Phonological Encoding in Children with Stuttering

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Project Report

Principal Investigator

Dr. Sangeetha Mahesh
Clinical Reader
Department of Clinical Services
All India Institute of Speech and Hearing
Manasagangothri,
Mysuru-06

Co-Investigator

Ms. Geetha M.P.
Speech Language Pathologist Grade 1
Department of Clinical Services
All India Institute of Speech and Hearing
Manasagangothri,
Mysuru-06

Research officer

Ms. Helga Maria Nivanka Ravel

All India Institute of Speech and Hearing

Manasagangothri, Mysuru -570006

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Dedicated to Children Who Stutter

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Abstract

Objective: *Few of the models and theories posited that individuals who stutter were found to have deficits in phonological encoding. The main aim of the study was 'to investigate/assess the phonological encoding using phoneme monitoring in silent naming task in children with stuttering and to compare their performance with children with no stuttering'.*

Design:

Thirty-Four children in the age range of 8 to 12 years who were diagnosed as having stuttering with a severity of mild and above degree and thirty-four age and gender matched children with no stuttering participated in the study. The study involves three major tasks namely, Simple Motor task, Phoneme monitoring task and Auditory Tone monitoring task. The present study was conducted in two phases: Stimulus Preparation and Task Design Programming; Administration of the tasks on Children who stutter (CWS) and Children who do not stutter (CNS) groups. The reaction time and accuracy of the participants' responses were measured automatically using DMDX software.

Results: *In simple motor task and auditory tone monitoring task, CWS took longer time to respond to onset of the target tone and was less accurate when compared to CNS. In phoneme monitoring task, CWS was found to be slow in monitoring the presence and absence of the target phoneme and less accurate when compared to CNS. CWS and CNS performed poorly in phoneme monitoring task when compared to auditory tone monitoring and simple motor tasks. With respect to reaction time and accuracy measures significant difference in the performance of all three tasks was not found across these three severity (mild, moderate and severe) groups although the performances of three severity groups were comparable.*

Conclusions: *It can be concluded that overall CWS of the present study experience general monitoring deficits and in specific they experience deficits in phonologic encoding process. CWS performed poorly in simple motor, auditory tone and phoneme monitoring tasks when compared to CNS. The present study adds on to the theoretical knowledge on nature of stuttering in children, especially supporting the multifactorial model of stuttering.*

Chapter I

INTRODUCTION

Stuttering is defined as a disruption in the fluency of verbal expression, which is characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable. These disruptions usually 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 being speech-related struggle. Also, there are not infrequent indications or report 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. The immediate source of stuttering is some incoordination expressed in the peripheral speech mechanism (Wingate, 1964).

The ultimate cause is presently unknown and may be complex or compound. Although numerous studies have been performed to investigate the cause of stuttering yet it remains undisclosed. It is commonly known that stuttering is associated with linguistic and motoric aspects. Peters and Starkweather, (1990) believed that stuttering is associated with a lack of balance between the linguistic and motoric systems involved in speech production. The literature states that Stuttering is considered as disorder of language development and this fact was emphasized by Bloodstein (2002). These conceptions inspired the researchers to comprehensively investigate the association between stuttering frequency and various linguistic variables. Numerous studies have investigated the impact of various linguistic variables such as lexical retrieval (Bloodstein & Gantwerk, 1967; Helmreich & Bloodstein, 1973; Dayalu, Kalinowski, Stuart, Holbert & Rastatter,2002) and morphological structure of the words, syntactical complexity (Hannah & Gardner, 1968; Brundage & Ratner, 1989) on frequency of stuttering and proved that there is a strong relationship between linguistic factors and stuttering.

Few of the models and theories posited that individuals who stutter were found to have deficits in phonological encoding and thus, phonological encoding deficits were considered as one of the probable causes for stuttering**.** Levelt (1989) defined phonological encoding as the processes involved in retrieving or building a phonetic or articulatory plan from each lemma or word and the utterance as a whole. It has been proposed that phonological encoding involves three components (1) Generation of segments that constitutes words, (2) Integration of sound segments with word frames and (3) Assignment of appropriate syllable stress (Levelt, 1989). This phonological encoding process serves as an interface between lexical processes and speech motor production (Levelt, 1989; Levelt, Roelofs & Meyer, 1999) and is significant for incremental speech planning and production. According to Levelt's speech production model, self monitoring of inner or silent speech occurs at the output of phonological encoding. Levelt (1989) and Levelt et al. (1999) argued that the speakers monitor their speech output for errors in the speech plan before sending the code for articulatory planning and execution. Thus monitoring which is considered as a natural sub-process of speech production is required to access the sub-lexical units such as phonemes. In case of individuals who stutter, it is said that fluency break down occurs because of their faulty covert monitoring mechanism. According to Gestural linguistic model (Browman & Goldstein, 1997; Saltzman & Munhall, 1989), the phonological encoding process is closely associated with speech motor production.

Contrary to Levelt (1989)'s model, WEAVER ++ (Roelofs, 2004) postulated that phonological encoding process occurs before the activation of speech motor system. WEAVER ++ (Roelofs, 2004) defines phonological encoding as the process by which the phonological code (i.e phonemes or syllables) of a word is retrieved and reassembled in an incremental, just in time manner to allow for efficient construction of phonological words. Therefore, this model suggests that individuals experience fluency breakdown because of delayed phonological encoding process that is they tend to take a longer time to retrieve and reassemble the phonemes with respect to the phonotactics of their respective languages. The psycholinguistic theories such as EXPLAN and CRH states that phonological deficit is considered as the causative factor for stuttering. The EXPLAN theory was proposed by Howell (2004) and in his theory he states that individuals stutters when there is a temporal asynchronies between execution (EX) and speech planning (PLAN). The asynchronies occur when these individuals experience difficulty in planning complex linguistic units or when they speak at a faster rate or when they try to adopt any coping strategies. According to covert repair hypothesis (Postma & Kolk, 1993), the primary symptoms of stuttering represent the overt manifestations of covert corrections of speech plan errors that are caused by delayed phonological encoding of speech sounds. The Fault line hypothesis was proposed by Wingate (1988) and he states that the individuals who stutter experience a delay in the retrieval and encoding of a syllable rhyme during speech production. It is said that in individuals who stutters, fault line occurs at the point of integration of the syllable onset and its rhyme.

Several studies have directly and indirectly supported an evidence of association between impaired phonological encoding and stuttering in children who stutters. Melnick, Conture and Ohde (2003) had directly assessed the phonological encoding skills in children with stuttering using priming task and they found out that the performance of both the groups namely children who stutter (CWS) and children who do not stutter (CNS) were comparable in related prime condition. Byrd, Conture and Ohde (2007) conducted a study using the picture naming auditory priming paradigm to directly assess the phonological encoding skills in children with and without stuttering. The results highlighted that the three year old CWS and CNS along with the five year old CWS were faster in the holistic priming condition. On the other hand, the five year old CNS were faster in the segmental condition. Thus it can be concluded that three year old CWS and CNS and five year old CWS were slower in the segmental condition These findings were attributed to the developmental differences in phonological encoding between the groups. By the age of five, CWS exhibit a delay in segmental encoding abilities when compared to neurotypical peers. Therefore, this study suggested a possible delay in the transition of phonemic competence from holistic to segmental processing abilities in children with stuttering.

Bonte and Blomert (2004);Jusczyk (1993) stated that the development of phonological encoding skills in typically fluent children begins with early acquisition of higher level phonological units such as syllables and rhymes. These higher level phonological units are considered to be as holistic units which are easier to process. Metsala and Walley (1998); Goswami (2002**)** stated that acquisition of holistic units are followed by the acquisition of segmentation skills which is considered as an ability to parse individual phonemes in speech as a consequence of progressive restructuring of the phonological lexicon into smaller phoneme sized units. This ability assesses the child’s competence in production and perception. The literature states that the transition from holistic to segmental level processing was found to be critical for fluent speech output. According to Levelt’s speech production model, incremental encoding of phonemes (segmentation) within word frames is considered essential to motor output. According to the Lexical Restructuring Model (Walley, Metsala & Garlock, 2003), at the age of two years typically fluent children begin to encode words incrementally as individual sound segments (phonemes) rather than as global syllable shapes. Brooks and Mac Whinney (2000) stated that this obvious growth in the ability to encode segments observed in two year old typically fluent children allows them to speak fluent verbal output. Therefore, the phonological encoding process can be impaired by the deficits in the timely acquisition and transition of holistic to segmentation skills which in turn affects the fluent speech production.

Byrd, Conture and Ohde (2007) found out that 5 year old children with stuttering failed to transit to segmentation stage and they appeared to retain more immature holistic representations and as a result of this, there is a breakdown in their fluent speech production. But the typically fluent peers had shifted to more mature incremental representation which is nothing but segmentation and their verbal output was found to be fluent. Howell and Au-Yeung (2002);Kolk & Postma (1997)**;** Perkins, Kent and Curlee (1991); Wingate (1988) posited that impairment in selection and preparation of phonemes that forms the words in speakers' output could be considered as the contributing factor for producing dysfluencies. Therefore they assume that delay or breakdown occurs during the process of phonological encoding.

Sasisekaran, Brady and Stein (2013) studied the phonological encoding process in older children with stuttering aged between 10 and 14 years of age using phoneme monitoring during silent picture naming task. The authors hypothesized that phoneme monitoring within words indicates the way the phonemes are encoded in speech output. Results revealed that CWS performed slowly in monitoring subsequent phonemes within bisyllabic words when compared to CNS. They did not find any significant difference between the groups in auditory tone monitoring tasks. The percentage of errors made by both the groups in phoneme and auditory tone monitoring tasks were found to be comparable. The performance of CWS group was found to be significantly slow when compared to CNS. Therefore, Sasisekaran et al. (2013) stated that CWS experience temporal asynchronies in one or more processes leading up to phoneme monitoring.

Need for the study

In summary, it is evident that there is a relationship between language and stuttering. Literature also supports the idea of phonological encoding deficits in adults and children with stuttering. Various paradigms have been used to study the phonological encoding deficits however, results are inconclusive. Most of the paradigms used to study the phonological encoding are indirect. Most of the paradigms pin pointed the presence of phonological encoding deficits as the cause for stuttering but rather identified phonological encoding to be one among various other factors contributing towards stuttering (Byrd et al., (2007)

Howell & Au-Yeung (2002); Kolk & Postma, 1997**;** Perkins, Kent & Curlee, 1991; Wingate, 1988.Though numerous studies have provided evidence to support the fact that altered efficiency in performing phonological encoding was observed among children with stuttering, none of these studies have clearly stated that their altered performance in phonological encoding is because of the delay in timely encoding of phonemic segments during speech production or due to the presence of more errors during the phonological encoding process or both.Very few western studies have assessed the phonological encoding process in children (Sasisekaran et al., 2013) who stutter and they directly support the idea of phonological encoding deficit in children who stutter. On the Indian forefront, no studies have been conducted to explore how the phonological encoding process takes place in children who stutter.

Therefore, the present study had taken up the phoneme monitoring task which specifically targets the phonological encoding deficits. The phoneme monitoring task during silent naming involves several sub-processes such as lexical retrieval, phonological encoding and monitoring of the target phoneme and motor response. In the present study, the performance in the phoneme monitoring task was contrasted with performance of other three tasks such as picture naming task, auditory tone monitoring and simple motor tasks in order to control for the possibility of any group differences observed because of the processes other than phonological encoding. The picture naming task involves processes that overlap with phoneme monitoring task and also additional processes such as lexical access and encoding followed by speech planning and execution. The auditory tone monitoring task will be similar to phoneme monitoring task with the exception that latter would require lexical access and encoding of individual phonemic segments for arriving at a decision. The simple motor task was included in the present study in order to rule out group and within group (CWS) differences in simple motor responses which were considered as the inherent component of the phoneme and auditory tone monitoring tasks. It is said in the literature that the process of phonological encoding is obscured from direct observations since it is deeply embedded in the process of language formulation and on the western forefront there are very few direct sources of evidence which supports the fact the children who stutter were found to have phonological encoding deficits. But on the Indian forefront, no direct source of evidence was found to support this above mentioned fact. Though studies have been conducted in western context, the results cannot be generalized to other languages since English is stress timed and Kannada is syllable timed. Thus the need arose to investigate phonological encoding skills in children who stutter aged between 8 and 12 years of Indian context and also with respect to severity of stuttering. To our knowledge, there are no studies performed on children with respect to Indian context in general and Kannada speakers in particular.

Aim

The main aim of the study was to investigate/assess the phonological encoding using phoneme monitoring in silent naming task in children with stuttering and to compare their performance with children with no stuttering'.

Objectives

- What is the difference in the speed of phoneme monitoring between CWS and CNS and also within the CWS group.
- What is the difference in the percentage of error response in phoneme monitoring between CWS and CNS and within CWS group
- What is the difference in the reaction time and percentage of error response in auditory tone monitoring task between CWS and CNS and within CWS group
- What is the difference in the reaction time and percentage of error response in simple motor task between CWS and CNS and within CWS group
- What is the difference between auditory tone and phoneme monitoring task in CWS and CNS and within CWS group
- What is the difference between simple motor and phoneme monitoring task in CWS and CNS and within CWS group

Hypothesis.:

- $H_0$1: There is no significant difference in speed of phoneme monitoring (reaction time) between CWS and CNS and within CWS group

$H_0$2:There is no significant difference in the percentage of error response in phoneme monitoring between CWS and CNS and within CWS group

$H_0$3:There is no significant difference in the reaction time and percentage of error response in auditory tone monitoring task between CWS and CNS and within CWS group.

- $H_0$4:There is no significant difference in the reaction time and percentage of error response in simple motor task between CWS and CNS and within CWS group
- $H_0$5:There is no significant difference between auditory tone and phoneme monitoring task in CWS and CNS and within CWS group
- $H_0$6:There is no significant difference between simple motor and phoneme monitoring task in CWS and CNS and within CWS group.

Chapter II

REVIEW OF LITERATURE

Some theorists postulated that the causal factor for the production of dysfluencies was found to be the difficulty with the underlying selection and preparation of the sounds that form the words in a speaker's message (Howell & Au-Yeung, 2002; Kolk & Postma, 1997; Perkins et al., 1991; Wingate, 1988). The psycholinguistic theories of stuttering hypothesize that during the process of phonological encoding, a delay or breakdown occurs when phonological words are constructed from individual phonemes (Howell & Au-Yeung, 2002; Kolk & Postma, 1997; Perkins et al., 1991; Wingate, 1988). Levelt, Roelofs and Meyer (1999) stated that phonological encoding process serves as an interface between lexical processes and speech motor production and it is crucial for incremental motor planning and production. Several empirical studies have stated that children who stutter are incompetent in performing phonological encoding when compared to children who do not stutter but the nature of this relatedness was not justified.

Phonological encoding in neurotypical individuals' speech

Levelt (1989) defined phonological encoding as the process involved in the generation of the sound segments that constitutes the word from the mental lexicon, retrieval of these segments and arrangement of these within an appropriate syllable frame and application of the appropriate syllable stress prior to the initiation of the articulation of speech segments. This phonological encoding process requires the individuals to covertly monitor their own speech in advance of their overt speech production. It is also stated in the literature that they can even monitor their speech after they speak. Hence the speakers can monitor their speech via dual routes. Undoubtedly this evidence proves that there is an interaction between phonological encoding and monitoring because both the processes are responsible for fluent speech and in case if their speech gets disrupted it can be corrected by the speaker as a result of the monitoring process. Therefore persons stutter when they have deficits within language formulation and self monitoring systems and also at the interaction level between phonological encoding and monitoring processes.

Levelt (1989) proposed a psycholinguistic model to explain the process of language comprehension and production in neurotypical developing children by dividing the language production system into three components such as **Conceptualizer, Formulator** and **Articulator**. The conceptualizer can access the speakers' intentions and world knowledge, physical and social context.So it assists the speaker in formulating the pre-verbal message before they could utter the verbal utterances. Thus the conceptualizer serves as an interface between the thought and language. The formulator would construct syntactic representation by using this pre-verbal message. The two subcomponents of formulator are grammatical encoding and phonological encoding. The grammatical encoding component has three functions: first it selects the words from mental lexicon, then it assigns the grammatical function to those words which were selected from mental lexicon and lastly, it constructs a phrasal representation in linear order. The phonological encoding component also has three functions: it decides the prosody of the sentence retrieves the phonological representation of the word and also determines the metrical form of the words. The motor program or articulatory program is considered as the end product of the second component which is the formulator. The articulatory program specifies the intonation of the utterance, how the phonemes/syllables should be pronounced and which syllable has to be stressed or unstressed. At the articulatory level, the motor program is translated by the motor system into articulatory movements that results in audible speech. Since the motor planning takes place way ahead of execution, the motor program is transferred from formulator to articulator via articulatory buffer. The motor program is temporarily held in the buffer, while the articulator takes out parts of it for motor execution. Figure 2.1 depicts the illustration of Levelt's model. Along the right side of the figure 2.1 is the speech comprehension component which is further subdivided into auditory processing of overt speech and speech comprehension proper and they are responsible for word recognition, syntactic analysis and mapping syntactic representation onto meaning. The end product of this component is referred to as parsed speech which is transferred to the conceptualizer component via speech comprehension system. In addition to this, speakers can get a feedback of their own speech before they overtly produce it which is termed as inner speech. This feedback channel is placed between articulatory buffer and language comprehension system and the feedback of their own speech is transferred to the conceptualizer. The conceptualizer checks whether the parsed speech matches with the speaker's inner speech since both the feedback loops are connected to it. Therefore, the covert monitoring process takes place at the level of conceptualizer. When a mismatch is detected by the conceptualizer, it halts all the components of language production and as a result of this, the overt speech gets interrupted momentarily. This moment is termed as editing phase where the detected error undergoes repair process.

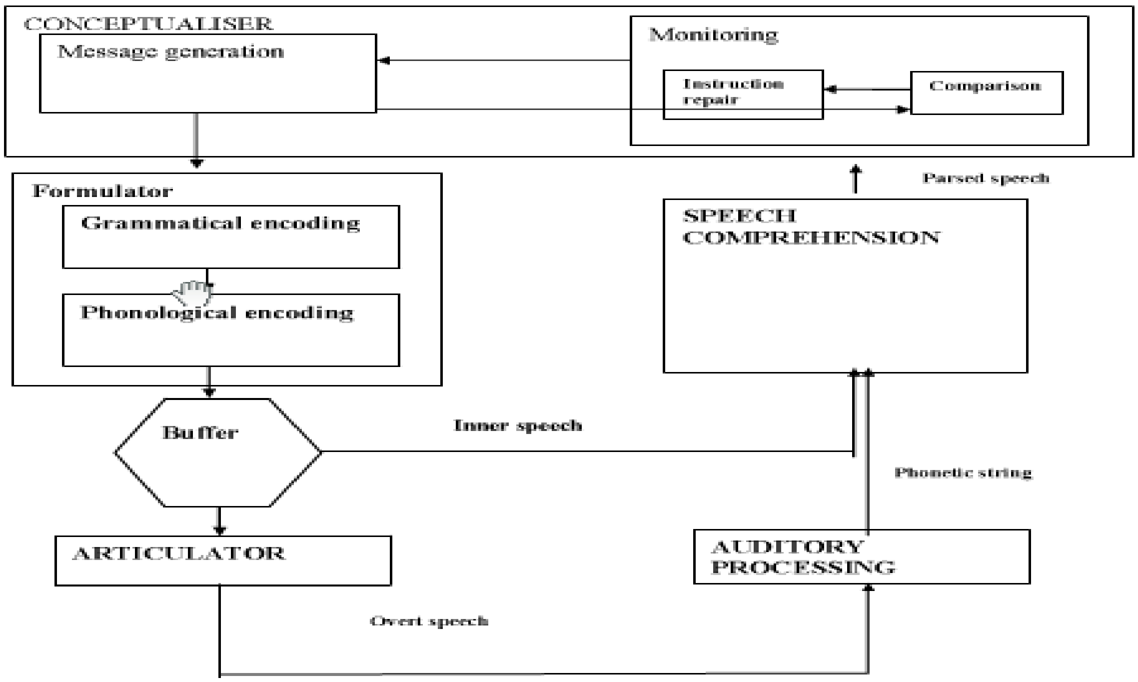

Figure 2.1: Blue print of the speaker – (Levelt, 1989).

(Source: Phonological encoding and monitoring in normal and pathological speech, Psychology press)

A study was conducted by Wheeldon and Levelt (1995) to prove the hypothesis that the speakers do monitor the phonological units but not the articulatory program. In this study, the participants were instructed to monitor for the target phonemic segments in the Dutch translation equivalent of visually presented English words. The position of the phonemic segments was randomly presented either at the onset, coda of the first syllable, or at the onset or coda of the second syllable. The subjects' monitoring latencies gradually increased along with the serial position of the segments within the target word. A segment monitoring task was included in the study to find out whether the participants monitor the phonological words or the articulatory program. In this task, the subjects' monitoring latencies increased and this finding attributes to the fact that the speakers monitor the phonological representation not the phonetic representation. The participants were asked to monitor for the presence of the target syllable in order to assess whether the syllabified segments or string of segments are monitored by the speakers. The results revealed that monitoring latencies for the syllable targets were faster and thus the authors concluded the study by stating that phonological words are monitored rather than the string of elements.

Levelt, Roelofs and Meyer (1999) elucidated phonological encoding using the computational model of spoken word production called WEAVER ++ model. This model focuses on the interaction between planning, comprehending and monitoring explicitly. This model involves three processes namely conceptual preparation, lemma retrieval and word form encoding. The word form encoding includes morphological, phonological and phonetic encoding (Roelofs, 2004). Using the WEAVER ++ model, the process of phonological encoding is illustrated in specific in the figure 2.2.

