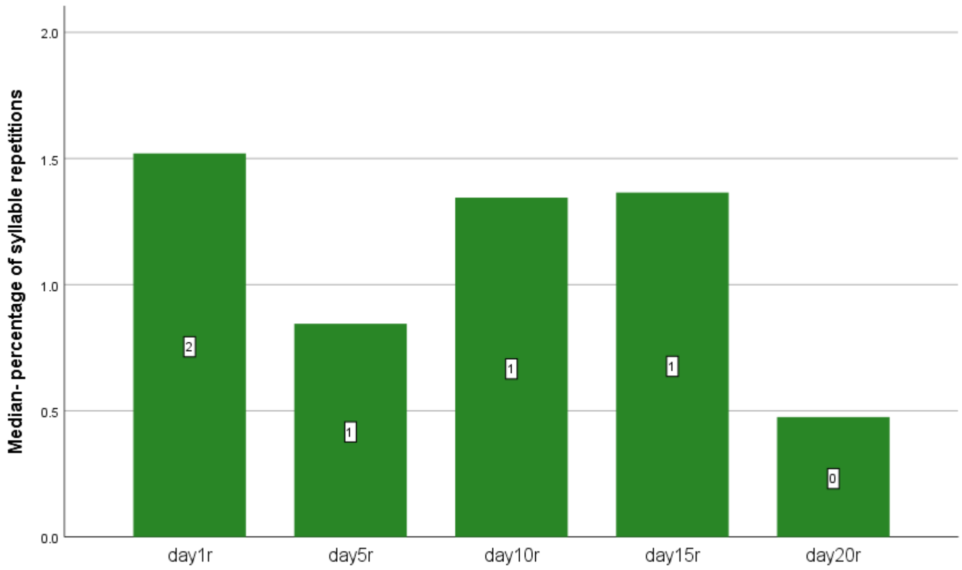
Table 4.5.

Mean, median, standard deviation, and interquartile range values for the percentage of syllable repetitions on Day 1, Day 5, Day 10, Day 15, and Day 20 (follow-up)

Days Of Treatment	Mean	Median	Std. Deviation	IQR
Day 1	1.917	1.520	1.446	1.519
Day 5	1.616	0.845	1.574	2.124
Day 10	1.632	1.345	0.838	1.083
Day 15	1.250	1.365	0.722	1.366
Day 20	0.615	0.475	0.461	0.753

Figure 4.5

Median values for the total percentage of syllable repetitions on Day 1, Day 5, Day 10, Day 15, and Day 20(follow-up)



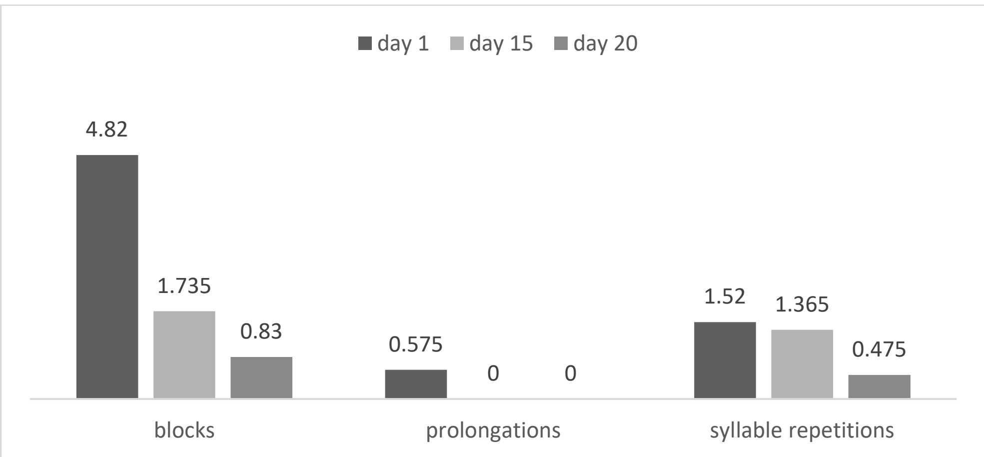
Note: r indicates Syllable repetitions

A trend in the types of dysfluencies was seen over the days (Day 1, Day 15, and Day 20), as per Figure 4.6. Blocks were the most predominant type of dysfluency, followed by syllable repetition and prolongations, which are the dysfluencies with the least median value. On post-treatment (day 15) and follow-up (day 20), the highest score reduction was seen for prolongation, followed by syllable repetition and, lastly, blocks.