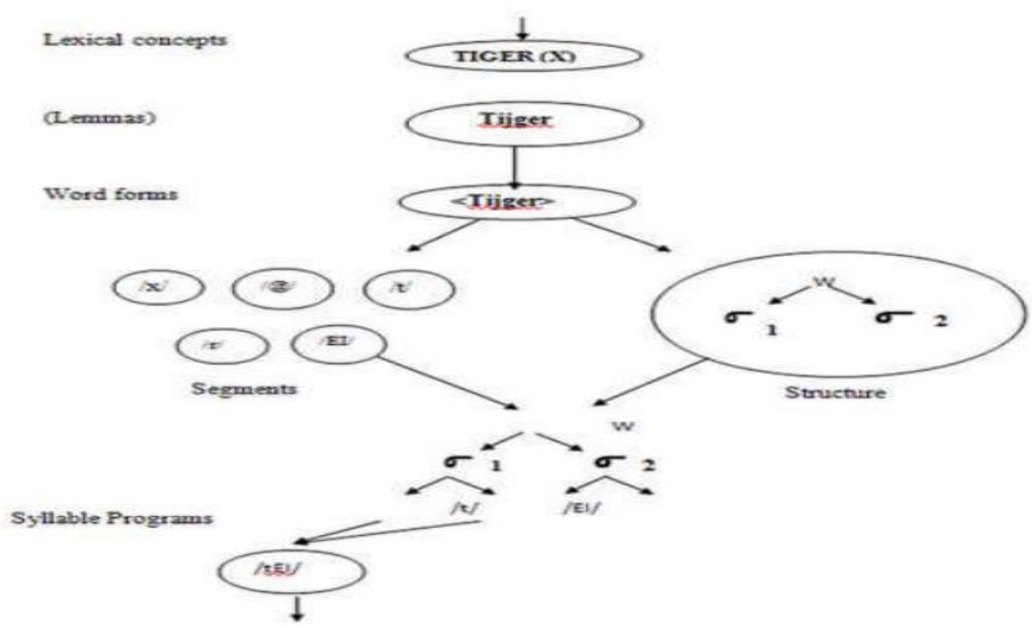

Figure 2.2: Illustration of the process of phonological encoding based on Weaver ++ model.

(Source: Phonological encoding and monitoring in normal and pathological speech, Psychology Press)

For the encoding of the word tiger, the two important memory representations TIGER at the lexical concepts and the lemmas (tijger) serves as inputs to the phonological encoding process. To utter the word /tiger/, activation takes place at the lexical level. The phonological encoding process begins with the word form. Most of the theories had proposed that encoding the word from involves two processes namely retrieving the phonological units and structure of words (identifying the number of syllables and syllable bearing stress. Thus the overall process is coined as the phonological encoding process. The WEAVER ++ model explains the phonological encoding abilities of individuals for the speech generated by self but not others.

Hence, Ramus, Peperkamp, Christophe, Jacquemot, Kouider and Dupoux (2010) proposed a general model of speech perception and production which includes components of WEAVER ++ model and also additional components in order to achieve a better understanding of the phonological encoding tasks.

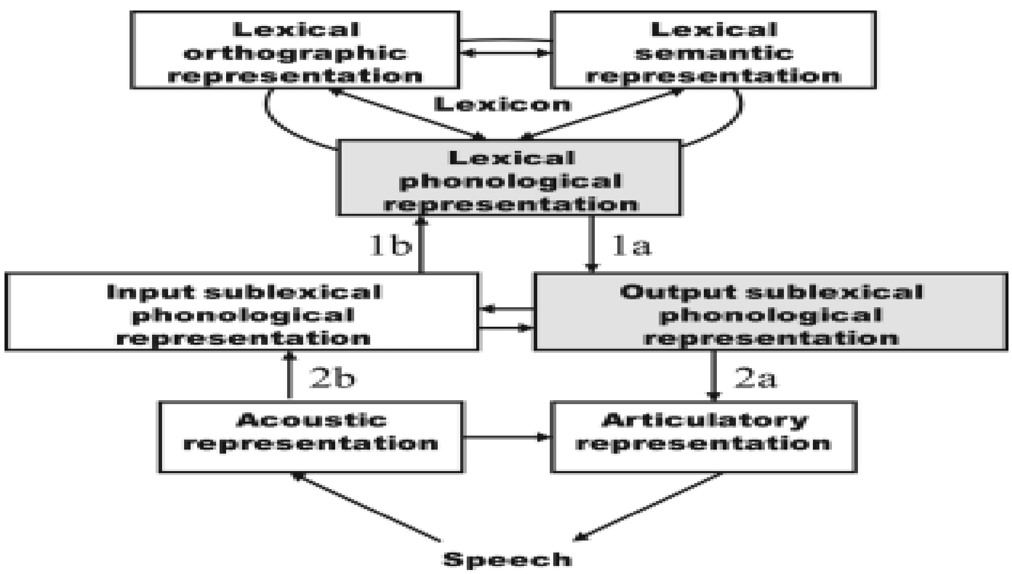

Figure 2.3: An information processing model of speech perception and production (Ramus et al., 2010).

(Source: Laboratory phonology 10; variation, phonetic detail and phonological representation (pp.311-340). Berlin: Monton de Gruyter)

According to this model (figure 2.3), the two routes namely lexical and phonological routes gets activated for performing phonological awareness tasks. The word form is received from an external source and as a result of this, the lexical route gets activated. This route access the information present in the lexicon to produce speech. This is achieved by retrieving the acoustic representation and decoding the acoustic signal into a specific phonological code at the input sub lexical phonological representation level. Then the lexicon is accessed to check whether there is a match between acoustically presented phonological words with that of the lexicon. Similar to WEAVER $^{++}$ model, the lexicon in this model has orthographic, semantic and phonological representations. The meaning is derived and the speech output is formulated at the lexicon level. To utter the word, the phonological code is retrieved from the lexical phonological representation and is transferred to the output sub lexical phonological representation. This output phonological representation is considered as the phonological encoding loop of the Levelt (1989)'s model. Then the phonological code is transmitted to the articulatory representation as the phonetic code leading to verbal response. Therefore, there is a bidirectional loop that involves sharing the information between the input and output sub lexical phonological representations that permits an individual to listen to the auditorily presented item and repeat it back without repairing any contributions from the lexicon (Ramus et al., 2010). This route was proposed to explain the process happens during the performance of phonological processing tasks using the non words. To encode the non words, the input received is directly transferred from the input sub lexical phonological representation towards the output sub lexical phonological representation since it does not involve lexical retrieval process. Therefore, the information processing model elucidates the phonological encoding process of an individuals' own speech as well as speech generated by others.

Dell (1986) proposed an influential model which focuses on the processes involved in phonological encoding. This model is similar to McClelland and Rumelhart (1981)'s seminal interactive activation model of word recognition. The illustration of this model is represented in figure 2.4. This model hypothesized that there are localist representations for different phonological units such as words, syllables and phonological clusters and the encoding process proceeds by spreading activation from a target unit. According to this model, to produce speech, a metrical frame to be produced is formed first and then the phonological elaboration of this frame is achieved when the appropriate phonologic segment nodes are activated in a neural network. In this model, the selection occurs at the phoneme level. The highly activated phoneme unit is selected in separate pools of units after some amount of time steps of activation spreading which is determined by the speech rate. These pools of units represent the onset (initial consonants), nucleus (vowel) and coda (final consonants) of the syllable.

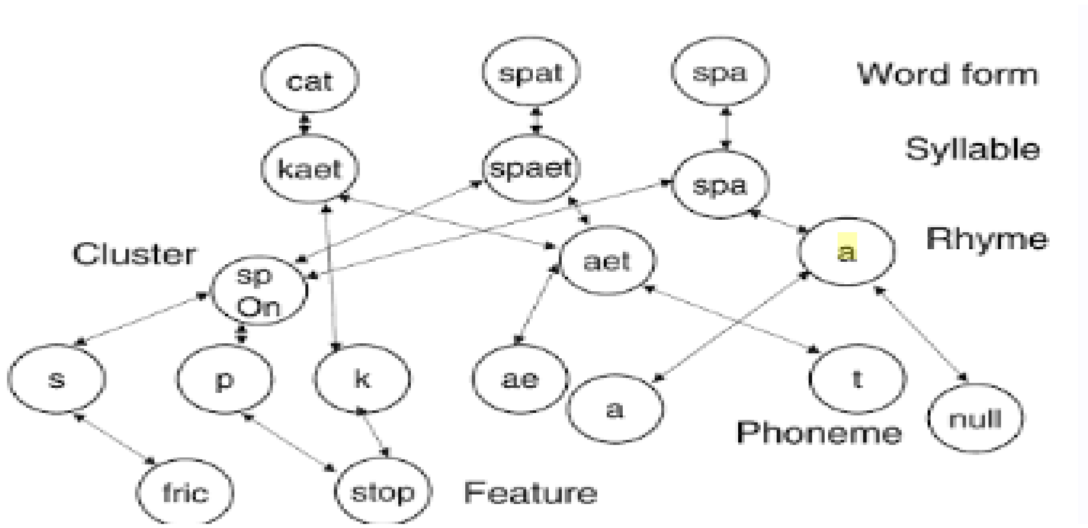

Figure 2.4: Dell’s (1986) model of word production

(Source: *Concise encyclopedia of brain and language*. Elsevier)

Speech errors do not occur when the phoneme units corresponding to the intended word are selected. It does occur when the competing phoneme unit has higher activation strength than the intended one. The probable reasons for the competing phonemic unit to get highly activated could be because of the residual activation where it would have been recently selected and the activation has not decayed yet or early activation of the units required to be selected in an upcoming syllable or faulty activation of the units because of the intrinsic noise. The naturalistic speech errors were accounted explicitly by Dell (1986)’s model. For example, Dell (1986) had simulated the effects of speech rate on the number of errors which is referred to as the lexical bias effect (by which errors tend to form existing words more often than the chance would predict); and the distribution of speech errors namely anticipations (in which a phoneme is said too early; e.g. ‘bake my bike’ instead of ‘take my bike’), perseverations (in which a phoneme is repeated in a subsequent word; ‘she pulled a pantrum’ instead of ‘she pulled a tantrum’) and exchanges (in which phonemes from different words are swapped; e.g. ‘waplemalnut’ instead of ‘maple nut’) with the help of this model.

Phonological encoding abilities in persons who stutter

Most of the psycholinguistic models hypothesize that disruptions in the normal or pathological speech occurs as a result of either the dysfunction of the processes involved in speech planning or faulty interaction between these processes and self-monitoring system of an individual. Some of the theories hypothesize that deficits in the ability to encode phonological units is considered as one of the causes for stuttering. Wingate (1988) proposed a psycholinguistic theory called Fault line hypothesis. According to this theory, stuttering occurs due to asynchrony in the assembly of phonologic units which occurs at the fault line of phonologic formulation that is where the initial consonant and vowel are linked. The initial consonant and vowel units are responsible for generating syllable stress. Thus, Perkins, Kent and Curlee (1991); Wingate (1988) reported that stuttering marks the failure to merge the prosodic and phonologic aspects of speech. Wingate (1988) reported that the specific sounds which were stuttered were found to be well articulated by the persons who stutter and so they did not have problem in articulating the sounds but they had problem in transiting from one phonemic unit to the next. Therefore, he considered stuttering as phonetic transition defect. He proposed that the origin of the fault line for stuttering is at the central and the loci for stuttering occur commonly on the stressed syllable. The persons who stutter were found to have difficulty in producing stressed syllables and this could be because of their inability to make laryngeal adjustments for varying pitch and loudness. This interference associated with the fact that stuttering as transition defect, Wingate (1988) concluded that stutterers have a general difficulty to produce stressed vowels, with the implication that the central processing difficulty leads to a failure to make the neuro-physiological adjustments necessary for speech.

Metsala and Walley (1998) proposed the *progressive restructuring framework* that young children start with word-like holistic lexical representations and progress to adult-like segmental/phonemic representations of lexical items. Metsala and Walley (1998) suggested that access to sublexical units, including rhymes, phonemes, and syllable onsets, can be attributed to the restructuring of the phonemic lexicon. Thus, superior verbal monitoring skills are likely an epiphenomenon of well-refined sub-lexical representations to adult-like segmental units. During typical development this restructuring is achieved in several stages but minimally requires the ability to process rhymes and segments in speech. Therefore, it is hypothesized that a deficit in phonological encoding during development could be reflective of a deficit in the processing and representation of holistic and/or segmental units in speech production.

According to the *Lexical Restructuring Model* **(**Walley, Metsala & Garlock, 2003) at around age two (near typical onset of childhood stuttering) children experience a significant increase in vocabulary growth and they begin to encode words incrementally as individual sound segments rather than as global syllable shapes. Brooks and Mac Whinney (2000) contend that this apparent growth in ability for segmental processing allows children to speak more fluently. Therefore, deficits in the timely acquisition and transition of whole-word to segmentation skills can impair the process of phonological encoding and be a possible mechanism of fluency disruption in persons who stutter.

According to another psycholinguistic theory, Neuropsycholinguistic model (Perkins, Kent & Curlee, 1991), stuttering occurs when sounds are not inserted at an appropriate time into the syllables during speech production. This theory hypothesize that moments of dysfluencies occurs when there is a dyssynchrony between the articulatory rate and insertion process (insertion of segments into syllable frame rate). The two systems which are involved in the insertion process are symbol and signal systems. The symbol system is responsible for linguistic processing whereas signal system is involved in providing syllable frames. A delay in providing the syllable frame (containing the slots into which speech segments are inserted) leads to dyssynchrony in the performance of symbol and signal systems and as a result of this, verbal output gets disrupted. The probable reasons for this dyssynchrony are uncertainty to express one's own thoughts, incompetent neural resources or competition for processing capacity (Perkins et al., 1991). Therefore, they concluded the theory by stating that stuttering occurs due to delay in linguistic processing which is because of segmental processing inefficiency or due to ineffective activation of the components that contribute to the final act of speaking.

According to covert repair hypothesis theory (Postma & Kolk, 1993), stuttering occurs as a result of covert attempts to correct the errors in the speaker's motor plan that is the phonologic encoding of an utterance. These failed covert attempts affect the fluency of one's speech. This theory explained the covert repair phenomenon and the occurrence of dysfluencies with the help of psycholinguistic models of speech production (Dell, 1986; Levelt, 1989). The persons who stutter tend to produce more errors because of their inability to select the correct phoneme. But these errors are hindered by self-monitoring system and the covert repair is done and as a result of this the error is removed from the motor plan. The persons with stuttering take longer time to covertly repair the errors and as a result of this, speech plan is interrupted in turn leading to dysfluencies (Postma & Kolk, 1993; Kolk & Postma, 1997). This theory does not emphasize on the fact that PWS have impaired self-monitoring or poor error detection skills. The theory states that compared to typically fluent individuals PWS tend to make more errors in their motor plan and so they need to make more covert repairs. Thus dysfluencies occur when they tend to correct or reduce the errors. Kolk and Postma (1993) used the model of language comprehension and production by Levelt (1989) to explain the occurrence of dysfluencies in the speech of PWS. According to Levelt (1989)'s model, the speech and language production involves three processes namely internal monitoring of speech, error detection and covert repair of the detected errors. This model has two loops namely internal and external loops which are responsible for error detection process. The functions of both the loops are mentioned in the figure 2.5.

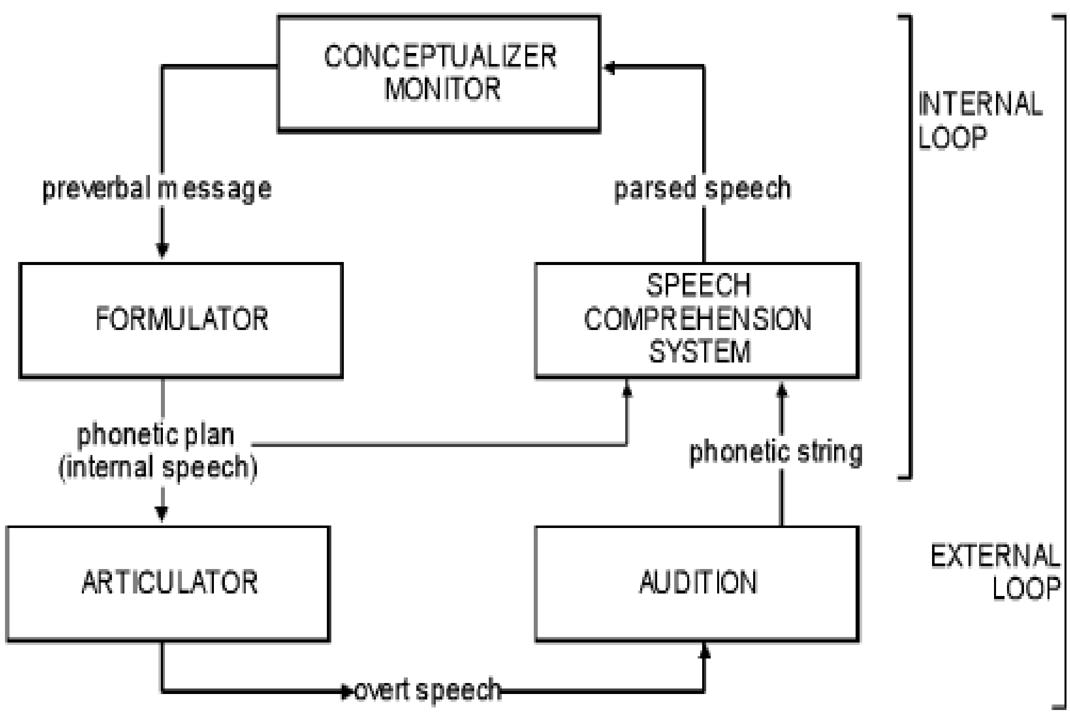

Figure 2.5: An illustration of the Levelt's monitoring loops.

(Source: Phonological encoding in normal and pathological speech, Psychology Press)

The internal loop comprises of the conceptualizer, before the generation of preverbal message and after the formulator generates the phonetic plan. The external loop includes after the speech output. Errors do occur in speech of typically fluent individuals and when these errors are detected, the flow of speech is disrupted because the speaker pauses and then they use fillers such as ‘uh’, ‘um’ or ‘I mean’ referred to as editing. They use fillers for the listeners to understand the repair process is going on. Therefore, the repair process begins after the pause. These self repairs can either be covert or overt. This theory states that among persons who stutter (PWS), the covert repairs which means repair which occurs at the prearticulatory stage does not happen easily since it leads to other effects such as hindering the progress of the utterance, obstructing the execution of forthcoming utterances and also iterations. These effects are seen because an erroneous plan is already sent to articulators which in turn requires radical intervention that is repairing some portion of the plan and as a result of this the correct portions of the plan becomes unavailable temporarily. Indeed, Kolk and Postma (1997) describe that the process of prearticulatory editing allows the speaker to repair the error before it is produced.

Kolk and Postma (1997) hypothesized that PWS have more phonologic errors in their speech and to this hypothesis was explained using spreading activation model [Dell (1986); Dell & O’ Seaghdha (1991)]. Postma and Kolk (1993) postulated that the activation rate of phonological unit loops were found to be slower that is the time taken for the nodes to reach a level of activation was found to be more when compared to that of other competing nodes. So when they speak at a normal rate, the phonological nodes get selected inappropriately for the generated frames which lead to inappropriate selection of phonemes. But when they speak at a slower rate, phonological nodes get selected appropriately for the generated frames and thus an errorless phonetic plan is generated.

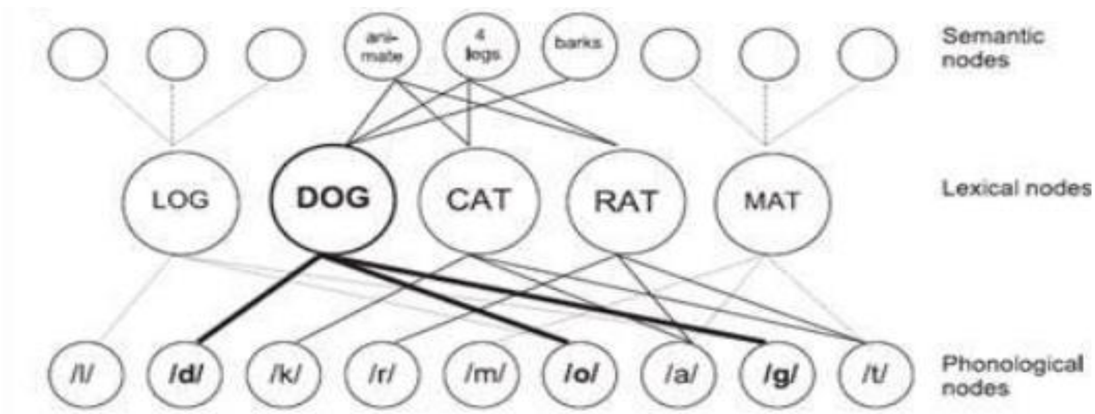

Figure 2.6: Illustration of lexical access model (Dell & O' Seaghdha, 1991).

(Source: Phonological encoding in normal and pathological speech, Psychology press)

Therefore, Postma and Kolk (1993) came to a conclusion that fast rate of speech and slower activation rate were considered as the contributing factors for stuttering. So for PWS, the time taken to activate the target phonological nodes was found to be delayed or slow when compared to PNS. Thus, it is said that for PWS, the intended sounds are in competition with other sounds for a longer period of time. According to this theory, when errors such as inappropriate selection of phonemes are detected by PWS, they tend to self repair or correct it which is perceived as dysfluencies by the listener.

According to covert repair hypothesis, self correction takes place during the phase of phonetic plan formulation and this happens with the help of monitoring device. This theory states that monitoring takes place prior to implementation of articulatory commands. When a error is detected in the phonetic plan by the speaker, he/she tends to correct the plan by interrupting the planning of phonologic sequence. The fluency of speech gets disrupted because of the covert repairs made prior to their speech output. This happens for all the speakers. It is postulated that the ability to encode phonologic sequences are impaired among PWS. Therefore, Kolk and Postma (1997) explained the phonological encoding phenomenon based on CRH theory that it is the process that uses a syntactic representation to derive a phonetic plan that is specific enough to serve as a set of instructions for the articulators. Hence, phonological encoding is considered as the prearticulatory stage for verbal output.