It is well noted in the literature that blocks are a persistent type of dysfluency (Gregory & Hill, 1999). Van Riper (1971) observed that children whose early stuttering involved repetitions had a better chance of recovery than those whose stuttering involved blocks and prolongations. Children who persistently stutter frequently exhibit disfluencies that are marked by struggle and tense, laborious articulatory attempts, according to Curlee (1980). Riley and Riley (1982) concurred that tense part-word repetitions and both audible and inaudible sound blocks in speech are associated with a higher risk of recurrent stuttering in children. According to parent accounts, children who have disfluencies that are mostly repetitions rather than blocks are more likely to overcome their stuttering, according to Dickson (1971).

Figure 4.6

Median values for the percentage of blocks, prolongations, and initial syllable repetitions on Day 1, Day 15, and Day 20.



In this study, blocks showed a continuous decreasing trend, while prolongations experienced a sudden drop by day 10 (see Figure 4.4) that persisted until day 20 (follow-up phase), indicating a more substantial effect of phonological encoding treatment on this type of dysfluency. According to Postma and Kolk (1993), prolongations are phonemic errors where a restart strategy is used by prolonging the audible syllable until a repair occurs. Prolongations are also considered compensatory stalling behaviors (Harrington, 1988) or anticipatory corrections of programming errors (Mackay, 1976). This suggests that as participants practiced the same set of non-words and improved their phoneme elision skills, the practice effects generalized to their speech.

A similar argument can be made for syllable repetitions, which are considered a milder form of dysfluency. However, the median scores for syllable repetitions varied across day 10 and day 15 (see Figure 4.5). The median scores, initially low on day 5, increased on day 10 and day 15 before dropping to an overall low on day 20. Based on the trends in the median scores for prolongations, it is likely that prolongations replaced syllable repetitions as a predominant dysfluency alongside blocks. This assumption is supported by various hypotheses that group prolongations and syllable repetitions are dysfluencies originating from similar linguistic errors (Hockett, 1967; Mackay, 1976; Harrington, 1988; Postma, 1991; Postma & Kolk, 1991).

To summarize, an overall statistically significant decrease in the percentage of dysfluencies was seen from Day 1 (pre-treatment) to Day 15(post-treatment). These values further decreased between Day 15 and Day 20 (Follow-up), signifying that treatment effects outlasted even when the treatment was not being given. An apparent reduction was seen in the percentage of blocks exhibited from Day 1 to Day 20.

Prolongations, on the other hand, showed a significant drop on Day 10 of the treatment. Owing to this, it can be assumed that the percentage of syllable repetitions increased on Day 10 and Day 15 compared to Day 5 of the treatment. However, the percentage of syllable repetitions also showed a significant decrease by Day 20 as compared to Day 1, thus exhibiting an overall improvement in the fluency of the participants. A similar statistically significant improvement in phonological encoding skills (non-word repetition) was seen pre-treatment and post-treatment.

Chapter V

Summary & Conclusion

The present study aimed to check for the effect of phonological working memory treatment on the percentage of dysfluencies in Adults who Stutter. Additionally, the study examined the subtypes of dysfluencies, including blocks, prolongations, and syllable repetitions, throughout the treatment period. It also assessed non-word repetition skills before and after the treatment.

Ten native Kannada-speaking Adults who Stutter were considered for the study. These participants were subjected to a phonological working memory treatment, including Non-word Repetition and Phoneme Elision, across three syllable lengths- 4-syllable, 5-syllable, and 7-syllable words. The treatment continued for three weeks (5 consecutive days per week), and the percentage of dysfluencies was calculated on Day 1(pre-treatment), Day 5, Day 10, Day 15(post-treatment), and Day 20(follow-up) through conversation sample analysis.

Appropriate statistical analyses were conducted, and results revealed a statistically significant improvement in the phonological encoding skills (non-word repetition) from pre-treatment to post-treatment. A statistically significant reduction is also seen in the overall percentage of dysfluencies from pre-treatment to post-treatment and from pre-treatment to follow-up phase. A decreasing trend was noted in the percentage of blocks. Prolongation showed a significant drop, with median values reaching zero by Day 10 of the treatment. Syllable repetition showed variability in the scores. However, they, too, showed a significant decline by day 20 of the treatment.

The present study thus proves that a treatment focused on improving the phonological working memory skills leads to improvement in the fluency of Adults who stutter. This improvement is maintained in the 7-day follow-up period as well.

Hence, including phonological encoding skills as goals during traditional stuttering therapy will significantly benefit the individuals who stutter and will show better maintenance of fluency as well.

As treatment of phonological encoding skills is rarely explored in stuttering literature, future studies can develop on the duration of treatment and the maintenance of fluency targets in various stuttering-inducing situations.