Vasic and Wijnen (2005) stated that evidence for covert repair hypothesis is inconclusive since the cause for the increased number of phonologic errors observed in PWS cannot be the covert repair of the errors but could be something beyond that. An attempt was made by them to elucidate the cause of stuttering. They proposed a theory named Vicious Circle Hypothesis by using Levelt (1989)'s model. According to their views based on Levelt (1989)'s model, one can hypothesize that monitoring process of the speech produced by the speaker necessitate attention. Levelt (1983) stated that PWS tend to repair the errors detected at the end of phrase and this reflects that they tend to vary their amount of attention required for self monitoring process. Vasic and Wijnen (2005) proposed that three parameters of attention such as effort, focus and threshold were found to be essential for monitoring. The amount of resources required for monitoring is referred to as effort, selective aspect of monitoring is referred to as focus and the requirement for the output to be acceptable is referred to as threshold. Vasic and Wijnen (2005) found that for PWS those three parameters are inappropriately set: greater effort is taken by them to monitor the speech than what is required, their focus is on temporal fluctuations and interruptions in speech and their threshold is set high for acceptable output and because of this, the normal and unavoidable discontinuities and temporal fluctuations are perceived as dysfluencies. Therefore, they concluded the theory by stating that PWS are more vigilant in monitoring the errors in phonetic plan and their threshold is less for initiating repairs. Vasic and Wijnen (2005) stated that such hyper vigilant monitoring system results in recurrent repairs of even minor sub-phonemic irregularities resulting in unnecessary reformulations of the speech plan ultimately resulting in a "vicious circle".

According to EXPLAN theory (Howell, 2004), a psycholinguistic theory, speech production involves dependent planning and execution processes. Fluency failures occur when the phonetic plan for the word to be spoken is not ready even after uttering the previous word. A discrepancy between planning and execution processes leads to fluency failures. This theory postulates that there are two factors which contribute to the discrepancy between the planning and execution processes namely, execution time of the prior word and the planning time of the current word. The time taken to formulate a motor plan decides whether the verbal output will be errorless or with errors. It also stresses on the fact that planning and execution processes indicates the linguistic and motoric aspects involved in verbal output. This theory emphasizes that when the execution time is long enough for ensuring that the plan for the word to be spoken is ready, then the verbal output will be fluent. In case if there is a problem at prosodic, lexical or other levels, then the planning time will increase leading to non-fluent speech. The two probable reasons for the occurrence of fluency failures are: their planning is made slow by the inherent properties of linguistic segments; speaking at a faster rate. This theory states that speakers take longer time to formulate the plan for the next work and so their speech gets interrupted. Thus, before or while producing a difficult word fluently, the speaker requires more time by repeating the word (which has been planned and executed) before producing the word whose plan is still not formulated. Therefore, Blacfkmer and Milton (1991) assumed that the speaker still has the plan for the previous word. Thus, EXPLAN theory gives us the best illustration of how language combines with speech in controlling one's speech fluency.

According to MacKay and Macdonald (1984) model, the content nodes are subdivided into sentential system, phonologic system and muscle movement system which are controlled independently. These nodes are activated sequentially. The sequencing node is considered as the non specific activating mechanism which activates the content nodes in the serial order. First the sequence Noun node is responsible for activating the target noun and the competing nouns. The noun with the greatest degree of priming will be activated by the sequencing noun. This is termed as most primed wins principle and this principle is applied for activating each of the nodes in the system. The timing nodes determines the time at which the sequence nodes gets activated. To code the components of the sentence, the sentence time node which is connected to the sequence node activates the content node. The phonologic time node is also connected to the sequence node which in turn activates the content nodes for coding the syllable components. Then the muscle node is connected to sequence node which in turn activates the content node which controls the muscle movements within the subsystems involved for speech production. Each of the timing nodes sends out pulses at specific interval but the mean pulse rate for each of the nodes differs from each other. When a timing node gets activated, all the sequence nodes connected to it gets primed simultaneously and the node with greatest degree of priming gets activated. The timing nodes for the three systems are controlled independently similar to sequence nodes.

For example, consider the word "Practice" where the first two phonemes are focused. The superordinate component node (pr) is activated first which in turn activates the sub ordinate components (p – initial stop and r – initial liquid). The activation of the subordinate components leads to the priming of their corresponding nodes (initial stop and initial liquid). The initial stop gets activated first with the help of the pulse from the phonologic time node whereas the priming of initial liquid gets inhibited temporarily by the inhibitory link. Then the initial stop node primes all the stop nodes and the stop /p/ being primed with highest degree gets activated under most primed wins principle. Then the initial stop activation level gets inhibited by its self. The same most primed wins principle applies for activating the target initial liquid /r/ after the initial stop node gets self inhibited. Errors occur when the competing node gets activated under the most primed wins principle when the sequencing and timing node mechanisms gets triggered or when the first subordinate node doesn't get self inhibited.

CALMS model (Healey, Trautman & Susca, 2004) focuses on the multidimensional perspectives about stuttering. This model includes five components that have an influence on stuttering such as cognitive, affective, linguistic, motor and social factors. The cognitive component focuses on thoughts (i.e. negative thoughts towards stuttering), perception (negative view of their own dysfluent speech) and understanding of stuttering. These factors have an impact on how PWS formulate their message and speak. The affective component includes feelings, emotions and attitudes towards stuttering and communication environment. The linguistic component relates to impact of PWS' language abilities on frequency of stuttering. The motor component is associated with secondary general motor behaviours and speech motor control associated with stuttering. The last which is the social component which related to PWS' linguistic competence in conversing with different communication partners in different speaking situations. For PWS, the motor, social, communicative and linguistic messages have an influence on their thoughts, feelings and perceptions about their communication experiences. All the five factors have variable influence on ones' type, frequency and duration of dysfluencies. Thus, stuttering is considered as a dynamic disorder since it is influenced directly and indirectly by all of these five factors. Therefore, PWS experience issues in terms of motor, cognitive, linguistic, social and affective aspects.

Studies that had focussed directly and indirectly into phonological encoding process

Only few studies have directly assessed the phonological encoding skills in children with stuttering. This could be due to lack of identification of tasks that tap into phonological encoding process. For instance, in some studies, the priming paradigm was used and it mainly assesses the organization and activation of the phonological lexicon. Melnick, Conture, and Ohde (2003) attempted to investigate phonological encoding by comparing 18, 3 to 5-year-old children with stuttering with 18 age-matched children who do not stutter. Their phonological encoding process was assessed by using a priming paradigm where speech reaction times were measured from three presentation conditions (no prime, phonologically related prime (initial consonant vowel [CV] or CCV of picture name), and phonologically unrelated prime (different initial CV or CCV)). Goldman Fristoe test of Articulation (Goldman & Fristoe, 1986) was administered to assess their articulation skills and a correlation between their articulation skills and the picture name reaction time was measured. They found significant difference between the control and experimental groups in phonologically related prime condition. CWS group were found to have higher variability in naming reaction time and no correlation between their articulatory proficiency and naming reaction time. High variability in performance was observed within the experimental group. Thus, this finding can be attributed to their phonologic knowledge and the processing difficulties faced by them (Melnick, Conture & Ohde, 2003).

In the year 2007, Byrd, Conture, and Ohde assessed the phonological encoding abilities of 13 3-year-olds and 13 5-year-olds children with and without stuttering using a picture naming auditory priming paradigm. The neutral (tone), holistic, or segmental primes were presented before the onset of target pictures. In this study, only the reaction time (from picture onset to the time of initiation of naming) was measured. The results revealed that the three year-old CWS and CNS responded faster in the holistic priming condition and slower in the segmental priming conditions. The five-year-old CNS responded faster in the segmental condition whereas the five-year-old CWS were fastest in the holistic condition. The findings attributes to the developmental differences in phonological encoding between the groups because by age five CWS appear to demonstrate a delay in segmental encoding abilities as compared to their typically fluent peers.

This finding implies that there is a potential delay in the transition of phonemic competence from holistic to segmental processing abilities in children with stuttering.

An attempt was made by Sasisekaran, Brady, and Stein (2013) to explore whether children who stutter experience a delay in the timely encoding of phonemic segments and also whether they exhibit more errors during phonological encoding process when compared to children who do not stutter. This study was influenced by the multifactorial models of stuttering and psycholinguistics theories of stuttering namely, EXPLAN and Covert Repair Hypothesis theory which stresses on the fact that phonological encoding acts as a causal variable for stuttering. Nine children with severe stuttering aged between 10 and 14 years and nine age- and sex-matched children who do not stutter were included in this study. The participants in both the groups were right-handed and native speakers of North American English.

The authors had used four tasks namely simple motor task, picture familiarization and silent naming task, phoneme monitoring task and auditory tone monitoring task. In simple motor task, the subjects were asked to click the left most button on the response box in response to the onset of the target tone 0.5KHz. The picture familiarization task was used to familiarize the subjects with the 12 target black and white line pictures of twelve bi-syllabic nouns which have the target consonants in the initial and final position. In phoneme monitoring task, the participants were asked to monitor the target phonemes occurring in initial and final positions of the 12 target bi-syllabic words. To each of the four blocks 12 target nouns were assigned and these 12 target nouns were presented twice in each block that is once with the target phoneme requiring a “yes” response and without the target phoneme requiring a “no” response. In the last task which is the auditory tone monitoring task, the stimuli used was 96 computer-generated auditory stimuli comprising of sequence of four pure tones which was distributed across four blocks. Half of the tone sequences which consisted of one 1 kHz tone and three 0.5 kHz tones require “yes” response. The remaining stimuli which consisted of four identical 0.5 kHz tones require “no” response.

The results from the phoneme monitoring task revealed that children who stutter were found to be significantly slower than the children who do not stutter. Among children who stutter, the time taken for them to monitor the phonemes positioned in first syllable offset was significantly different from the time they took to monitor the phonemes positioned in second syllable onset. With respect to the percent errors in phoneme monitoring task, the authors had found some significant group differences. To compensate for such errors, children with stuttering had adapted post-lexical search strategies which may have led to slower monitoring times. Based on the participants' performance in simple motor task, the authors have stated that the observed differences in phoneme monitoring task were not dependent of the differences observed in simple motor task. Thus the authors revealed that children who stutter were found to be slower in encoding segmental units during speech. This finding is supported by theory namely EXPLAN (Howell, 2004) which states that children who stutter experience temporal asynchronies in encoding of phonemic units during speech planning and execution.

The results from the picture naming task revealed that children who stutter were found to have delay in phonological encoding since they were found to be slow in picture naming when compared to children who do not stutter. Based on the results obtained from the above mentioned tasks, the authors have stated that children who stutter were delayed in the timely generation of an appropriate phonetic plan. The result from the auditory tone monitoring task revealed no significant difference between the groups. This finding suggests that children who stutter have difficulty in monitoring the speech. Therefore, children who stutter were found to have deficits in their phonological encoding ability which was indicated by their slower phoneme monitoring performance. But the findings of their study does not support the evidence that fluency failures occurs due to deficits in phonological encoding abilities since Sasisekaran, Brady, and Stein (2013) had used covert speech tasks to assess CWS' phonological encoding skills whereas stuttering occurs in overt speech.

Indirect sources of evidence supporting phonological encoding deficit in children who stutter

Few studies have found that children with stuttering tend to stutter more in utterances of increasing phonemic complexity. On studying the dysfluencies in conversational samples of seven children diagnosed with co-existing stuttering and phonological disorders, Wolk, Blomgren and Smith (2001) found that the percentage of stuttering in initial consonant clusters with phonological errors was higher than in those without phonological errors. Howell, Au-Yeung and Sackin (2000) also found that the dysfluencies occurred frequently on the phonologically complex sounds. This finding implies that children with stuttering face difficulties while encoding late emerging phonemic units.

Arnold, Conture and Ohde (2005) investigated the storage and retrieval of segmental units in children with stuttering and children without stuttering by measuring the reaction times to words varying in phonological neighbourhoods. The authors found that nine, 3 to 5-year-old CWS performed significantly different from age- and gender-matched CNS when they were asked to name the target pictures with sparse and dense phonological neighbourhoods. The findings indicated that the reaction times of both children with and without stuttering were significantly shorter and more accurate on phonologically sparse than phonologically dense words. This finding contradicts to the findings of other mentioned studies that there is a minimal contribution of the phonological processes on the difficulties faced by CWS in producing errorless speech.

Influence of phonological awareness abilities on phonological encoding skills

An attempt was made to investigate whether the phonological awareness abilities of CWS has an effect on their phonological encoding skills**.** Pelczarski and Yaruss (2014) compared the phonological encoding abilities of 5 and 6 year-old children who stutter and children who do not stutter by assessing their performance on age appropriate phonological awareness tasks. The participants were monolingual American English speakers. Many recent studies of phonological encoding state that tasks such as rhyme monitoring, phoneme monitoring, and segmentation could be considered as phonological awareness tasks. Since the main objective was to measure the subjects' phonological awareness abilities, the authors had assessed these abilities using the using phonological awareness subtests of the Comprehensive Test of Phonological Processing: Ages 5–6 (CTOPP; Wagner, Torgesen, & Rashotte, 1999). The Phonological Awareness Composite Score represents a combination of the standard scores of three subtests: sound matching, blending words, and elision.

In the sound matching subtest, the participants were required to listen to the target word followed by a list of words and determine which words shared an initial or final phoneme with a target word. The next subtest is the blending word subtest where the subjects were asked to form real words by blending the sounds together. In the third subtest which is the elision subtest where the participants are required to segment the spoken words and form a new word by removing specific phonological segments. These three subtests together form the Phonological Awareness Composite Score measuring a child's "awareness of and access to the phonological structure of oral language" (Wagner et al., 1999).

The authors found that in two of the three phonological awareness tasks, children who stutter had scored significantly less when compared to children who do not stutter. Several theories of stuttering points out that the difficulty with the selection and preparation of sounds that form the words in a speakers' message could be considered as the cause for dysfluencies (Howell & Au-yeung, 2002). The authors had also stated that differences observed in phonological awareness and phonological encoding measures are robust which suggests that when combined with other factors such as Motoric, linguistic, cognitive abilities, the phonological processing systems of children who stutter may become overwhelmed and lead to stuttered speech. Therefore, the authors have concluded the study by stating that some aspects of phonological encoding is delayed or disrupted in children who stutter.

Phonological working memory skills of children with stuttering

Bosshardt (1993) observed that persons who stutter performed poorly on memory span tasks due to their slowed overt speech rate. Bosshardt (1993) also found that adults who stutter took a longer time to recall the consonant – vowel –consonant syllables on short term recall task. Hence, Bosshardt (1993) concluded the study by stating that slowed speech rate did have an impact on their performance in memory span tasks. This interaction included factors such as slow phonological encoding, slow rehearsal time, and a deficit in elaborative memory processes of AWS. The speech rate and working memory paradigm hypothesized that as the rate of articulation increases, the memory span also increases (Hulme, Muir & Lawrence, 1984; Siegler, 1998).

Although research has shown that slowed speech rate of adults who stutter (AWS) had an effect on their memory span, there is little evidence to support the same claim among CWS (Kelly & Conture, 1992; Yaruss, 1997; Yaruss & Conture, 1995). Therefore, if CWS show reduced working memory skills, speech rate alone would not be considered as a causal role for this difference. An attempt was made by Reilly and Donaher (2005) to find whether CWS (age range of 7-8 years) and CNS showed group differences on a digit and letter span task or not. The participants were monolingual English speakers. The authors had presented twenty separate audio clips as test stimuli and three audio files recorded as a familiarization sequence. The advanced stimulus and cue slides were presented at preset intervals using Microsoft PowerPoint. The test stimuli comprised 20 trials of seven randomly mixed digits and letters. The oral and written responses of the participants were recorded.

The results revealed that CNS showed significantly higher recall than CWS across both oral and written recall modalities. These results suggest that response modality alone cannot be accounted for the reduced memory capacity observed in the CWS. If the interaction between speech rate and working memory paradigm holds true, then the discrepancies in recall that are observed between CWS and CNS could be attributed to slowed speech rate of CWS. This indicates that they were found to be slow in covert rehearsals. Therefore the authors concluded the study by stating that children with stuttering were found to have impaired covert rehearsals because their verbal working memory is impacted by their phonological processing difficulties.

Paden, Yairi, and Ambrose (1999) found that CWS experience a rapid catch-up of phonological abilities during early adolescence. Gillam, Cowan, and Marler (1998)**;** Weismer (1996) stated that the effects of phonological processing delays on working memory may emerge during phonological encoding or at an earlier stage of word processing. Similar to the findings of Bosshardt (1993), the reduced recall abilities of CWS may be related to an interaction of factors including phonological encoding, rehearsal time, and the development of more elaborate memory strategies.

Many researchers propose that the construction of phonological segments during phonological encoding requires the use of phonological memory, or the ability to maintain phonological and auditory information for short-term retrieval while the entirety of the phonological code is constructed (Acheson & MacDonald, 2009; Alt & Plante, 2006; Bajaj, 2007; Haberlandt, Thomas, Lawrence, & Krohn 2005). Several authors have also hypothesized that young children who stutter have lower phonological memory abilities than young children who do not stutter. Thus, Pelczarski and Yaruss (2016) designed a study to address this need by investigating whether the phonological memory (non-word repetition and digit span) skills of children who stutter different from children who do not stutter or not and also if the children who stutter demonstrate the expected strong relationship between phonological memory and other language measures (i.e. articulation abilities, expressive/receptive vocabulary) or not (Coady & Evans, 2008).

Sixteen children who stutter and 13 children who do not stutter aged between 5 to 6 years participated in the study. The participants were monolingual English speakers. Non-word Repetition and the Memory for Digits subtests of the CTOPP were chosen to assess the participants' phonological memory. In the Non-word Repetition subtest, the subjects were asked to repeat as soon as they listen to digital recordings of non-word stimuli that ranged from 1 syllable non-words to 7-syllable non-words. The subjects did not possess consistent phonological errors. In the Memory for Digits subtest, the child was instructed to listen to digital audio recordings of numeric strings (ranged from 2 to 10 digits) and repeat them back exactly as they were heard.

The results revealed that in the Non-word Repetition subtest, children who stutter performed significantly less well than children who do not stutter. Both the groups did not perform significantly different from each other on the Memory for Digits subtest. The authors found that children who stutter exhibit a different relationship between phonological memory abilities and language abilities when compared to CNS. The relationships between -P and GFTA-2, GFTA-2 and digit span and PPVT-III and digit span were found to be significantly stronger for the CNS as compared to CWS.

Rhyme and Segmentation skills in Children with Stuttering

To prove the hypotheses that the phonological abilities of the older children who stutter are different from that of typically fluent children, Sasisekaran and Byrd (2013) had attempted to investigate the rhyme and segmentation skills in children who stutter aged between 7 and 13 years using a silent monitoring task. Sasisekaran and Weber Fox (2012) reported that the performance in phoneme monitoring task improves with age since most of the cognitive processes which are essential to perform phoneme monitoring task emerges with increasing age. As hypothesised by Covert Repair Hypothesis, if Children who stutter are delayed in the acquisition of encoding skills and based on the findings of rhyme and phoneme encoding difficulties (e.g., Byrd et al., 2007; Weber Fox, Spruill, Spencer & Smith, 2008), if they are delayed in the transition from whole-word to segment encoding, then these two findings will have an impact on their performance in phoneme and rhyme monitoring tasks. The authors had used four tasks such as picture naming, phoneme monitoring, rhyme monitoring and tone-sequence monitoring. The procedures which were used for picture naming and phoneme monitoring tasks were as same as mentioned in the previous study. The frequently occurring 28 monosyllabic target nouns which consisted of 7 target consonants (occurring in initial and coda positions), each occurring twice alone and twice in a consonant cluster were considered as stimuli for the phoneme monitoring task. In the tone monitoring task, the participants were asked to hear two tone sequences and on hearing those two sequences, they were asked to respond as to whether the two sequences are same or not. In the rhyme monitoring task, a non-word was presented followed by a picture of a target word and the participant was asked to respond as to whether the items rhymed or not. Twenty-eight monosyllabic non-words which were developed from the target words were considered as the stimuli for the above mentioned task.

The results revealed that among the three tasks, children with stuttering group was slower than the control group. Moreover, in both the groups, the subjects were faster in rhyme monitoring followed by tone sequence monitoring and phoneme monitoring. A significant main effect of Complexity was observed such that monitoring of the consonant clusters took longer than monitoring of the singleton. A significant main effect of Position was observed such that monitoring the phonemes in the offset position took longer than monitoring those at syllable onset positions. Therefore, children with stuttering group took longer to monitor consonant clusters compared to singletons; particularly those in the word/syllable offset position compared to the onset position.

Therefore, findings of their study indicate that CWS may be comparable to CNS in rhyme and segmentation skills which are considered to underlie phonological encoding abilities. The authors have found preliminary evidence indicating that the difficulties in segmentation skills may begin to emerge with increasing task complexity in CWS. This finding supports the fact that impairment in phonological encoding skills is considered to be the causative of stuttering.

Non-word repetition and rhyme judgement tasks were used to investigate the architecture of phonologic lexicon and the acquisition of rhyme and segmentation skills among children who stutter. In the year 2004, Hakim and Ratner used Children's test of non-word repetition(Gathercole, Willis, Baddeley & Emslie, 1994) to compare the performance of non-word repetition task between eight CWS and age matched CNS. For one, two and three syllable non-word repetition tasks, more phonemic errors and few correct productions were observed in

CWS group but only at the three syllable level, there was significant difference between the groups. In both the groups, more phonemic errors were observed at four and five syllable non word repetition tasks.

Anderson, Wagovichand Hall (2006) compared the performance of 12 CWS and 12 CNS aged between 3 and 5 years of age using Children's test of non-word repetition (Gathercole et al., 1994). In two and three syllable non word repetition tasks, CWS exhibited fewer correct productions and only in three-syllable non word repetition task, more phonemic errors were observed when compared to the control group. Therefore, this finding implies that CWS were found to have weaker phonological working memory skills when compared to typically fluent children. The findings of above mentioned studies provide an indirect source of evidence which supports the fact that CWS may have deficits in segmentation skills. Contradicting to these two studies, Bakhtiar, Ali and Sadegh (2007) compared the performance of CWS (aged between 5 and 7 years) and CNS in non word repetition tasks and found no significant difference in mean phonemic errors between both the groups.