5.1. Clinical Implications

- This innovative study improves phonological working memory in adults who stutter, demonstrating that treatment reduces dysfluencies significantly and maintains these improvements during a 7-day follow-up.
- It highlights that three weeks of practice enhance non-word repetition skills, increasing phonological encoding scores and resulting in better fluency.
- The research monitors changes in dysfluency types, such as blocks, prolongations, and syllable repetitions, over three weeks, offering insights into the recovery process by noting both the progress and persistence of residual dysfluencies at the end of treatment.
- This study addresses a previously researched phonological deficit in persons who stutter and thus aims to work on these deficits as an adjunct to the traditional fluency shaping and stuttering modification approaches.

5.2 Limitations

As the current study is an exploratory work, it presents its limitations. From the onset, the study could have focused on the treatment effects on different stuttering severity, gender, and age groups. The non-word list could have been designed with a more detailed consideration of phonological complexity and phonotactic probability. Customizing the non-word list to match each participant's difficulty with specific phonemes (stuttering more on words beginning with particular phonemes) would have been beneficial. Although the study analyzed stuttering severity using conversation samples collected by the researcher on different treatment days, a more accurate assessment of fluency could have been achieved if samples were collected by unfamiliar individuals or in different stuttering-inducing conditions tailored to each participant. Additionally, incorporating a measure that focused on participant attitudes or feedback after treatment would have provided valuable insights.

5.3 Future Directions

- Future research can investigate the impact of phonological working memory treatment in various individualized stressful situations to assess fluency maintenance.
- Conducting more sessions can help determine the long-term benefits of phonological working memory treatment on fluency. Will increased practice lead to better fluency maintenance?
- Integrating the treatment protocol with traditional fluency shaping or stuttering modification therapy can help evaluate if it results in improved scores and better maintenance.

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Appendix I

Phonological Encoding test (Non-Word Repetition)

Serial no.	Number of syllables	IPA
1	4	d̪ebanat̪a
2	4	bʰəmot̪kəva
3	4	gərasaga
4	4	məɭunega
5	4	vəd̪əraka
6	5	bʌngadʰənija
7	5	həbaɪt̪ənəɳi
8	5	jakabaɭaga
9	5	pəgarakəta
10	5	liharid̪usu
11	7	gərasapovikula
12	7	rohad̪anebakeju
13	7	dərpagaɳarikapu
14	7	mət͡ʃakapant̪ahapa
15	7	t̪ukaʃpaɳakʰira

Appendix II

Phonological Working Memory Treatment

Serial no.	Number of syllables	IPA
4 syllable non-words		
1	4	təlikəna
2	4	kaːpirəli
3	4	gakʌmrət͡ʃa
4	4	kat̪ad̪uraːn
5	4	məsarət̪a
6	4	vənbisud̪a
7	4	gilad̪ema
8	4	ʃʌbukeːt̪a
9	4	samkobəri
10	4	sʌnt̪apikal
11	4	kənabat̪a
12	4	sət̪ad̪iːku
13	4	gatahəra
14	4	nivaːʃara
15	4	gəɭabəd̪a
16	4	nəhagəra
17	4	t̪əd͡ʒənbəra
18	4	rəkatəri
19	4	t̪amkoriba
20	4	lɪgakensu

5-syllable non-words		
1	5	nəkasuit̪a
2	5	gərabəlatı
3	5	ginakərəyo
4	5	kelabakuli
5	5	t̪anavukidu
6	5	chakamkeriga
7	5	yamaːdolaːnaː
8	5	dusabivikai
9	5	satambʰanava
10	5	chiɭut̪eraga
11	5	kakotaina
12	5	palanijəra
13	5	sət̪anəndəga
14	5	tikarat̪kola
15	5	vanat͡ʃəruːdu
16	5	pit̪akut̪ima
17	5	niːkʰaːmurəja
18	5	dadʰukumuban
19	5	rugarəmbuku
20	5	lit̪anabanga
7 syllable non-words		
1	7	bəlaganedarake
2	7	ruroguhapəʃʌna

3	7	nanayamakangəd̪a
4	7	t̪a:viyod̪egavani
5	7	gut͡ʃəngat͡ʃulat̪ana
6	7	d͡ʒəngaʃɪʃubʰudapa
7	7	ranakahintaməki
8	7	gəvat͡ʃənalindabʰe
9	7	vigabənid̪ut̪a:re
10	7	d͡ʒɪnamburdulaʃara
11	7	gəvət̪abʰarapuɳa
12	7	t̪iʃasabʰunərədʰa
13	7	sət̪ulikahant̪apal
14	7	neverat̪ad͡ʒiyige
15	7	yanakobaʰdyaratsu
16	7	rirəkamamʃamisai
17	7	vəpaʃanabʰanəʃa
18	7	hənapəravampəra
19	7	ʃəkaʃalihənava
20	7	səlot͡ʃenahambiʃo