An attempt was made to use rhyme paradigms for investigating phonological encoding abilities in both adults and children who stutter. Rhyme paradigm usually involves the participants to make rhyme judgements on word pairs. The processes involved in rhyme judgement includes retrieving the phonological representation of each word in the word pair, holding it in the working memory via articulatory loop and segmenting it into the corresponding onset and rime elements (Besner, 1987). Rhyme judgement is made by comparing the rime of two words in a pair. Fox Weber et al., (2008) used visual rhyming paradigm to assess the performance of 10 CWS aged between 9 and 13 years and 10 age matched CNS and reported that CWS were found to have reduced behavioural accuracy in rhyme judgement. This finding implies that during rhyme judgement, CWS may have less stable neural representation for the prime in the prime target pair. The findings from studies using rhyme paradigms failed to identify the specific deficit in phonologic encoding among CWS.

Covert Phonological encoding abilities among adults with stuttering

Several studies used paradigms such as riming, non-word repetition, rhyme monitoring, phonological awareness tasks and rapid automatized naming tasks to investigate phonological encoding abilities in adults who stutter (AWS). These paradigms failed to assess the covert phonological encoding process in specific since they were considered as overt speech production tasks which are associated with motor execution. Therefore, the only paradigm which is proved to be useful in assessing the phonological encoding skills is the phoneme monitoring task where it does not involve overt speech production.

Sasisekaran, Smyth and Johnson (2006) investigated phonological encoding skills during silent speech in adults with stuttering and adults without stutteringby using a phoneme-monitoring paradigm. The phoneme monitoring paradigm was adapted from an earlier study performed by Wheeldon and Levelt (1995) where they had used a translation task to assess phoneme monitoring skills in bilingual Dutch participants. But in this study, a silent picture naming task was used instead of a language translation task**.** Levelt et al., (1999); Wheeldon and Levelt (1995) had suggested that both translation and silent picture naming tasks require similar sub-processes, namely lexical retrieval, followed by phonological encoding and monitoring of the phonological code, which then results in a motor response. The translation and picture naming tasks were hypothesized to indicate deficits in phonological encoding, since both tasks require subjects to phonologically encode segments in order to make a phoneme-monitoring decision.

To find out whether any observed group differences could attribute to processes other than phonological encoding or not, the authors had also included an overt picture naming task, an auditory tone-monitoring task, and a simple motor task. These tasks were chosen with an aim of comparing the two participant groups in lexical access, general monitoring skills, and speed of motor response. They intended to investigate whether persons who stutter (PWS) and persons who do not stutter (PNS) differ in the time taken to detect the presence or absence of target phonemes in the phoneme-monitoring task; whether PWS and PNS differ in the percent of error judgments in phoneme monitoring and whether PWS and PNS differ in their response time and percent of error judgments in the overt picture naming, auditory, or simple motor tasks.

Eleven adults who stutter (aged from 18 to 49 years) and age matched adults who do not stutter were considered for the study. The participants were native English speakers. In the familiarization task, the subjects were asked to familiarize themselves with the names corresponding to each of the 14 target pictures and then they were asked to name it aloud. In phoneme monitoring task, the subjects were asked to monitor the target phonemes (/p/, /t/, /k/, /b/, /d/, /g/, /s/, /l/, /f/, /r/, /l/) occurred in one of the four target positions within each of the fourteen bi-syllabic words. These 14 target words were presented in four blocks. In addition to this, each target phoneme was presented two to seven times across the four target consonant positions. The method used for auditory tone monitoring task was similar to the one used in Sasisekaran study (children) but the number of computer-generated auditory stimuli used was 106. The procedure used for simple motor task was similar to the procedure used in Sasisekaran et al. (2013)study.

The results revealed that adults who stutter response times were slower when compared to adults who do not stutter in both the tasks namely, simple motor and picture naming tasks but the authors could not observe any statistical difference between both the tasks. For all the subjects, the authors had observed that the time taken to monitor the target phonemes in first position (C^1) was significantly faster when compared to other three positions (C^2, C^3, C^4). The results of the auditory tone monitoring task revealed that that the reaction time for monitoring the target tones across the four tone positions was susceptible to the left to right positioning of the tones within the presented tone sequence. The results of the phoneme monitoring error data analysis revealed that there was left to right increase in the percent of error judgments within target words but only the difference between C^1 and C^2, however, was statistically significant. The results of the average percent scores in auditory tone monitoring task for both the groups revealed that that the percent of error judgments for the tones in the final position of the tone sequence was significantly greater than the other three positions.

Therefore the results revealed that the adults who stutter were found to be slower in monitoring bi-syllabic words when compared to adults who do not stutter. This slowed monitoring performance implies a difficulty at the level of phonological monitoring and thus it is not due to manual reaction time or auditory monitoring deficit. This lends support to theories of stuttering that states that delayed phonological encoding results in the moments of stuttering. The authors had also hypothesized that apart from delays in the activation and selection of phonemes during encoding, the group differences observed in phoneme monitoring were found to be the result of the difficulties in storing and retrieving the speech plan from the speech buffer as opposed to delays in the activation and selection of phonemes during phonological encoding.

Darshini and Swapna (2015) attempted to explore how the phonological encoding process takes place in speakers of different Indian languages since each language has its own linguistic structure and the influence of linguistic factors on stuttering vary from one language to another. So the aim of their study was to investigate the phonological encoding process in Kannada speaking individuals with stuttering. The paradigm used in this study was phoneme monitoring paradigm on two tasks namely silent naming and auditory perception. They had also investigated the influence of severity of stuttering on their phonological encoding abilities.

Fifteen adult Kannada speakers aged between 18-25 years with and without stuttering were considered as subjects in this study. Twenty seven trisyllabic picturable words were considered as stimuli for this study. The nine phonemes such as /p/,/t/,/k/,/b/,/s/,/m/,/t/,/r/and/h/ occurred in initial, medial and final positions of those target words. Based on a thorough review of case files of adult Kannada speakers with stuttering who reported to Department of clinical services, All India Institute of Speech and Hearing, Mysuru with the presence of phoneme specific dysfluencies in their speech and also based on the study by Sasisekaran et al. (2006), these target phonemes were considered. This study also included tasks such as familiarization and overt picture naming tasks. The procedures used for familiarization and overt picture naming tasks in this study were same as mentioned in the previous studies. In the phoneme monitoring in silent naming task, the subjects' phonological encoding abilities were assessed by measuring their reaction time (ms) and accuracy in the course of monitoring the target phonemes in the word which is presented graphically during silent naming. The 27 target words were assigned in two blocks and in each block the target word occurred twice (once with the target phoneme requiring yes response and once without the target phoneme requiring no response). The next experiment which is the phoneme monitoring in auditory perception was used to assess the subjects' reaction time (ms) and accuracy of responses in the course of monitoring the target phoneme for an auditorily presented word. This was also done to find out the group differences in terms of speech perception. The procedure used in this experiment was similar to the procedure used in the previous experiment but the only difference from the first experiment is, here the target words were presented auditorily.

The results of this study revealed that with respect to the reaction measures, adults with stuttering performed significantly poorer when compared to the control group in both the tasks namely silent naming and auditory perception. In terms of accuracy measures, the performances of both the groups were comparable in both the tasks. Therefore, the findings of their study indicates that the delay observed in the process of monitoring for that target phonemes in silent naming could attribute to the delay in the phonological encoding abilities which supports the psycholinguistic theories of stuttering namely covert repair hypothesis.

On comparing the reaction time and accuracy measures on both the tasks across the different severities of stuttering, the authors found statistically significant difference in the performance across the different severity groups only for the accuracy measures in the silent naming task. They also found that the reaction time measures in phoneme monitoring in silent naming and auditory perception tasks did not have an effect on the severity of stuttering. In the silent naming task, adults with severe stuttering performed poorly when compared to mild stutterers. This finding implies that in regard to the accuracy measures, greater the severity of stuttering; greater was the number of errors in their phonetic plan in their self formulated speech. The increase in the number of errors in phonetic plan could be attributed to poor levels of activation required for activating the specific phonemes in them.

This mismatch between the activation levels and the retrieval of the phonemes results in the retrieval of inappropriate phonemes (Dell, 1986; Dell & O' Seaghdha, 1991). However absence of a poor performance observed in the auditory perception task with respect to accuracy measures implies that the subjects did not experience any deficit in monitoring phonemes in the speech production of others.

In the year 1994, Wijnen and Boers used priming paradigm where adults who stutter (AWS) and adults who do not stutter (ANS) had to learn sets of five word pairs in Dutch. In each set, the second word within each pair either began with the same phoneme (consonant-vowel / consonant only) or not. The subjects were instructed to listen to the first word of the pair and recall the second word belonging to that pair as quickly as possible. Results revealed that for both the groups, a comparable naming facilitation effect in speech initiation time was found in the homogeneous primed condition comprising of consonant- vowel items. A reduced facilitation was observed in AWS group only in the consonant only primed items. This finding implies that AWS experienced delay in encoding words specific to stressed vowels and this delay was reduced or eliminated by using a consonant vowel prime Wijnen and Boers (1994).

An attempt was made to observe if there are any rhyme monitoring differences between AWS and ANS. Bosshardt and Fransen (1996) did not observe any rhyme monitoring differences between 14 AWS and 14 age matched ANS in silent pose reading task but a comparable performance was observed in semantic monitoring task where they had to monitor for semantic categories while reading the pose. Bosshardt, Balmer and De Nil (2002) found that AWS performed poorly on a semantic monitoring task when compared to ANS in sentence generation task. This finding attributes to the cognitive processing limitation experienced by AWS and it implies that the organization of speech production system in AWS may be susceptible to interference from concurrent attention demanding tasks such as sentence generation task (Bosshardt et al., 2002). In rhyme monitoring task, Bosshardt and Fransen (1996) observed that AWS were significantly less accurate when compared to ANS.

Weber-Fox, Spencer, Spruil and Smith (2004**)** provided evidence for cognitive limitations in concurrent with phonological tasks in AWS. In their study, evoked response potential was used to assess rhyme judgements across variety of prime target pairs in 11 AWS and 11 ANS. They found AWS were slow in identifying dissimilar rhymes from orthographically and visually similar targets since this task requires more cognitive processing. But across all other conditions, performance was not significantly different between both the groups and this finding attributes to the age related processing differences. Thus their study does not rule out the role of phonologic encoding in AWS completely.

Postma, Kolk and Povel (1990) used tongue twisters to assess the phonologic encoding skills of 19 AWS and 19 ANS. They reported that in overt condition the difference was more when comparing the performance of both the groups whereas in silent condition small difference was observed. AWS were found to slow in both overt and covert speech tasks though the covert speech tasks involve minimal to negligible motor planning and execution. They couldn't conclude the study by stating that it could be because of deficits in encoding phonologic words since the tasks used in the study involves different cognitive processes such as semantic, syntactic and phonemic encoding and also speech motor planning (Yetkin et al. 1995).

To conclude, Stuttering is considered to be the disorder of language in general and phonological encoding in specific as suggested by psycholinguistic theories on stuttering. Levelt, Roelofs and Meyer (1999); Roelofs (2004) defined phonological encoding as a process that involves the retrieval of phonological code (phonemes or syllables) of a word in an incremental just in time manner for the efficient formation of the phonological words. On the western forefront, studies which had directly tapped the phonological encoding process among adults who stutter found that they were slow in monitoring the bisyllabic words when compared to typically fluent adults. This delayed reaction time attributes to the deficits at the level of phoneme monitoring but not as a result of manual reaction time or auditory monitoring deficits. This finding implies that delayed phonological encoding is considered as the causal factor for the occurrence of dysfluencies (Howell, 2004; Perkins et al., 1991; Postma & Kolk, 1993; Wingate, 1988). On the Indian forefront, among adults who stutter, it was found that a delay was observed in the process of monitoring for the target phonemes in silent naming and this finding was attributed to the delay in the phonological encoding abilities which supports the psycholinguistic theories of stuttering namely covert repair hypothesis. Very few western studies have assessed the phonological encoding process in children who stutter and they indirectly and directly support the idea of phonological encoding deficit in children who stutter. Thus, CWS were found to have temporal asynchronies in one or more processes leading up to phoneme monitoring (Sasisekaran, Brady & Stein, 2013). On the Indian forefront, no studies have been conducted to explore how the phonological encoding process takes place in children who stutter. Therefore, the present study attempts to use phoneme monitoring paradigm to assess the covert phonological encoding process in specific.

Chapter III

METHOD

Participants

Inclusion Criteria for the clinical group

Thirty Four children (30 males and 4 females) in the age range of 8 to 12 years (Mean = 10.54, SD=1.42) who were diagnosed as having developmental stuttering with a severity of mild and above degree of stuttering comprised the clinical group. The participants had not undergone any form of speech therapy. All the participants were native speakers of Kannada and right handed. The medium of instruction in the school was English. All the children were ruled out for neurological, intellectual, sensory (vision and hearing) or communication disorders and also other related medical problems by asking parents/caregivers informally and the research officer observed for presence of any symptoms related to oro-motor issues during clinical interview. These participants were randomly selected from department of clinical services, AIISH, Mysuru. Table 3.1 represents the demographic details of the clinical group.

Inclusion Criteria for the typically developing group

Thirty Four age and gender (30 males and 4 females) matched children with no stuttering comprised the control group. All these children were right handed and native speakers of Kannada. These participants were matched with the clinical group for the socioeconomic status using the NIMH socioeconomic status scale (Venkatesan, 2011). All the participants who belonged to the control group were reported to have no history of sensory, neurological, communicative, academic, coginitive, intellectual or emotional disorders and orofacial abnormalities. These participants were randomly recruited from Holy Trinity and Gangothri Public schools, Mysuru.

Table 3.1 *Demographic details of the clinical group*

Clinical group	Age/gender	Stuttering Severity	SSI score
S1	12.3/M	Moderate	26
S2	12.1/M	Severe	29
S3	12.2/M	Mild	18
S4	12.7/M	Severe	30
S5	12.5/M	Moderate	26
S6	12.6/M	Severe	32
S7	12.3/M	Severe	33
S8	12.5/M	Mild	18
S9	12.6/M	Severe	29
S10	12.1/F	Mild	13
S11	12.3/F	Moderate	22
S12	11.3/M	Moderate	25
S13	11.2/M	Moderate	23
S14	11.1/M	Moderate	25
S15	11.3/M	Moderate	22
S16	11.4/M	Moderate	24
S17	11.5/M	Moderate	26
S18	11.7/M	Moderate	30
S19	10.5/M	Moderate	26
S20	10.3/M	Mild	14
S21	10.2/M	Moderate	26
S22	10.3/M	Moderate	21
S23	10.6/M	Severe	33
S25	10.3/F	Moderate	23
S26	9.5/M	Moderate	25
S27	9.2/M	Severe	35
S28	9.3/M	Mild	11
S29	9.2/M	Mild	12
S30	9.3/M	Mild	20
S31	9.5/M	Mild	18
S32	8.3/M	Mild	16
S33	8.2/M	Moderate	24
S34	8.1/F	Moderate	22

Test Materials used

The following assessment tools were administered on children with stuttering and children with no stuttering.

- The stuttering severity was assessed by a Speech Language Pathologist using Stuttering Severity Index-4 (SSI-4) (Riley, 2004).

- The Handedness Preference was assessed using Modified Laterality Preference Schedule tool (Venkatesan, 1992).
- Computerized re-standardized version of Kannada articulation test to assess correct production (Deepa & Savithri, 2010).
- To rule out the linguistic deficits in children from both the groups, semantic section from Linguistic Profile test (Suchitra & Karanth, 1990),
- To rule out cognitive linguistic ability, Cognitive Linguistic Assessment Protocol for children (Anuroopa, 2006) was administered.

The children who passed these screening tests were considered for the study.

Ethical Protocol

The parents of thirty-four participants from both the groups were explained about the purpose and procedure of the study and an informed written consent for their willingness to allow their children to participate in the study was also obtained.

Design of the tasks: The experiment of the present study included four tasks namely,

- Simple Motor task
- Picture Familiarization and Naming task
- Phoneme Monitoring task
- Auditory Tone Monitoring task

The picture familiarization task was presented prior to phoneme monitoring task. The purpose of this order of presentation was to familiarize the participants with the target pictures. The other three tasks were randomized and presented. The experiment protocol was taken as mentioned in Sasisekaran, Brady and Stein (2013)'s study. To rule out group differences in simple motor responses, simple motor task was designed since the simple motor responses were considered as an inherent component of the phoneme and auditory tone monitoring tasks. The performance in phoneme monitoring task was contrasted with performance in other three tasks such as picture naming task, auditory tone monitoring task and simple motor task in order to control any possibilities of any other processes other than phonological encoding causing the group differences.

The present study was conducted in two phases

- Stimulus Preparation and Task Design Programming
- Administration of the tasks on Children who stutter (CWS) and Children who do not stutter (CNS) groups

Phase 1: Stimulus preparation and Task Design Programming

Simple Motor Task

Purpose: This task was designed to assess the time taken to perform simple manual responses by the participants of both the groups.

Stimulus:500 Hz pure tone of duration of 550 ms was considered as the stimulus for this task.

Instrumentation:500 Hz pure tone of duration 550 millisecond (ms) was generated using a high quality web based audio frequency signal generator. DMDX software (version 5) was used to present 500 Hz pure tones of duration 550 ms and also to assess the reaction time and accuracy of the subjects' simple manual responses.

Design: The participants were presented with fifteen trials, each consisting of inter-stimulus interval blank screen varying between 700ms, 1400 ms and 2100 ms followed by the presentation of 500 Hz pure tone of 550 ms in length. This was programmed on the DMDX software (version 5) with the assistance of technical staff. The participants were instructed to respond to the onset of the target tone by pressing "**key 1**" (programmed specifically on the laptop keyboard) as quickly as possible. The inter-stimulus interval was varied to reduce the anticipatory button press. The presentation order of the trials was randomized. Five catch trials were given for practice purpose.

Picture Familiarization and Naming task

Purpose: This task was done to familiarize the participants with 34 target colored pictures were selected from the internet and saved in jpg format and their names that were considered for the phoneme monitoring task. It mainly serves as a purpose to rule out the influence of lexical retrieval on the interpretation of the participants' responses, guide the participant to arrive at the target word and also to avoid any kind of confusions.

Stimulus: Seventeen phonemes (/ṭ/, /d̪/, /r/, /v/, /p/, /ḍ/, /dʒ/, /g/, /ʃ/, /k/, tʃ, /s/, /n/, /t̪/, /m/, /b/, /h/) were selected based on the mean percentage of highly dysfluent phonemes (Sangeetha & Geetha, 2015). Thirty Four Kannada bisyllabic nouns (CVCV) with a frequency value of below 10 were considered. The words having frequency value of below ten was considered as the most frequently used words in Kannada language. The frequency of each word was noted from Morphophonemic analysis of the Kannada language by Ranganatha (1982). The target phonemes occurred in initial and medial positions of the target words. Five Speech Language Pathologists (SLPs) were asked to validate thirty four target pictures representing the 34 target nouns. The judges were asked to rate the target pictures based on four parameters such as image agreement (picture to name correspondence), name agreement (correspondence between the given name for the target noun and the name provided by the participants), word familiarity (assessed based on how familiar the target noun is from experience) and image appropriateness (judged based on whether the representation of the target noun is appropriate to the age range). They were asked to respond by using a 4 point rating scale for each of the parameters as follows: For image and name agreement: 0 – no correspondence, 1- least correspondence, 2- partial correspondence, 3- most correspondence; For word familiarity: 0 – unfamiliar, 1- least familiar, 2- partial familiar, 3- most familiar; For appropriateness: 0 – absolutely inappropriate, 1- slightly inappropriate, 2- slightly appropriate, 3- absolutely appropriate. The target pictures with 75% agreement between the five judges were considered for the study. Out of 34, five target pictures (such as /gu:ḍu/, as /gu:be/;/ʃiva/ as /sha:le/, /nari/, as /na:ji) /ba:le/ as /bale/ and /t̪ale/{picture changed}) were rated as partial correspondence/ familiar/ appropriate by three judges and these pictures were modified as per the suggestions given. The target pictures which were modified were validated again by five SLPs and these pictures had an agreement of 75% among the five judges. The validated and finalized target pictures are attached in the Appendix.

Instrumentation: The target pictures were presented via computer.

Design: In this task, thirty four target pictures were randomly presented manually on the computer screen and the participants were asked to name the pictures overtly.

Phoneme Monitoring Task

Purpose: The task was designed to measure the participants' response time in ms and accuracy in monitoring the presence or absence of target phonemes during silent picture naming.

Stimulus: In this task, thirty four pictures from the picture familiarization and naming task were used in order to elicit phoneme monitoring responses. The five Speech Language Pathologist's (SLP's) were made to listen to audio samples of the target phonemes and asked them to give feedback on loudness and clarity of the sample. The seventeen target phonemes were presented along with vowel /a/ but the subjects were asked to monitor the target phoneme irrespective of the sound preceding or following it. The target pictures were presented in two blocks. In the first block, thirty four pictures occurred twice (once with the phoneme as a target, thus requiring participants to provide a "Yes" response and once without the phoneme as a target requiring a "No" response). In the second block, twenty target pictures were randomly presented (the pictures represent the ten target words having the phoneme as the target requiring a "Yes" response and ten without the phoneme as a target requiring a "No" response). The presentation order of the trials was randomized within each block and the order of the presentation of two blocks was counterbalanced across the participants.

Instrumentation: The seventeen target phonemes were pre-recorded (audio) using PRAAT software (version 5.3). The recording of the target phonemes was done in a sound treated room at an appropriate intensity. The target phonemes were uttered by the native Kannada adult speaker. The colored pictures representing thirty fourbisyllabic target words were selected from the internet and saved in jpg format. DMDX software (version 5) was used for the presentation of the target phonemes and pictures, phonemes to be monitored and recording of the reaction time and accuracy of the subjects' manual responses in the computer.

Design: In both the blocks, the trials were presented with an opening screen of 700 ms followed by auditory presentation of the pre-recorded target phoneme. This was followed by random inter stimulus interval of 700 ms, 1400 ms and 2100 ms. The inter stimulus interval (ISI) between auditory presentation of the target phoneme and visual presentation of the target picture was varied between 700 ms, 1400 ms, 2100 ms in order to reduce the anticipatory button press. Followed by this was the presentation of the target picture which appeared on the screen for 3000 ms and then the participant's response time was measured. The same target picture was presented again with a gap of 500 ms for the participant to name it aloud. The target picture was presented again to check if the child was thinking of the target word as opposed to another word when responding to the monitoring task. Presentation of the next trial in the sequence was initiated automatically after 3000 ms in case of "No" response. This was programmed on the DMDX software (version 5) with the help of technical staff. If the target phoneme was present in the target word, the subjects were asked to indicate through a "Yes" response by pressing the "key 1"and "No" "by pressing the "key 2"incase if the target phoneme was not present in the target word. Five catch trials were given for practice purpose. Figure 3.1 illustrates the steps followed in programming the presentation of each trial of both the blocks in DMDX software.

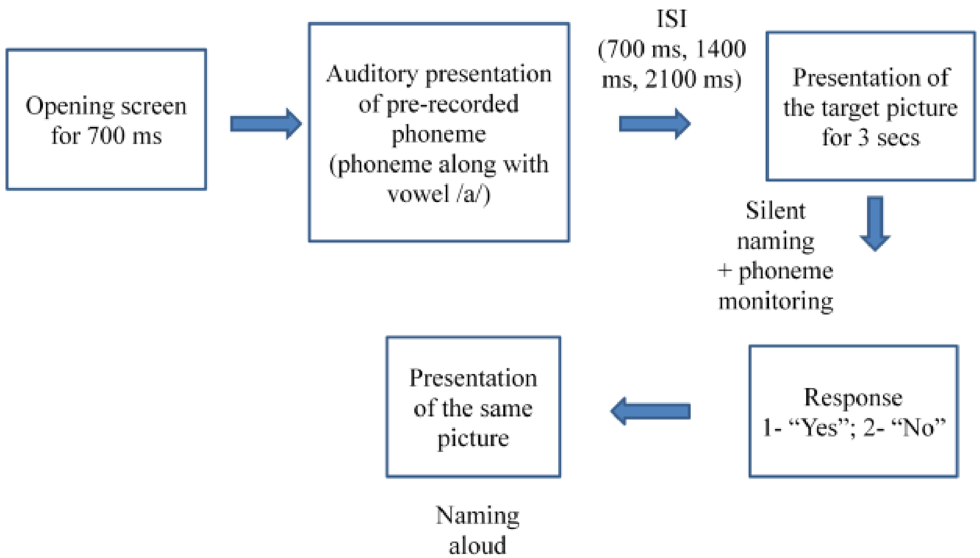

Figure 3.1: Pictorial illustration of phoneme monitoring task design

Auditory Tone Monitoring Task

Purpose: To measure participant's response time in ms and accuracy in monitoring the presence of target tone that is 1 KHz in the presented tone sequence.

Stimulus: For this task, 1 KHz and 500 Hz pure tones were used. Twenty trials were presented in both the blocks with ten trials in each block. The target tone selected for this task was 1 KHz. In each block, half of the trials i.e. five of the trials had tone sequences comprising of 1 KHz and 500 Hz tones. The position of 1 KHz tone was distributed across initial and medial position of two tone sequence (e.g. 1 KHz, 500 Hz; 500 Hz, 1 KHz). These tone sequences required a "Yes" response from the participants indicating the presence of the target tone i.e. 1 KHz. The other five trials had tone sequences comprising of two 500 Hz tones (e.g. 500 Hz, 500 Hz; 500 Hz, 500 Hz). These tone sequences required a "No" response from the participants indicating the absence of the target tone. The order of the tone sequences were randomized within each block and the order of the presentation of two blocks were counterbalanced across the participants.

Instrumentation: The length of each of the bisyllabic words was measured using PRAAT software (version 5.3). 1 KHz and 500 Hz pure tones of duration 0.42 seconds (s) were generated using a high quality web based audio frequency signal generator. The length of the tone which is 0.42 seconds was made to two pure tone sequence (each tone of duration of 0.21 seconds where the overall length of the tone was split equally) using PRAAT software (version 5.3). The length of the tone was equivalent to the average length of the target bisyllabic words which was found to be 0.42. DMDX software (version 5) was used to measure the participant's reaction time and accuracy of their manual responses.

Design: In both the blocks, each trial was presented with an opening screen for 700 ms followed by auditory presentation of a pre-recorded target tone (1 KHz). This was followed by random inter stimulus interval of 700 ms, 1400 ms and 2100 ms. The inter stimulus interval between hearing the target tone and subsequent two tone sequence was varied between 700 ms, 1400 ms and 2100 ms in order to reduce anticipatory button press. The presentation of the two pure tone sequence with a gap of 50 ms followed the inter stimulus interval.This was programmed on the DMDX software (version 5) with the help of technical staff. If the target tone was present in the tone sequence, the subjects were asked to indicate through a "Yes" response and "No" incase if the target tone was not present in the tone sequence. Response time was measured from the onset of the tone sequence till the participants press the button. Presentation of the next trial in the sequence was initiated automatically after 3 seconds in case of "No" response. Five catch trials were given for practice purpose. Figure 3.2 illustrates the steps followed in programming the presentation of each trial of both the blocks in DMDX software.

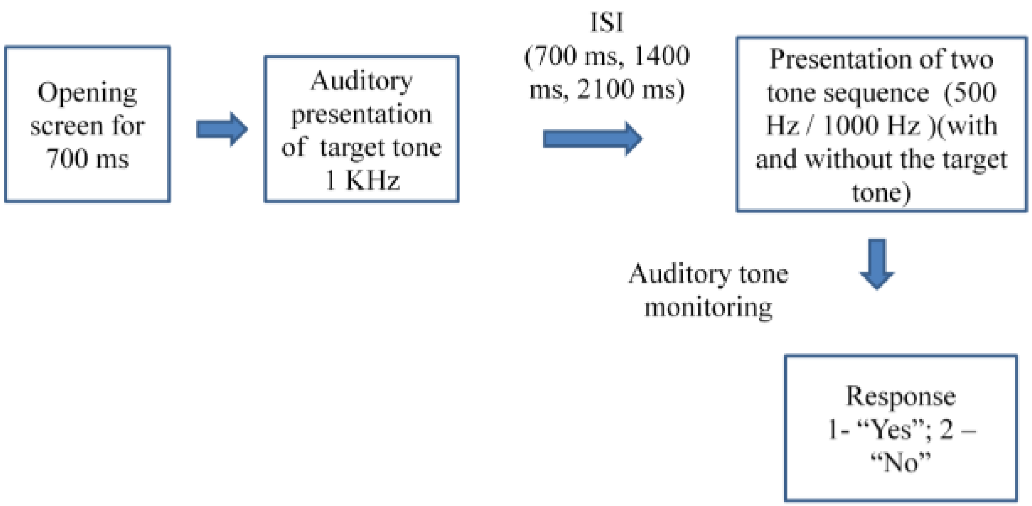

Figure 3.2: Pictorial illustration of auditory tone monitoring task design

Pilot Study

Pilot study was conducted after programming the three tasks such as Simple motor task, phoneme and auditory tone monitoring using DMDX software. It was conducted on 5 (males- 3; females -2; each in the age range of 8-12 years) typically developing school children with an aim of confirming the duration of presentation of the target stimuli and checking the accuracy of programming of DMDX software. While doing the pilot study, the total duration of the overall experiment was known and each participant took approximately 120 minutes to complete the whole experiment. The requirement of the rest period during the testing within and across the blocks for all three tasks was also identified.

Modifications were made to the program of two tasks based on the observations made during pilot study. The modifications which were made are as follows: In Phoneme Monitoring Task, initially a total of 136 trials that is, 68 trials were presented in each of the two blocks. Due to time constraints and difficulties faced by the children to sustain attention for a long time, 68 trials were presented in one block and 20 trials were presented in second block. Rest period was included within the first block. In the Auditory tone monitoring task, initially 68 trials were presented in each of the two blocks. Since majority of the tone sequences were repeatedly presented, 10 trials were presented in each of the two blocks. The duration of the rest period within and across the blocks was controlled by the participants.

Phase 2: Administration of the tasks on CWS and CNS groups

Procedure: For the participants of both the groups, the testing protocol was initiated with the random presentation of three tasks such as simple motor task, auditory tone and phoneme monitoring tasks with an exception that the picture familiarization task was always presented prior to phoneme monitoring task.

In ***Simple Motor task***, each participant was made to sit comfortably in front of the 15 inch laptop screen and the testing was done in a distraction free environment. The participants were instructed to respond to the onset of the target tone by pressing "**key 1**" (programmed specifically on the laptop keyboard) as quickly as possible. For each participant, this task took 10 minutes to complete.

In ***Picture Familiarization task***, first, the participants were familiarized with the thirty four target pictures that were considered for the phoneme monitoring task and later these target pictures were randomly presented on the laptop screen for them to overtly name it. In case of any errors made by the participants, a corrective feedback was provided i.e. the naming errors were corrected by the tester and verbal cue was also provided in order to guide the subject to arrive at the target word. Two to three attempts were provided to the participants until they correctly name the target pictures which were named incorrectly in the first attempt. After familiarizing them with the target pictures, the participants were instructed to monitor for the target phonemes in the target words in the phoneme monitoring task. The approximate time taken by each participant to complete the task was 15 minutes.

In ***Phoneme Monitoring task,*** each participant was made to sit comfortably in front of the laptop screen and the testing was done in a distraction free environment. The participants were instructed that first they would hear a phoneme for e.g. /ṭa/ and then after a small time gap, a picture that they had named earlier would appear on the screen for e.g. picture of /lo:ṭa/. Since the target phonemes were presented along with vowel /a/, the subjects were asked to monitor the target phoneme irrespective of the sound preceding or following it. On seeing the target picture, they were asked to identify the heard phoneme in the pictorial representation of the target word (irrespective of its position in the target word) by covertly naming it. The response keys such as **"key 1"** and **"key 2"** were programmed specifically on the laptop keyboard. If they identify the heard phoneme in the target word, then they were asked to press **"key 1"** indicating **"Yes"** and if the heard phoneme is not in the target word, they were asked to press **"key 2"** indicating **"No"**. The participants were instructed to press the response keys as quickly as possible. This was followed by a small time gap and then the same picture was presented again for them to name it aloud. This task took 30 minutes for each participant to complete.

In ***Auditory Tone monitoring task,*** each participant was made to sit comfortably in front of the laptop screen and the testing was done in a distraction free environment. The participants were instructed that they would hear a tone first which would be followed by a small time gap. Followed by this was the presentation of two tone sequence. The response keys such as **"key 1"** and **"key 2"** were programmed specifically on the laptop keyboard. The participants were asked to press **"key 1"** indicating **"Yes"** if the first tone that they hear is in the two tone sequence irrespective of its position and press **"key 2"** indicating **"No"** if the target tone is not in the tone sequence. The subjects were instructed to press the response keys as quickly as possible. Each participant took 15 minutes to complete this task.

The time taken to complete the entire experiment was 70 minutes approximately. The participants took 10 minutes (approximately) to complete the catch trials of each of the tasks. In the three tasks such as simple motor task, auditory tone and phoneme monitoring tasks, break was given to the participants after the completion of one block. But in the phoneme monitoring task, rest period was given within the first block i.e. after presentation of 34 stimuli. The duration of the rest period was controlled by the participants, i.e. the participants were instructed to press the spacebar once they were ready to continue.

Analysis

The reaction time and accuracy of the participants' responses were measured automatically using DMDX software. The incorrect responses were indicated by negative sign in the software and time lapsed errors were indicated by -4000 ms. For the two tasks (such as auditory tone and phoneme monitoring tasks), the tone and phoneme monitoring reaction time to "Yes" and "No" responses in both initial and medial positions were obtained and averaged for each of the subjects in both the groups separately. For simple motor task, the reaction time to only "Yes" response was obtained and averaged for each of the participants in both the groups separately. For measuring the accuracy, the number of accurate responses for each task was counted and then a raw score was obtained for a total set of 88 stimuli for phoneme monitoring task, 20 stimuli for auditory tone monitoring task and 15 stimuli for simple motor task of both the groups.

Chapter IV

RESULTS

The present study was aimed to compare the performance of children with stuttering and children with no stuttering in phonological encoding using phoneme monitoring in silent naming task. In specific, an attempt was made to investigate the reaction time and accuracy of the participants' responses in three tasks such as simple motor task, auditory tone monitoring and phoneme monitoring tasks. For all these three tasks, a comparison was made between the groups and within children who stutter group in terms of two measures such as reaction time and accuracy. The present study also aimed to find out if there is any difference between auditory tone and phoneme monitoring tasks in both children who stutter (CWS) and children who do not stutter (CNS) groups as well as within children who stutter group. The data obtained in all three tasks were averaged and analysed using statistical measures in SPSS software.

Reliability

Five of the randomly sampled participants were selected for re-administration of the experiment post 4 days of initial administration in order to find out if the experiment can consistently produce the same results over time. To check the reliability Cronbach's Alpha statistical procedure has been carried out and the same information is provided in table 4.1

Table 4.1 *Reliability for CNS and CWS*

	Cronbach's Alpha statistical score	
Task		
Phoneme Monitoring Task **<u>Reaction measures</u>**	**CWS**	**CNS**
Yes responses	0.91***	0.97***
No responses	0.73*	0.76*
Yes Initial	0.88**	0.88**
Yes Medial	0.71*	0.74*
No Initial	0.82**	0.86**

No Medial	0.85**	0.85**
Phoneme Monitoring Task Accuracy measures	**CWS**	**CNS**
Yes responses	0.91***	0.95***
No responses	0.81**	0.84**
Yes Initial	0.75*	0.76*
Yes Medial	0.95***	0.95***
No Initial	0.77*	0.77*
No Medial	0.72*	0.75*
Auditory Tone Monitoring Task <u>Reaction measures</u>	**CWS**	**CNS**
Yes responses	0.79*	0.79*
No responses	0.75*	0.77*
Yes Initial	0.82**	0.84**
Yes Medial	0.76*	0.78*
No Initial	0.82**	0.82**
No Medial	0.72*	0.76*
Auditory Tone Monitoring Task Accuracy measures	**CWS**	**CNS**
Yes responses	0.89**	0.89**
No responses	0.88**	0.88**
Yes Initial	0.73*	0.79*
Yes Medial	0.75*	0.77*
No Initial	0.71*	0.78*
No Medial	0.88**	0.88**
Simple Motor Task Reaction time	0.86**	0.89**
Simple Motor Task Accuracy measures	0.83**	0.87**

Note: *acceptable, **good, ***excellent

The results are presented under following sections

- Comparison of speed of simple motor responses in simple motor task
- Comparison of accuracy of simple motor responses in simple motor task.
- Comparison of reaction time measures in phoneme monitoring task
- Comparison of accuracy in phoneme monitoring responses in phoneme monitoring task
- Comparison of speed of tone monitoring in auditory tone monitoring task
- Comparison of percentage of error tone monitoring responses in auditory tone monitoring task
- Difference between auditory tone and phoneme monitoring tasks
- Difference between simple motor and phoneme monitoring tasks

Simple Motor Task

Comparison of speed of simple motor responses in simple motor task across CWS and CNS and also within CWS group

Mann Whitney U test which is a non parametric test was chosen to compare the differences between two independent groups namely CWS and CNS since both the groups were not normally distributed. Results revealed significant difference ($|z| = 2.19$, $p < 0.05$) between CWS and CNS groups in the speed of manual responses. Thus, on comparing the mean values as indicated in table 4.2, it was found that CWS took the longest time in responding to the onset of the target tone when compared to CNS. Figure 4.1 represents the mean values for reaction time measure of simple motor task between CWS and CNS.

Table 4.2: *Mean, SD and Median values for reaction time measure of simple motor task between CWS and CNS*

Group	N	Mean	SD	Median
CNS	34	381.79	128.80	335.74
CWS	34	502.23	229.49	429.78

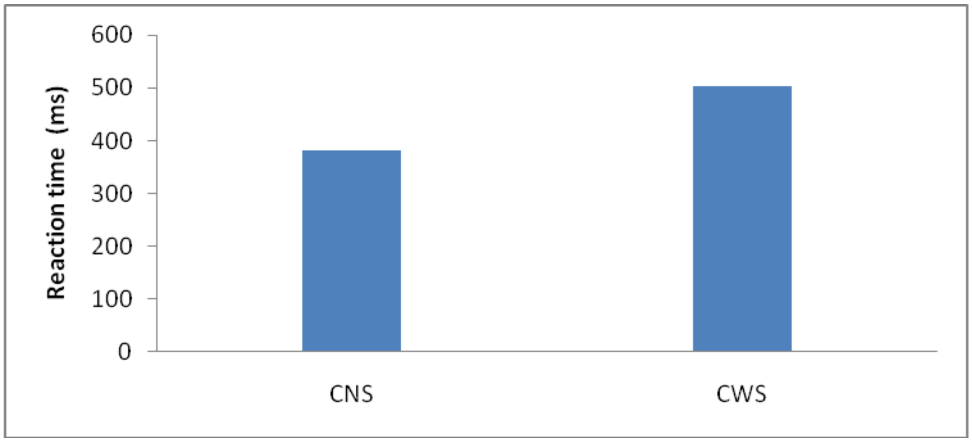

Figure 4.1: Mean values for reaction time measure of simple motor task between CWS and CNS

Within CWS groups, a comparison was made based on severity (mild, moderate and severe). Kruskal-Wallis H test which is a non parametric test allows the comparison of two or more groups of an independent variable and this was used because of the less and unequal sample size in each group. The results indicated no significant difference (χ^2 (2) = 3.27, $p>0.05$) among children with mild, moderate and severe stuttering. Based on Mean values as mentioned in table 4.3, children with moderate stuttering took longer time in responding to onset of the target tone followed by children with severe and mild stuttering though the difference was not statistically significant. Figure 4.2 represents the mean values for reaction time measure of simple motor task between different severities of stuttering.

Table 4.3: *Mean, SD and Median values for reaction time measure of simple motor task between different severities of stuttering*

Severity	N	Mean	SD	Median
Mild	10	418.67	195.31	391.84
Moderate	17	560.87	224.60	518.28
Severe	7	479.20	275.54	360.23

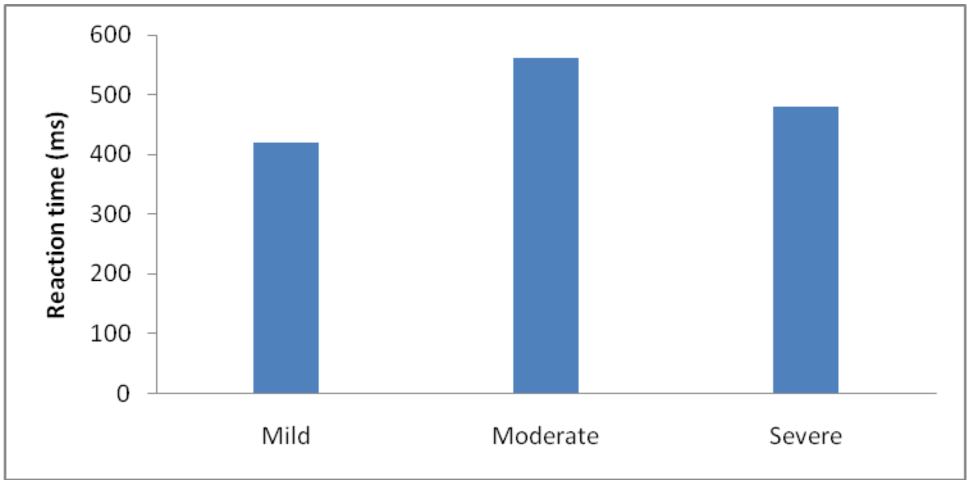

Figure 4.2: Mean values for reaction time measure of simple motor task between different severities of stuttering

Comparison of accuracy of simple motor responses in simple motor task across CWS and CNS and also within CWS group

Since CWS and CNS groups were not normally distributed, Mann Whitney U test was used. In terms of accuracy measure, it was found that both the groups were comparable based on the mean values i.e. CNS group was more accurate in responding to the onset of the target tone when compared to CWS group but the difference in the performance between the groups were not statistically significant ($|z| = 1.66$; $p>0.05$) with a mean rank of 37.04 for CNS group and 31.96 for CWS group. Table 4.4 indicates the mean, SD and median values for accuracy measure of simple motor task between the groups. Figure 4.3 represents the mean values for accuracy measure of simple motor task between CWS and CNS.

Table4.4: *Mean and SD values for accuracy measure of simple motor task between CWS and CNS*

Group	N	Mean	SD	Median
CNS	34	99.41	1.91	100
CWS	34	98.23	3.40	100

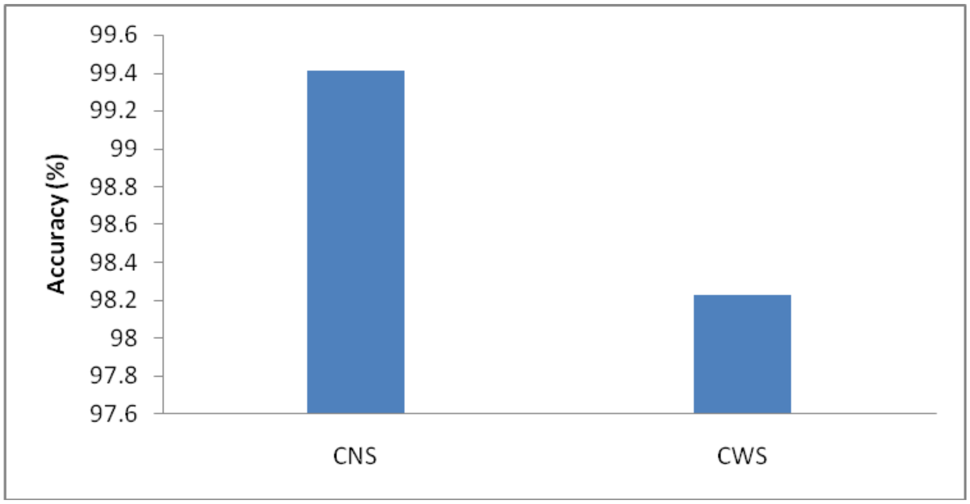

Figure 4.3: Mean values for accuracy measure of simple motor task between CWS and CNS

Within the CWS group, Kruskal Wallis test showed no significant difference (χ^2 (2) = 0.81; p>0.05) among children with mild, moderate and severe stuttering in terms of accuracy measure with a mean rank of 18.20 for children with mild stuttering, 16.41 for children with moderate stuttering and 19.14 for children with severe stuttering. The mean values suggested that children with severe stuttering performed more accurately followed by children with mild and moderate stuttering but the differences in their performance were not significant. The mean, SD and median values for three severity groups are mentioned in table 4.5. Figure 4.4 represents the mean values for accuracy measure of simple motor task between different severities of stuttering

Table 4.5: *Mean, SD and Median values for accuracy measure of simple motor task between different severities of stuttering*

Severity	N	Mean	SD	Median
Mild	10	98.66	2.81	100
Moderate	17	97.64	4.04	100
Severe	7	99.04	2.51	100

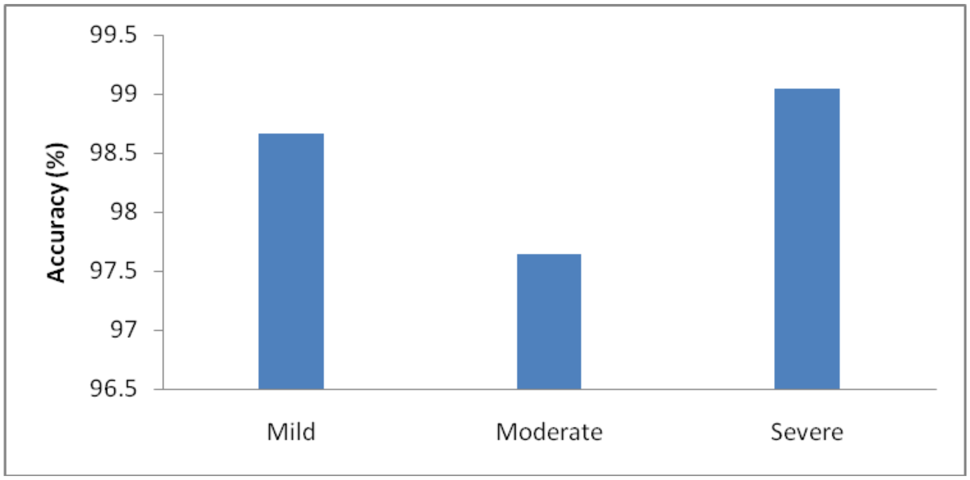

Figure 4.4: Mean values for accuracy measure of simple motor task between different severities of stuttering

Phoneme Monitoring Task

Comparison of reaction time measures in phoneme monitoring task across CWS and CNS and also within CWS group

Since both the groups were normally distributed, Independent t test was used and the results suggested significant difference between CWS and CNS groups in phoneme monitoring response time to correct responses ("Yes" responses ($t(66) = 3.49$; $p<0.01$) and "No" responses ($t(66) = 5.26$; $p<0.001$)). A significant difference was found between CWS and CNS groups in the speed of monitoring the target phoneme occurring in initial position ($t(66) = 3.81$; $p<0.001$) and also in the medial position ($t(66) = 2.51$; $p<0.05$). In initial ($t(66) = 4.64$; $p<0.001$) and medial ($t(66) = 5.14$; $p<0.001$) positions, there was significant difference between CWS and CNS groups in the speed of monitoring to "No" responses. This was further supported by comparing the mean values and it was noted that the participants from CWS group were found to be slow in eliciting correct responses ("Yes" and "No") when compared to children who do not stutter. For CWS group, their speed of monitoring the presence of target phoneme in initial and medial positions was observed to be slow when compared to participants from CNS group. For CNS group, their speed of monitoring in eliciting "No" responses was faster across both the positions when compared to CWS group. Table 4.6 indicates the mean and SD values of phoneme monitoring response times of "Yes" and "No" responses for CWS and CNS groups and table 4.7 represents the mean and SD values of phoneme monitoring response times for CWS and CNS groups with respect to positions. Figure 4.5 represents the mean values for reaction time measure of phoneme monitoring task between CWS and CNS.

Table 4.6: *Mean and SD for reaction time measure (Yes and No responses) of phoneme monitoring task between CWS and CNS*

Group	N	Yes Total Response		No Total Response	
		Mean	**SD**	**Mean**	**SD**
CWS	34	1974.97	318.70	2238.90	307.71
CNS	34	1738.23	233.70	1896.65	221.78

Table 4.7: *Mean and SD for reaction time measure (Yes and No responses) of phoneme monitoring task between CWS and CNS with respect to positions*

Group	N	Yes Initial Response		Yes Medial Response		No Initial Response		No Medial Response	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
CWS	34	1879.17	310.14	2129.32	482.49	2237.10	327.16	2238.41	335.76
CNS	34	1635.59	206.74	1870.70	356.89	1914.36	239.00	1877.92	232.67

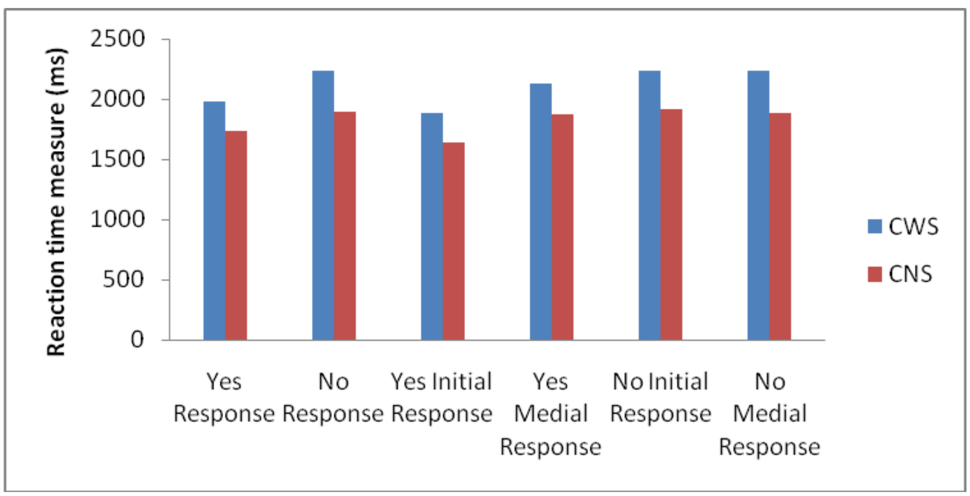

Figure 4.5: Mean values for reaction time measure of phoneme monitoring task between CWS and CNS

Comparison was made between phoneme monitoring time to "Yes" responses and "No" responses, phoneme monitoring time to "Yes" responses in initial position and "Yes" responses in medial position and phoneme monitoring time to "No" responses in initial position and "No" responses in medial position. Paired t test results showed the difference between the reaction time in eliciting "Yes" and "No" responses to be significant (CNS - t (33) = 6.32; $p<0.001$; CWS - t (33) = 4.90; $p<0.001$) since the reaction time in eliciting "Yes" responses (CNS- M= 1738.23; SD = 233.70; CWS- M= 1974.97; SD = 318.70) was shorter than the reaction time in eliciting "No" responses (CNS- M= 1896.65; SD = 221.78; CWS- M= 2238.90; SD = 307.71). The speed of monitoring the presence of phoneme in initial position (CNS- M= 1635.59; SD = 206.74; CWS- M= 1879.17; SD = 310.14) was significantly shorter (CNS - t (33) = 5.22; $p<0.001$; CWS - t (33) = 3.09; $p<0.01$) than in medial position (CNS- M= 1870.70; SD = 356.89; CWS- M= 2129.32; SD = 482.49). For the control group, the speed of eliciting "No" responses in initial position (M= 1914.36; SD = 239.00) was longer than in medial position (CNS- M= 1877.92; SD = 232.67) whereas for the CWS group, the speed of eliciting "No" responses in initial position (CWS- M= 2237.10; SD = 327.16) was shorter than in medial position (CWS- M= 2238.41; SD = 335.76) but the difference was not significant (CNS - t (33) = 1.35; $p>0.05$; CWS - t (33) = 0.03; $p>0.05$).

Within CWS groups, a comparison was made based on severity (mild, moderate and severe). Among children with mild, moderate and severe stuttering, Kruskal-Wallis H test results showed no significant difference in the phoneme monitoring response times to "Yes" (χ^2 (2) = 3.79; $p>0.05$) and "No" (χ^2 (2) = 4.20; $p>0.05$) responses. In terms of positions, the difference in the speed of monitoring the presence (Initial - χ^2 (2) = 5.00; $p>0.05$; Medial - χ^2 (2) = 2.86; $p>0.05$) and absence (Initial - χ^2 (2) = 3.33; $p>0.05$; Medial - χ^2 (2) = 4.91; $p>0.05$) of target phonemes was not significant among the three severity groups.

The mean values were comparable across three severity groups indicating that the phoneme monitoring response time to "Yes" and "No" responses was longer in children with mild stuttering followed by children with moderate and severe stuttering. With respect to positions, children with moderate stuttering took the longest time in monitoring the presence of target phoneme occurring in initial position whereas children with severe stuttering took the least time. The speed of monitoring the presence of target phoneme in medial position was found to be slower among children with mild stuttering whereas children with severe stuttering were found to be faster compared to other two groups. Children with moderate stuttering took the longest time in monitoring the absence of target phoneme in initial position whereas in medial position, children with mild stuttering took the longest time in monitoring the absence of target tone. Children with severe stuttering took the least time in monitoring the absence of target tone in both the positions. Though the performances of three severity groups were comparable but the difference in their performance was not significant. Table 4.8 represents the mean and SD values of phoneme monitoring response times to "Yes" and "No" responses for all three severity groups, table 4.9 represents the mean, SD and median values of phoneme monitoring response times to "Yes" responses across both the positions for all three severity groups and table 4.10 represents the mean, SD and median values of phoneme monitoring response times to "No" responses across both the positions for all three severity groups Figure 4.6 represents the mean values for reaction time measure of phoneme monitoring task between different severities of stuttering

Table 4.8: *Mean, SD and Median values for reaction time measure (Yes and No responses) of phoneme monitoring task between different severities of stuttering*

Group	**N**	**Yes Total Response**			**No Total Response**		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Mild	10	2047.03	318.97	2131.02	2321.11	330.23	2353.52
Moderate	17	2017.53	327.92	2054.89	2270.89	313.18	2280.12
Severe	7	1974.97	318.70	1999.60	2043.77	192.50	2115.59

Table 4.9: *Mean, SD and median values for reaction time measure (Yes responses) of phoneme monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**Yes Initial Response**		**Yes Medial Response**	
		Mean	SD	Mean	SD
Mild	10	1934.21	326.22	2197.42	333.82
Moderate	17	1937.59	308.46	2165.84	599.36
Severe	7	1658.64	210.26	1943.37	321.54

Table 4.10: *Mean, SD and Median values for reaction time measure (No response) of phoneme monitoring task between different severities of stuttering with respect to positions*

Group	N	No Initial Response		No Medial Response	
		Mean	SD	Mean	SD
Mild	10	2333.02	378.99	2317.74	307.76
Moderate	17	2246.72	319.76	2283.95	370.14
Severe	7	2076.70	234.42	2014.50	194.37

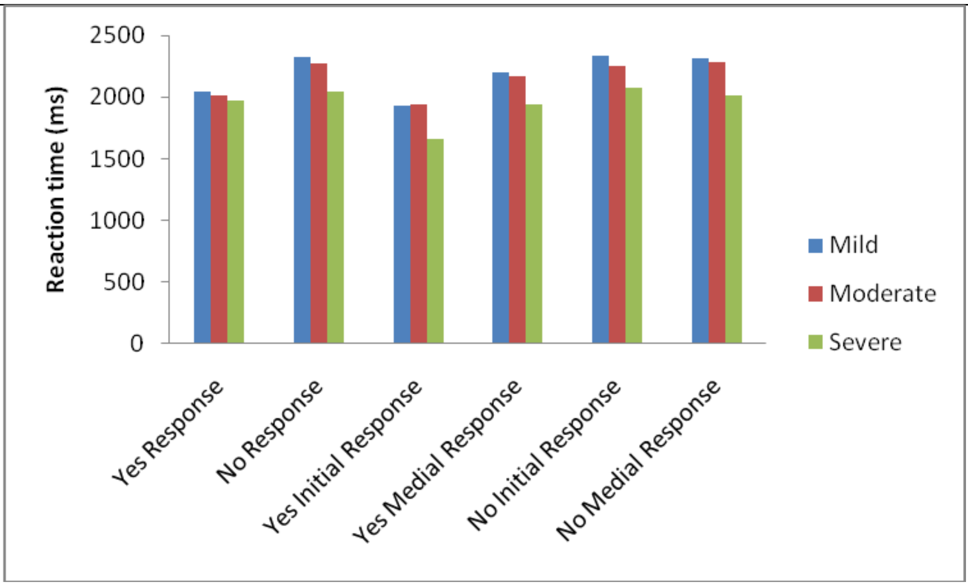

Figure 4.6: Mean values for reaction time measure of phoneme monitoring task between different severities of stuttering

Comparison of accuracy of phoneme monitoring responses in phoneme monitoring task across CWS and CNS and also within CWS group

Since CWS and CNS groups were not normally distributed, Mann Whitney U test was used. It showed significant difference (|z| = 3.50; p<0.001) between both the groups in terms of phoneme monitoring accuracy measure of "Yes" responses. Significant difference (|z| = 0.97; p<0.05) was also found between both the groups in terms of phoneme monitoring accuracy measure of "No" responses. Thus, CNS were more accurate in eliciting "Yes" and "No" responses when compared to CWS. With respect to initial and medial positions, the difference between both the groups in phoneme monitoring response time to "Yes" (Initial - |z| = 2.56; p<0.05; Medial - |z| = 3.70; p<0.001) and "No" (Initial - |z| = 3.11; p<0.01; Medial - |z| = 3.12; p<0.01) responses was also observed to be significant. Based on the mean values, it was revealed that children who stutter were less accurate in monitoring the presence and absence of target phoneme occurring in initial and medial positions of the target words when compared to children who do not stutter. Table 4.11 represents the mean, SD and median values for accuracy measure of "Yes" and "No" responses in phoneme monitoring task between CNS and CWS groups, table 4.12 represents the mean, SD and median values for accuracy measure of "Yes" responses in phoneme monitoring task between CNS and CWS groups with respect to positions and table 4.13 represents the mean, SD and median values for accuracy measure of "No" responses in phoneme monitoring task between CNS and CWS groups with respect to positions. Figure 4.7 represents the mean values for accuracy measure of phoneme monitoring task between CNS and CWS groups

Table 4.11: *Mean, SD and Median values for accuracy measure (yes and no responses) of phoneme monitoring task between CNS and CWS groups with respect to positions*

Group	**N**	**Yes Total Response**			**No Total Response**		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
CNS	34	86.59	11.00	91.17	89.35	8.59	91.17
CWS	34	71.79	18.39	73.52	78.46	16.86	82.35

Table 4.12: *Mean, SD and Median values for accuracy measure (Yes responses) of phoneme monitoring task between CNS and CWS with respect to positions*

Group	**N**	**Yes Initial Response**			**Yes Medial Response**		
		Mean	SD	Median	Mean	SD	Median
CNS	34	92.04	8.30	94.11	81.14	16.11	85.29
CWS	34	83.39	15.22	85.29	60.20	24.66	58.82

Table 4.13: *Mean, SD and Median values for accuracy measure (No responses) of phoneme monitoring task between CNS and CWS with respect to positions*

Group	**N**	**No Initial Response**			**No Medial Response**		
		Mean	SD	Median	Mean	SD	Median
CNS	34	87.71	10.96	94.11	91.00	9.18	94.11
CWS	34	74.74	19.77	79.41	82.17	15.56	88.23

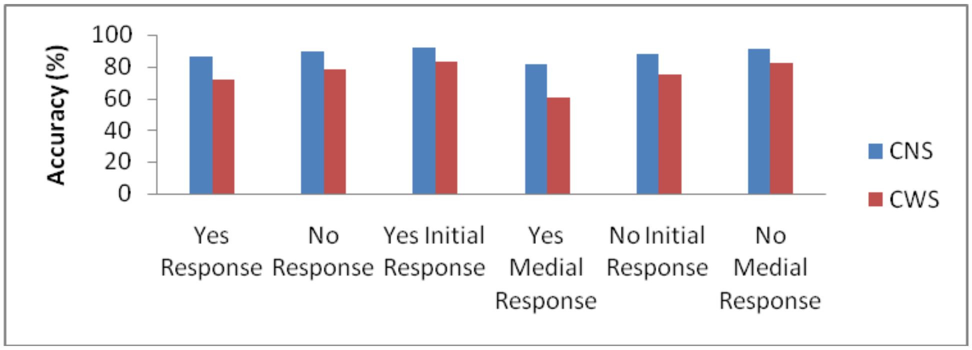

Figure 4.7: Mean values for accuracy measure of phoneme monitoring task between CNS and CWS groups

Comparison was made between phoneme monitoring accuracy measure of "Yes" responses and "No" responses, phoneme monitoring accuracy measure of "Yes" responses in initial position and "Yes" responses in medial position and phoneme monitoring accuracy measure of "No" responses in initial position and "No" responses in medial position. The Wilcoxon signed rank test results showed significant difference between accuracy measure of "Yes" and "No" responses for CWS group ($|z| = 2.02$; $p<0.05$) but for CNS group, significant difference was not found ($|z| = 1.66$; $p>0.05$). Significant difference was found between the accuracy measure of monitoring the target phonemes in initial and medial positions (CNS- $|z| = 4.28$; $p<0.001$; CWS- ($|z| = 4.71$; $p<0.001$). There was significant difference between the accuracy measure of "No" responses in initial and medial positions for the CWS group ($|z| = 3.31$; $p<0.01$) but not for CNS group ($|z| = 1.61$; $p>0.05$). The mean values were compared and results showed that the participants elicited "No" responses (CNS - M = 89.35; SD = 8.59; CWS - M = 78.46; SD = 16.86) more accurately than "Yes" responses (CNS - M = 86.59; SD = 11.00; CWS - M = 71.79; SD = 18.39). Monitoring the presence of target phonemes in initial position (CNS - M = 92.04; SD = 8.30; CWS - M = 83.39; SD = 15.22) was found to be more accurate than in medial position (CNS - M = 81.14; SD = 16.11; CWS – M = 60.20; SD = 24.66). Monitoring the absence of target phonemes in medial position (CNS - M = 91.00; SD = 9.18; CWS - M = 82.17; SD = 15.56) was found to be more accurate than in initial position (CNS - M = 87.71; SD = 10.96; CWS - M = 74.74; SD = 19.77).

The mean values for percentage of error responses in phoneme monitoring task were compared among children with mild, moderate and severe stuttering. The results revealed that children with severe stuttering were less accurate in eliciting "Yes" responses whereas children with mild stuttering were found to be most accurate. In eliciting "No" responses, children with severe stuttering were found to be most accurate whereas children with mild stuttering were less accurate. Across initial position, children with mild stuttering were found to be most accurate in eliciting "Yes" responses whereas children with severe and moderate stuttering were found to be equally less accurate in monitoring the target phonemes. In medial position, children with moderate stuttering were least accurate in eliciting "Yes" responses whereas children with mild stuttering were found to be most accurate in monitoring the target phonemes. Across initial position, children with mild stuttering were found to be less accurate in eliciting "No" responses whereas children with severe stuttering were found to be highly accurate. In medial position, children with mild stuttering were least accurate in eliciting "No" responses whereas children with severe stuttering were found to be highly accurate. Though the severity groups were comparable, Kruskal Wallis test showed no significant difference among children with mild, moderate and severe stuttering in terms of phoneme monitoring accuracy measure of "Yes" (χ^2 (2) = 1.70; $p>0.05$) and "No" (χ^2 (2) = 0.70; $p>0.05$) responses. With respect to initial and medial positions, no significant difference was found among children with mild, moderate and severe stuttering in terms of phoneme monitoring accuracy measure of "Yes" (Initial - χ^2 (2) = 1.69; $p>0.05$; Medial - χ^2 (2) = 1.78; $p>0.05$) and "No" (Initial - χ^2 (2) = 0.24; $p>0.05$; Medial - χ^2 (2) = 1.22; $p>0.05$) responses. Table 4.14 indicates the mean, SD and median values for accuracy measure of "Yes" and "No" responses in phoneme monitoring task for three severity groups, table 4.15 indicates the mean, SD and median values for accuracy measure of "Yes" responses across both the positions in phoneme monitoring task for three severity groups and table 4.16 indicates the mean, SD and median values for accuracy measure of "Yes" responses across both the positions in phoneme monitoring task for three severity groups. Figure 4.8 represents the mean values for accuracy measure of phoneme monitoring task between different severities of stuttering

Table 4.14: *Mean, SD and Median values for accuracy measure (Yes and No responses) of phoneme monitoring task between different severities of stuttering*

Group	N	Yes Total Response			No Total Response		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Mild	10	76.47	19.85	82.35	74.70	20.85	80.88
Moderate	17	68.51	17.26	70.58	79.23	16.12	82.35
Severe	7	73.10	20.12	73.52	81.93	13.41	82.35

Table 4.15: *Mean, SD and Median values for accuracy measure (yes responses) of phoneme monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**Yes Initial Response**			**Yes Medial Response**		
		Mean	SD	Median	Mean	SD	Median
Mild	10	85.88	19.64	94.11	67.05	21.69	67.64
Moderate	17	82.35	14.55	82.35	54.67	24.05	58.82
Severe	7	82.35	10.73	82.35	63.86	30.26	64.70

Table 4.16: *Mean, SD and Median values for accuracy measure (no responses) of phoneme monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**No Initial Response**			**No Medial Response**		
		Mean	SD	Median	Mean	SD	Median
Mild	10	71.17	22.08	79.41	78.23	21.48	82.35
Moderate	17	76.12	19.78	76.47	82.35	13.63	88.23
Severe	7	76.47	18.60	82.35	87.39	9.25	88.23

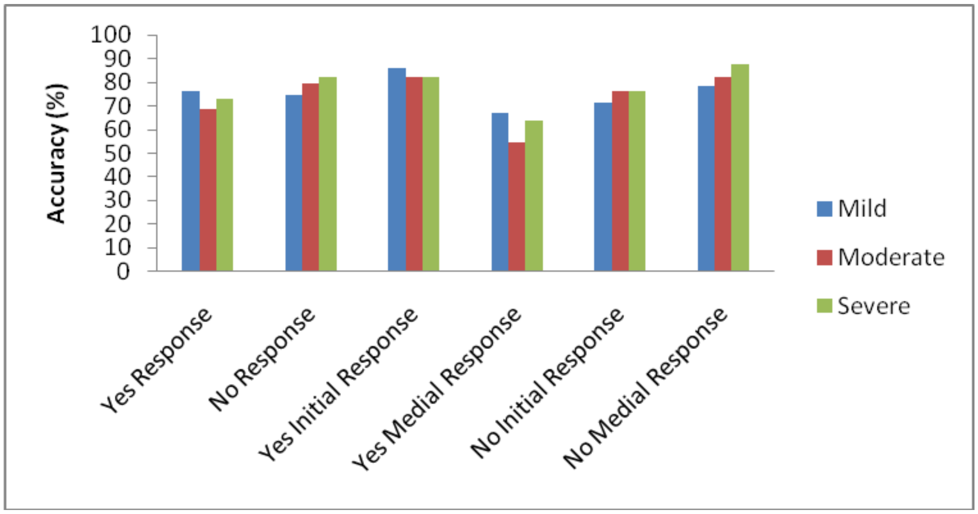

Figure 4.8: Mean values for accuracy measure of phoneme monitoring task between different severities of stuttering

Auditory Tone Monitoring Task

Comparison of reaction time measures in auditory tone monitoring task across CWS and CNS and also within CWS group

Independent t test which is a parametric test was chosen to compare the means between two independent groups namely CWS and CNS on the same dependent variable i.e. reaction time measures of “Yes” and “No” responses and also with respect to two target positions (initial and medial). Both the groups were normally distributed. The independent t test results indicated that there was significant difference between CWS and CNS groups in tone monitoring response time to “Yes” responses ($t(66) = 3.66$; $p<0.01$) and “No” responses ($t(66) = 2.80$; $p<0.01$). A significant difference was found between CWS and CNS groups in the speed of monitoring the presence of the target tone occurring in initial position ($t(66) = 3.34$; $p<0.01$) and also in the medial position ($t(66) = 3.42$; $p<0.01$). There was no significant difference between CWS and CNS groups in the speed of monitoring the absence of the target tone in the initial position ($t(66) = 1.70$; $p>0.05$) but there was significant difference between the groups in the speed of monitoring the absence of the target tone in the medial position ($t(66) = 3.10$; $p<0.01$).

The mean values were found to be comparable across both the groups, indicating that the participants from CWS group were slow in eliciting “Yes” and “No” responses when compared to participants from CNS group. The participants from CNS group were found to be faster in monitoring the presence of target tone (1 KHz) occurring in initial and medial positions when compared to participants from CWS group. For CWS group, their speed of monitoring the absence of target tone in both the positions was found to be slower when compared to CNS group. Table 4.17 represents the mean and SD values of tone monitoring response time for both the groups and table 4.18 represents the mean and SD values of tone monitoring response time for both the groups across initial and medial positions. Figure 4.9 represents the mean values for reaction time measure of auditory tone monitoring task between CWS and CNS.

Table 4.17: *Mean and SD for reaction time measure (Yes and No responses) of auditory tone monitoring task between CWS and CNS*

Group	N	Yes Total Response		No Total Response	
		Mean	**SD**	**Mean**	**SD**
CWS	34	1339.66	298.47	1213.20	301.12
CNS	34	1109.20	213.85	1028.69	238.41

Table 4.18: *Mean and SD for reaction time measure (Yes and No responses) of auditory tone monitoring task between CWS and CNS with respect to positions*

Group	N	Yes Initial Response		Yes Medial Response		No Initial Response		No Medial Response	
		Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
CWS	34	1370.56	367.22	1326.15	316.91	1208.28	297.53	1215.41	298.47
CNS	34	1118.47	242.35	1102.22	212.88	1075.40	344.94	1011.97	210.18

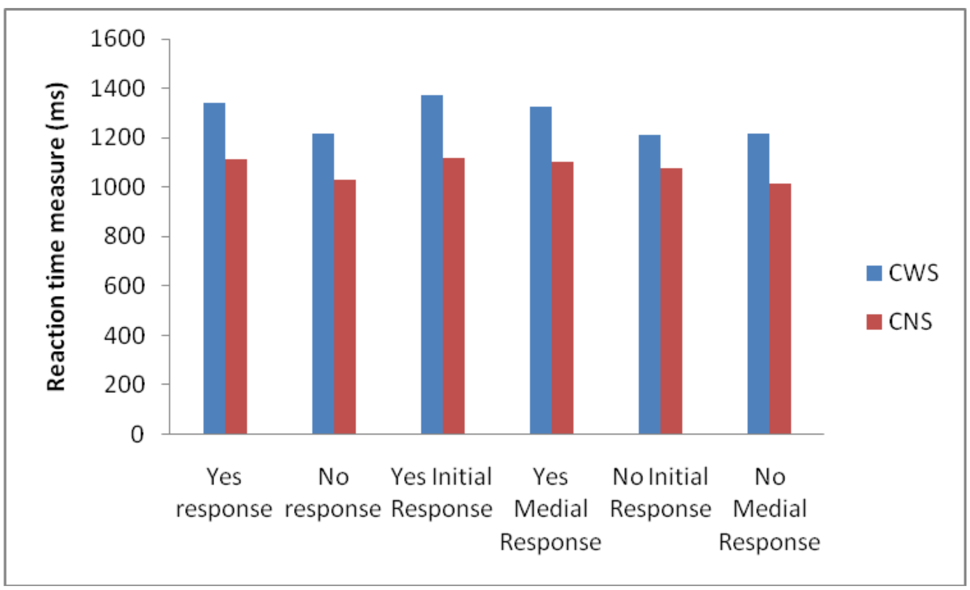

Figure 4.9: Mean values for reaction time measure of auditory tone monitoring task between CWS and CNS

The comparison was made between reaction time measure of “Yes” responses and “No” responses, reaction time measure of “Yes” responses in initial position and “Yes” responses in medial position and reaction time measure of “No” responses in initial position and “No” responses in medial position for both the groups. Paired t test results revealed that the reaction time in eliciting “Yes” (CNS - M = 1109.20; SD = 213.85; CWS - M = 1339.66; SD = 298.47) responses was longer than the reaction time in eliciting “No” (CNS - M = 1028.69; SD = 238.41; CWS - M = 1213.20; SD = 301.12) responses and this was indicated by a significant difference (CNS - t (33) = 2.67; $p<0.05$; CWS - t (33) = 3.64; $p<0.01$) between reaction time in eliciting “Yes” and “No” responses. The difference between the speed of monitoring the presence of tone in initial and medial positions was not significant (CNS - t (33) = 0.65; $p>0.05$; CWS - t (33) = 0.84; $p>0.05$) but based on mean values, it was noted that the speed of monitoring the presence of tone in initial position (CNS - M = 1118.47; SD = 242.35; CWS - M = 1370.56; SD = 367.22) was longer than in the medial position (CNS - M = 1102.22; SD = 212.88; CWS - M = 1326.15; SD = 316.91). For the control group, the speed of eliciting “No” responses in initial position (CNS - M = 1075.40; SD = 344.94) was longer than in medial position (CNS - M = 1011.17; SD = 210.18) whereas in the CWS group, the speed of eliciting “No” responses in initial position (CWS - M = 1208.28; SD = 297.53) was shorter than in medial position (CWS - M = 1215.41; SD = 320.35) but the difference between the speed of monitoring the absence of tone in initial and medial positions was not significant (CNS - t (33) = 0.12; $p>0.05$; CWS - t (67) = 2.80; $p>0.05$).

Within CWS groups, a comparison was made based on severity (mild, moderate and severe). On comparing the mean values, it was found that the tone monitoring response time to “Yes” responses was longer in children with severe stuttering followed by children with moderate and mild stuttering. For “No” responses, the reaction time was longer for children with moderate stuttering followed by children with mild and severe stuttering. Therefore, in terms of reaction time to “Yes” and “No” responses, all the three severity groups were found to be comparable but the difference between the groups in the tone monitoring response times to “Yes” (χ^2 (2) = 0.00; $p>0.05$) and “No” (χ^2 (2) = 1.61; $p>0.05$) responses was not statistically significant.

With respect to positions, children with severe stuttering took the longest time in monitoring the presence of the target tone occurring in initial position whereas children with moderate stuttering took the least time. The speed of monitoring the presence of the target tone in medial position was found to be slower among children with moderate stuttering whereas children with severe stuttering were found to be faster compared to other two groups. Children with moderate stuttering took the longest time in monitoring the absence of target tone in initial position whereas children with severe stuttering took the least time. The tone monitoring response time to "No" response in medial position was found to be longer among children with mild stuttering whereas children with severe stuttering were found to be faster compared to other two groups. However, the difference in the speed of monitoring the presence (Initial - χ^2 (2) = 1.19; p>0.05; Medial - χ^2 (2) = 0.82; p>0.05) and absence (Initial - χ^2 (2) = 1.16; p>0.05; Medial - χ^2 (2) = 1.94; p>0.05) of target tones was not significant among the three severity groups. Table 4.19 represents the mean, SD and median values of tone monitoring response times of "Yes" and "No" responses across the three severity groups. The mean, SD and median values of tone monitoring response times of "Yes" responses in both the positions across the three severity groups are represented in table 4.20. The mean, SD and median values of tone monitoring response times of "No" responses in both the positions across the three severity groups are represented in table 4.21. Figure 4.10represents the mean values for reaction time measure of auditory tone monitoring task between different severities of stuttering.

Table 4.19: *Mean, SD and Median values for reaction time measure (Yes and No responses) of auditory tone monitoring task between different severities of stuttering*

Group	**N**	**Yes Total Response**			**No Total Response**		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Mild	10	1334.71	367.53	1387.31	1229.62	327.62	1318.88
Moderate	17	1340.64	308.16	1378.66	1251.89	314.67	1213.29
Severe	7	1344.36	184.51	1310.77	1095.79	229.98	1179.08

Table 4.20: *Mean, SD and Median values for reaction time measure (Yes responses) of auditory tone monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**Yes Initial Response**			**Yes Medial Response**		
		Mean	SD	Median	Mean	SD	Median
Mild	10	1339.15	394.12	1328.89	1330.79	412.57	1330.67
Moderate	17	1332.07	358.86	1374.83	1355.62	314.59	1415.19
Severe	7	1508.90	370.26	1505.46	1247.94	153.41	1180.98

Table 4.21: *Mean, SD and Median values for reaction time measure (No responses) of auditory tone monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**No Initial Response**			**No Medial Response**		
		Mean	SD	Median	Mean	SD	Median
Mild	10	1199.23	337.83	1180.99	1252.16	341.68	1319.82
Moderate	17	1254.29	321.36	1217.17	1250.33	321.44	1245.47
Severe	7	1109.47	150.96	1095.86	1078.11	293.44	1201.71

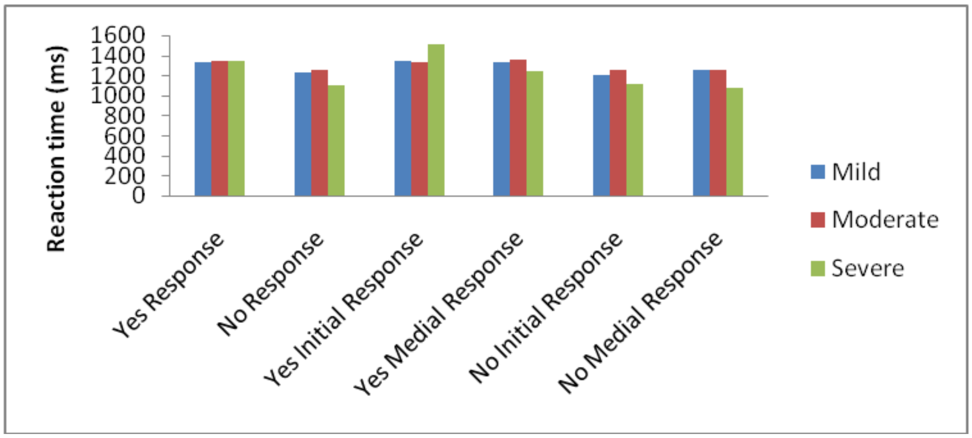

Figure 4.10: Mean values for reaction time measure of *auditory tone monitoring task between different severities of stuttering*

Comparison of accuracy of tone monitoring responses in auditory tone monitoring task across CWS and CNS and also within CWS group

Since CWS and CNS groups were not normally distributed, Mann Whitney U test was used. It showed no significant difference (|z| = 0.408; p>0.05) between both the groups in terms of accuracy measure of "Yes" responses. On comparing the mean values, it was found that CNS was found to be more accurate than CWS in eliciting "Yes" responses but it was not statistically significant. For accuracy measure of "No" responses, both the groups were comparable i.e. CWS was less accurate in eliciting "No" responses when compared to CNS but the difference was not statistically significant (|z| = 0.97; p>0.05). CWS were less accurate in monitoring the presence of target tone occurring in initial and medial positions when compared to CNS. In comparison to CNS, CWS were more accurate in eliciting "No" responses when the target tone did not occur in initial but in medial position, they were found to be less accurate. On comparing the mean values, difference was noted in the accuracy measure between the groups across both the positions but this difference was found to not significant [accuracy measure of "Yes" (initial - |z|

= 1.77; p>0.05; Medial - |z| = 0.25; p>0.05); accuracy measure of "No" (- |z| = 0.40; p>0.05; Medial - |z| = 0.26; p>0.05)]. Table 4.22, 4.23 and 4.24 represents the mean, SD and median values for percentage of error responses in auditory tone monitoring task between CNS and CWS groups with respect to "Yes" and "No" responses and across positions. Table 4.25 represents the mean rank values for accuracy measure of auditory tone monitoring task between CNS and CWS groups with respect to positions. Figure 4.11 represents the mean values for accuracy measure of auditory tone monitoring task between CNS and CWS groups

Table 4.22: *Mean, SD and Median values for accuracy measure (Yes and No responses) of auditory tone monitoring task between CNS and CWS groups with respect to positions*

Group	**N**	**Yes Total Response**			**No Total Response**		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
CNS	34	91.76	9.36	95	90.88	10.55	90
CWS	34	88.82	14.51	90	89.70	17.49	100

Table 4.23: *Mean, SD and Median values for accuracy measure (Yes responses) of auditory tone monitoring task between CNS and CWS with respect to positions*

Group	**N**	**Yes Initial Response**			**Yes Medial Response**		
		Mean	SD	Median	Mean	SD	Median
CNS	34	96.32	8.98	100	88.72	14.04	100
CWS	34	90.44	15.09	100	87.74	18.94	100

Table 4.24: *Mean, SD and Median values for accuracy measure (No responses) of auditory tone monitoring task between CNS and CWS with respect to positions*

Group	**N**	**No Initial Response**			**No Medial Response**		
		Mean	SD	Median	Mean	SD	Median
CNS	34	91.17	17.27	100	90.68	11.74	100
CWS	34	91.91	17.10	100	88.23	19.47	100

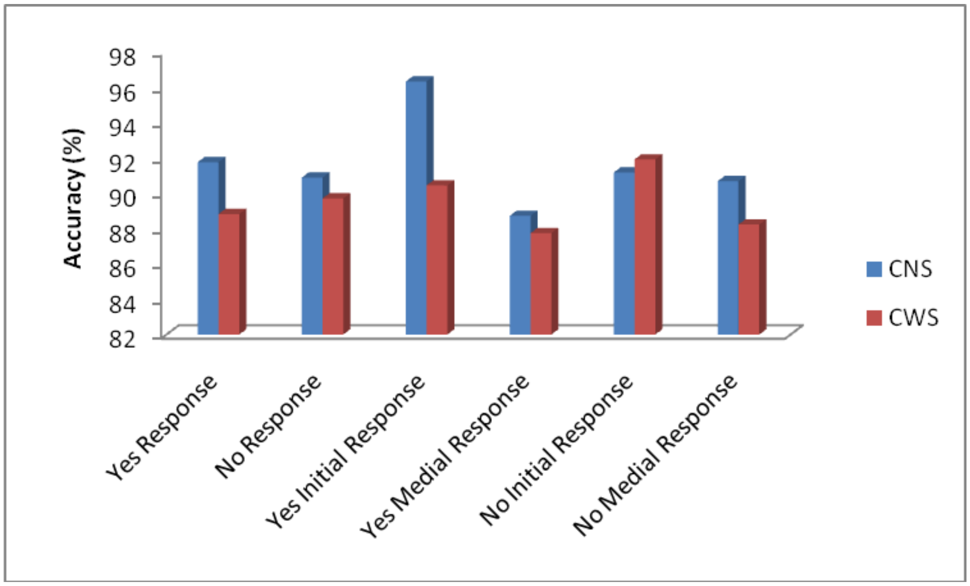

Figure 4.11: Mean values for accuracy measure of auditory tone monitoring task between CNS and CWS groups

Table 4.25: *Mean Rank values for accuracy measure of auditory tone monitoring task between CNS and CWS groups with respect to positions*

Group	N	Yes Initial Mean Rank	Yes Medial Mean Rank	No initial Mean Rank	No medial Mean Rank
CNS	34	37.65	33.97	34.03	33.91
CWS	34	31.35	35.03	34.97	35.09

The comparison was made between accuracy measure of "Yes" responses and "No" responses, accuracy measure of "Yes" responses in initial position and "Yes" responses in medial position and accuracy measure of "No" responses in initial position and "No" responses in medial position for both the groups. Wilcoxon signed rank test results indicated that significant difference was not found between accuracy measure of "Yes" and "No" responses (CNS -|z| = 2.86; p>y0.05; CWS -|z| = 4.35; p>0.05). No significant difference was found between the accuracy measure of monitoring the presence of target tone in initial and medial positions for CWS group ($|z|$ = 0.46; $p>0.05$). Significant difference was found between the accuracy measure of monitoring the presence of target tone in initial and medial positions for CNS group ($|z|$ = 2.56; $p<0.05$). Even with respect to the accuracy measure of "No" responses in initial and medial positions, significant difference was not found (CNS - $|z|$ = 0.59; $p>0.05$; CWS - $|z|$ = 1.70; $p>0.05$). On comparing the mean values, it was found that both the groups were comparable though the difference in their performance in this was not statistically significant. In CNS group, it was observed that "Yes" (M = 91.76; SD= 9.36) responses were more accurate than the "No" (M = 90.88; SD = 10.55) responses and vice versa for CWS group (Yes - M = 88.82; SD= 14.51; No - M = 89.70; SD= 17.49). Monitoring the presence of target tone in initial position (CNS- M = 96.32; SD = 8.98; CWS- M = 90.44; SD = 15.09) was found to be more accurate than in medial position (CNS - M = 88.72; SD = 14.04; CWS- M = 87.74; SD = 18.94). Monitoring the absence of target tone in initial position (CNS- M = 91.17; SD = 17.27; CWS- M = 91.91; SD = 17.10) was found to be more accurate than in medial position (CNS- M = 90.68; SD = 11.74; CWS- M = 88.23; SD = 19.47).

Within the CWS group, Kruskal Wallis test showed no significant difference among children with mild, moderate and severe stuttering in terms of accuracy measure of "Yes" (χ^2 (2) = 0.03; $p>0.05$) and "No" (χ^2 (2) = 3.22; $p>0.05$) responses. With respect to initial and medial positions, no significant difference was found among children with mild, moderate and severe stuttering in terms of accuracy measure of "Yes" (Initial - χ^2 (2) = 0.25; $p>0.05$; Medial - χ^2 (2) = 0.20; $p>0.05$) and "No" (Initial - χ^2 (2) = 2.03; $p>0.05$; Medial - χ^2 (2) = 3.26; $p>0.05$) responses. Although the difference in the performance across three groups was not significant, based on the mean values it was noted that, children with mild and severe stuttering were highly and equally accurate in eliciting "Yes" responses whereas children with moderate stuttering were found to be less accurate. In eliciting "No" responses, children with mild stuttering were found to be less accurate whereas children with severe stuttering was found to be more accurate. Across initial position, children with severe stuttering were found to be less accurate in eliciting "Yes" responses whereas children with moderate stuttering were found to be most accurate. In medial position, children with moderate stuttering were least accurate in eliciting "Yes" responses whereas children with severe stuttering were found to be highly accurate. Across initial position, children with mild stuttering were found to be less accurate in eliciting "No" responses whereas children with severe stuttering were found to be most accurate. Across medial position, children with mild stuttering were found to be less accurate in eliciting "No" responses whereas children with moderate stuttering were found to be most accurate. Table 4.26 represents the mean, SD and median values of accuracy measure of "Yes" and "No" responses for all three severity groups, table 4.27 represents the mean SD and median values of accuracy measure of "Yes" responses across both the positions for all three severity groups, table 4.28 represents the mean SD and median values of accuracy measure of "No" responses across both the positions for all three severity groups and table 4.29 represents the mean rank values for accuracy measure of auditory tone monitoring task between different severities of stuttering. Figure 4.12 represents the mean values for accuracy measure of auditory tone monitoring task between different severities of stuttering.

Table 4.26: *Mean, SD and Median values for accuracy measure (Yes and No responses) of auditory tone monitoring task between different severities of stuttering*

Group	**N**	**Yes Total Response**			**No Total Response**		
		Mean	**SD**	**Median**	**Mean**	**SD**	**Median**
Mild	10	90.00	13.33	95	84	17.76	90
Moderate	17	87.64	16.78	90	91.76	17.04	100
Severe	7	90.00	11.54	90	92.85	18.89	100

Table 4.27: *Mean, SD and Median values for accuracy measure (Yes responses) of auditory tone monitoring task between different severities of stuttering with respect to positions*

Group	**N**	**Yes Initial Response**			**Yes Medial Response**		
		Mean	SD	Median	Mean	SD	Median
Mild	10	90.00	17.48	100	90.00	16.10	100
Moderate	17	91.17	15.15	100	85.29	22.73	100
Severe	7	89.28	13.36	100	90.47	13.11	100

Table 4.28: *Mean, SD and Median values for accuracy measure (No responses) of auditory tone monitoring task between different severities of stuttering with respect to positions*

Group	N	No Initial Response			No Medial Response		
		Mean	SD	Median	Mean	SD	Median
Mild	10	87.50	17.67	100	81.66	19.95	83.33
Moderate	17	92.64	19.29	100	91.17	16.78	100
Severe	7	96.42	9.44	100	90.47	25.19	100

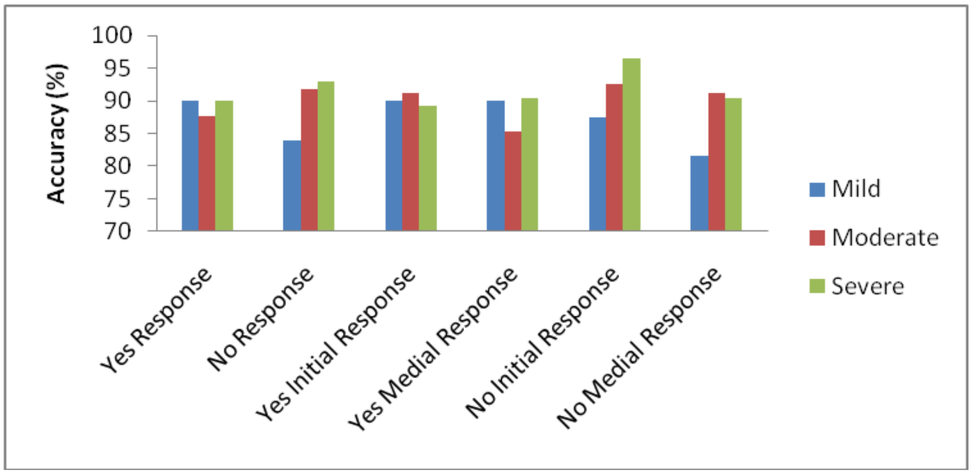

Figure 4.12: Mean values for accuracy measure of auditory tone monitoring task between different severities of stuttering

Table 4.29: *Mean Rank values for accuracy measure of auditory tone monitoring task between different severities of stuttering*

Group	N	Yes Mean rank	No Mean Rank	Yes Initial Mean Rank	Yes Medial Mean Rank	No initial Mean Rank	No medial Mean Rank
Mild	10	17.95	13.60	17.65	18.45	14.75	13.55
Moderate	17	17.32	18.59	17.97	16.88	18.41	18.68
Severe	7	17.29	20.43	16.14	17.64	19.21	20.29

Comparison between auditory tone and phoneme monitoring tasks across the groups and within CWS group

A significant main effect of tasks (F (1) = 452.89; p<0.001), response (F (1) = 4.18; p<0.05), positions (F (1) = 5.70; p< 0.05) and group (F (1) = 25.75; p<0.001) was found. It was found that there was no group influence on the tasks, response and position since no significant interaction effect was found between group and task (F (1) = 1.55; p>0.05), group and response (F (1) = 0.06; p>0.05) and group and position (F (1) = 0.47; p>0.05). No significant interaction effect was found between task, position and group (F (1) = 0.00; p>0.05), response, position and group (F (1) = 0.98; p>0.05) and task, response, position and group (F (1) = 0.42; p>0.05). Significant interaction effect was found between task and response (F (1) = 66.00; p<0.001), task and position (F (1) = 19.21; p<0.001), response and position (F (1) = 17.63; p<0.001), task, response and position (F (1) = 19.64; p<0.001) and task, response and group (F (1) = 5.02; p<0.05).

Since there is an interaction effect between task and response, task and position, response and position, task, response and position and task, response and group, further paired sample t test was carried out. Paired sample t test results indicates that there was significant difference between tone monitoring response time to "Yes" responses and phoneme monitoring response time to "Yes" responses (CNS - t (33) = 15.54; p<0.001; CWS - t (33) = 9.58; p<0.001) and tone monitoring response time to "No" responses and phoneme monitoring response time to "No" responses (CNS - t (33) = 16.59; p<0.001; CWS - t (33) = 15.66; p<0.001). Across both the positions, significant difference was found between tone monitoring response time to "Yes" responses and phoneme monitoring response time to "Yes" responses (CNS - initial - t (33) = 12.55; p<0.001; medial - t (33) = 14.01; p<0.001; CWS - initial - t (33) = 6.54; p<0.001; medial - t (33) = 9.46; p<0.001) and tone monitoring response time to "No" responses and phoneme monitoring response time to "No" responses (CNS - initial - t (33) = 11.72; p<0.001; medial - t (33) = 18.28; p<0.001; CWS - initial - t (33) = 15.82; p<0.001; medial - t (33) = 14.09; p<0.001). Therefore, both the groups have performed poorly in phoneme monitoring task compared to auditory tone monitoring task in terms of reaction time measure.

The mean values were compared and signifies that phoneme monitoring response time to "Yes" responses (CNS - M = 1738.23; SD = 233.70; CWS - M = 1974.97; SD = 318.70) were longer than tone monitoring response time to "Yes" responses (CNS - M = 1109.20; SD =

213.87; CWS - M = 1339.66; SD = 298.47).The phoneme monitoring response time to "No" responses (CNS - M = 1896.65; SD = 221.78; CWS - M = 2238.90; SD = 307.71) were longer than tone monitoring response time to "No" responses (CNS - M = 1028.69; SD = 238.41; CWS - M = 1213.20; SD = 301.12). Across both the positions, the speed of monitoring the presence of target tone (CNS - Initial – M = 1118.47; SD = 242.35, Medial – M = 1102.22; SD – 212.88; CWS - Initial – M = 1370.56; SD = 367.22, Medial – M = 1326.15; SD – 316.91) was faster than the monitoring speed of presence of the target phonemes (CNS - Initial – M = 1635.59; SD = 206.74, Medial – M = 1870.70; SD – 356.89; CWS - Initial – M = 1879.17; SD = 310.14, Medial – M = 2129.32; SD – 482.49). The reaction time in eliciting "No" responses in phoneme monitoring task (CNS - Initial – M = 1914.36; SD = 239.00, Medial – M = 1877.92; SD – 232.67; CWS - Initial – M = 2237.10; SD = 327.16, Medial – M = 2238.41; SD – 335.76) was found to be slower when compared to reaction time in eliciting "No" responses in auditory tone monitoring task (CNS - Initial – M = 1075.40; SD = 344.94, Medial – M = 1011.17; SD – 210.18; CWS - Initial – M = 1208.28; SD = 297.53, Medial – M = 1215.41; SD – 320.25). This finding indicates that both the groups performed poorly in phoneme monitoring task compared to auditory tone monitoring task.

To compare the performance within CWS group based on their severity, Wilcoxon signed rank test was used. Among children with mild stuttering, significant difference was found between tone monitoring response time to "Yes" responses and phoneme monitoring response time to "Yes" responses ($|z| = 2.80$; $p<0.01$), tone monitoring response time to "No" responses and phoneme monitoring response time to "No" responses ($|z| = 2.80$; $p<0.01$) and also with respect to both the positions (yes initial - $|z| = 2.49$; $p<0.05$; yes medial - $|z| = 2.80$; $p<0.01$; no initial - $|z| = 2.80$; $p<0.01$; no medial - $|z| = 2.80$; $p<0.01$). Among the participants from the mild group, they took longer time in monitoring the presence of target phonemes (M = 2047.03; SD = 318.87) when compared to tone monitoring response time (M = 1334.71; SD = 367.53). Their phoneme monitoring response time to "No" responses (M = 2321.11; SD = 330.23) was more than their tone monitoring response time to "No" responses (M = 1229.62; SD = 327.62). Their phoneme monitoring response time to "Yes" responses in initial position (M = 1934.21; SD = 326.22) was more than their tone monitoring response time to "Yes" responses in initial position (M = 1339.15; SD = 394.12). Their phoneme monitoring response time to "Yes" responses in medial position (M = 2197.42; SD = 333.82) was more than their tone monitoring response time to “Yes” responses in medial position (M = 1330.79; SD = 412.57). Their phoneme monitoring response time to “No” responses in initial position (M = 2333.02; SD = 378.99) was more than their tone monitoring response time to “No” responses in initial position (M = 1199.23; SD = 337.83). Their phoneme monitoring response time to “No” responses in medial position (M = 2317.74; SD = 307.76) was more than their tone monitoring response time to “No” responses in medial position (M = 1252.16; SD = 341.68).

Among children with moderate stuttering, significant difference was found between tone monitoring response time to “Yes” responses and phoneme monitoring response time to “Yes” responses (|z| = 3.62; $p < 0.001$), tone monitoring response time to “No” responses and phoneme monitoring response time to “No” responses (|z| = 3.62; $p < 0.001$) and also with respect to both the positions (“Yes” initial - |z| = 3.52; $p < 0.001$; “Yes” medial - |z| = 3.29; $p < 0.001$; “No” initial - |z| = 3.62; $p < 0.01$; “No” medial - |z| = 3.62; $p < 0.01$). Among the participants from the moderate group, they took longer time in monitoring the presence of target phonemes (M = 2017.53; SD = 327.92) when compared to tone monitoring response time (M = 1340.64; SD = 308.16). Their phoneme monitoring response time to “No” responses (M = 2270.89; SD = 313.18) was more than their tone monitoring response time to “No” responses (M = 1251.89; SD = 314.67). Their phoneme monitoring response time to “Yes” responses in initial position (M = 1937.59; SD = 308.46) was more than their tone monitoring response time to “Yes” responses in initial position (M = 1332.07; SD = 358.86). Their phoneme monitoring response time to “Yes” responses in medial position (M = 2165.84; SD = 599.36) was more than their tone monitoring response time to “Yes” responses in medial position (M = 1250.33; SD = 321.44). Their phoneme monitoring response time to “No” responses in initial position (M = 2246.72; SD = 319.76) was more than their tone monitoring response time to “No” responses in initial position (M = 1254.29; SD = 321.36). Their phoneme monitoring response time to “No” responses in medial position (M = 2165.84; SD = 599.36) was more than their tone monitoring response time to “No” responses in medial position (M = 1355.62; SD = 314.59).

Among children with severe stuttering, significant difference was found between tone monitoring response time to “Yes” responses and phoneme monitoring response time to “Yes” responses (|z| = 2.19; $p < 0.05$), tone monitoring response time to “No” responses and phoneme monitoring response time to “No” responses (|z| = 2.36; $p < 0.05$), tone monitoring response time to “Yes” responses in medial position and phoneme monitoring response time to “Yes” responses in medial position (|z| = 2.19; $p < 0.05$), tone monitoring response time to "No" responses in both positions and phoneme monitoring response time to "No" responses in both positions (initial - |z| = 2.36; $p < 0.05$; medial – |z| = 2.3; $p < 0.05$). No significant difference was found between tone monitoring response time to "Yes" responses in initial position and phoneme monitoring response time to "Yes" responses in initial position (|z| = 1.01; $p > 0.05$). Among the participants from the severe group, they took longer time in monitoring the presence of target phonemes (M = 1768.66; SD = 236.27) when compared to tone monitoring response time (M = 1344.36; SD = 184.51). Their phoneme monitoring response time to "No" responses (M = 2043.77; SD = 192.50) was more than their tone monitoring response time to "No" responses (M = 1095.79; SD = 229.98). Their phoneme monitoring response time to "Yes" responses in initial position (M = 1658.64; SD = 210.65) was more than their tone monitoring response time to "Yes" responses in initial position (M = 1508.90; SD = 370.26). Their phoneme monitoring response time to "Yes" responses in medial position (M = 1943.37; SD = 321.54) was more than their tone monitoring response time to "Yes" responses in medial position (M = 1247.94; SD = 153.41). Their phoneme monitoring response time to "No" responses in initial position (M = 2076.70; SD = 234.42) was more than their tone monitoring response time to "No" responses in initial position (M = 1109.47; SD = 150.96). Their phoneme monitoring response time to "No" responses in medial position (M = 2014.50; SD = 194.37) was more than their tone monitoring response time to "No" responses in medial position (M = 1078.11; SD = 293.44).

In terms of accuracy measure, Wilcoxon signed rank test results for the CWS group revealed significant difference between accuracy measure of "Yes" responses in auditory tone monitoring task and accuracy measure of "Yes" responses in phoneme monitoring task (|z| = 3.17; $p<0.01$), accuracy measure of "No" responses in auditory tone monitoring task and accuracy measure of "No" responses in phoneme monitoring task (|z| = 2.90; $p<0.01$) and also with respect to positions ("Yes" medial - |z| = 3.70; $p<0.001$; "No" initial - |z| = 4.01; $p<0.001$; No medial - |z| = 1.83; $p<0.05$). Significant difference was not found between "Yes" responses with respect to initial position in auditory tone monitoring task when compared to "Yes" responses with respect to initial position in phoneme monitoring task ("Yes" medial - |z| = 1.79; $p>0.05$). For the CNS group, significant difference was not found between accuracy measure of "Yes" responses in auditory tone monitoring task and accuracy measure of "Yes" responses in phoneme monitoring task (|z| = 1.34; $p>0.05$), accuracy measure of "No" responses in auditory tone monitoring task and accuracy measure of "No" responses in phoneme monitoring task (|z| = 0.85; p>0.05) and also with respect to positions ("Yes" initial - |z| = 1.41; p>0.05; "Yes" medial - |z| = 1.66; p>0.05; "No" initial - |z| = 1.58; p>0.05; "No" medial - |z| = 0.06; p>0.05).

Based on the mean values, the participants were more accurate in monitoring the presence of target tone (CNS - M = 91.76; SD= 9.36; CWS - = 88.82; SD= 14.51) when compared to phonemes (CNS - M = 86.59; SD= 11.00; CWS - = 71.79; SD= 18.39). They were more accurate in monitoring the absence of target tone (CNS - M = 90.88; SD= 10.55; CWS - = 89.70; SD= 17.49) when compared to phonemes (CNS - M = 89.35; SD= 8.59; CWS - = 78.46; SD= 16.86). In initial position, they were more accurate in monitoring the presence of target tone (CNS - M = 96.32; SD= 8.98; CWS - = 90.44; SD= 15.09) when compared to phonemes (CNS - M = 92.04; SD= 8.30; CWS - = 83.39; SD= 15.22). In medial position, they were more accurate in monitoring the presence of target tone (CNS - M = 88.72; SD= 14.04; CWS - = 87.74; SD= 18.94) when compared to phonemes (CNS - M = 81.14; SD= 16.11; CWS - = 60.20 SD= 24.66). Even in initial position, they were more accurate in eliciting "No" responses (CNS - M = 91.17; SD= 17.27; CWS – M = 91.91; SD= 17.10) in auditory tone monitoring task when compared to phoneme monitoring task (CNS - M = 87.71; SD= 10.96; CWS – M = 74.74; SD= 19.77). But in the medial position, CNS were more accurate in eliciting "No" responses in phoneme monitoring task (M = 91.00; SD= 9.18) compared to auditory tone monitoring task (M = 90.68; SD= 11.74) whereas CWS were more accurate in eliciting "No" responses in auditory tone monitoring task (M = 88.23; SD= 19.47) compared to phoneme monitoring task (M = 82.17; SD= 15.56). Therefore, both the groups performed more accurately in auditory tone monitoring task compared to phoneme monitoring task except for accuracy measure of "No" responses in medial position.

To compare the performance within CWS group based on their severity, Wilcoxon signed rank test was used. Among children with mild stuttering, significant difference was not found between accuracy measure of "Yes" responses in auditory tone monitoring task and accuracy measure of "Yes" responses in phoneme tone monitoring task (|z| = 1.58; p> 0.05), accuracy measure of "No" responses in auditory tone monitoring task and accuracy measure of "No" responses in phoneme tone monitoring task (|z| = 0.66; p> 0.05) and also with respect to both the positions ("Yes" initial - |z| = 1.01; p> 0.05; "Yes" medial - |z| = 1.88; p> 0.05; "No" initial - |z| = 1.58; p> 0.05; "No" medial - |z| = 0.29; p> 0.05). Within the mild group, the participants were more accurate in eliciting “Yes” responses (M = 90.00; SD = 13.33) in auditory tone monitoring task when compare to phoneme monitoring task (M = 76.47; SD = 19.85). In initial position, the participants were more accurate in eliciting “Yes” responses (M = 90.00; SD = 17.48) in auditory tone monitoring task when compare to phoneme monitoring task (M = 85.88; SD = 19.64). In medial position, the participants were more accurate in eliciting “Yes” responses (M = 90.00; SD = 16.10) in auditory tone monitoring task when compare to phoneme monitoring task (M = 67.05; SD = 21.69). In initial and medial positions, the participants were more accurate in eliciting “No” responses (initial- M = 87.50; SD = 17.67; medial - M = 81.66; SD = 19.95) in auditory tone monitoring task when compare to phoneme monitoring task (initial - M = 71.17; SD = 22.08, medial - M = 78.23; SD = 21.48).

Among children with moderate stuttering, significant difference was found between accuracy measure of “Yes” responses in auditory tone monitoring task and accuracy measure of “Yes” responses in phoneme tone monitoring task ($|z|$ = 2.39; $p < 0.05$), accuracy measure of “No” responses in auditory tone monitoring task and accuracy measure of “No” responses in phoneme tone monitoring task ($|z|$ = 2.86; $p < 0.001$) and also with respect to both the positions (“Yes” medial - $|z|$ = 2.62; $p < 0.001$; “No” initial - $|z|$ = 3.36; $p < 0.001$; “No” medial - $|z|$ = 2.73; $p<0.001$). But in initial position, significant difference was not found between accuracy measure of “Yes” responses in auditory tone monitoring task and accuracy measure of “Yes” responses in phoneme monitoring task (“Yes” initial - $|z|$ = 1.24; $p> 0.05$). Within the moderate group, the participants were more accurate in eliciting “Yes” responses (M = 87.64; SD = 16.78) in auditory tone monitoring task when compared to phoneme monitoring task (M = 68.51; SD = 17.26). In initial position, the participants were more accurate in eliciting “Yes” responses (M = 91.17; SD = 15.15) in auditory tone monitoring task when compare to phoneme monitoring task (M = 85.29; SD = 22.73). In medial position, the participants were more accurate in eliciting “Yes” responses (M = 85.29; SD = 22.73) in auditory tone monitoring task when compare to phoneme monitoring task (M = 54.67; SD = 24.05). In initial and medial positions, the participants were more accurate in eliciting “No” responses (initial- M = 92.64; SD = 19.29; medial - M = 91.17; SD = 16.78) in auditory tone monitoring task when compare to phoneme monitoring task (initial - M = 91.17; SD = 16.78, medial - M = 82.35; SD = 13.63).

Among children with severe stuttering, significant difference was not found between accuracy measure of “Yes” responses in auditory tone monitoring task and accuracy measure of

“Yes” responses in phoneme tone monitoring task ($|z| = 1.35$; $p > 0.05$), accuracy measure of “No” responses in auditory tone monitoring task and accuracy measure of “No” responses in phoneme tone monitoring task ($|z| = 1.35$; $p > 0.05$) and also with respect to both the positions (“Yes” initial - $|z| = 0.84$; $p > 0.05$; “Yes” medial - $|z| = 1.78$; $p > 0.05$; “No” medial - $|z| = 0.94$; $p > 0.05$) except “No” initial - $|z| = 1.99$; $p < 0.05$. Within the severe group, the participants were more accurate in eliciting “Yes” responses (M = 90.00; SD = 11.54) in auditory tone monitoring task when compare to phoneme monitoring task (M = 73.10; SD = 20.12). In initial position, the participants were more accurate in eliciting “Yes” responses (M = 89.28; SD = 13.36) in auditory tone monitoring task when compare to phoneme monitoring task (M = 82.35; SD = 10.73). In medial position, the participants were more accurate in eliciting “Yes” responses (M = 90.47; SD = 13.11) in auditory tone monitoring task when compare to phoneme monitoring task (M = 63.86; SD = 30.26). In initial and medial positions, the participants were more accurate in eliciting “No” responses (initial- M = 96.42; SD = 9.44; medial - M = 90.47; SD = 25.19) in auditory tone monitoring task when compare to phoneme monitoring task (initial - M = 76.47; SD = 18.60, medial - M = 87.93; SD = 13.41).

Comparison between simple motor and phoneme monitoring tasks across the groups and within CWS group

Wilcoxon signed rank test results significant difference between the participants’ performances in simple motor task and phoneme monitoring task in terms of reaction time (CNS - $|z| = 5.08$; $p < 0.001$; CWS - $|z| = 5.08$; $p < 0.001$) and accuracy measures (CNS - $|z| = 4.85$; $p < 0.001$; CWS - $|z| = 5.05$; $p < 0.001$). This finding signified that the participants of both the groups were found to be slow in responding in phoneme monitoring task (CNS - M = 2102.35; SD = 271.70; CWS - M = 1817.58; SD = 381.79) when compared to simple motor task (CNS - M = 502.23; SD = 229.49; CWS - M = 381.79; SD = 128.80). In terms of accuracy measure, the participants of both the groups performed more accurately in simple motor task (CNS - M = 99.41; SD = 1.91; CWS - M = 98.23; SD = 3.40) when compared to phoneme monitoring task (CNS - M = 87.97; SD = 8.57; CWS - M = 75.12; SD = 14.30). Therefore, both the groups performed accurately and faster in simple motor task compared to phoneme monitoring task.

Among children with mild stuttering, the difference between the performances in phoneme monitoring and simple motor tasks was found to be significant in terms of reaction time (|z| = 2.80; p<0.01) and accuracy measures (|z| = 2.80; p<0.01). On comparing the mean values, it was found that their reaction time was longer (M = 2168.55; SD = 295.24) and less accurate (M = 75.88; SD = 19.63) in phoneme monitoring task when compared to simple motor task (reaction time measure- M = 418.67; SD = 195.31; accuracy measure- M = 98.66; SD = 2.81). Among children with moderate stuttering, the difference between the performances in phoneme monitoring and simple motor tasks was found to be statistically significant in terms of reaction time (|z| = 3.62; p<0.001) and accuracy measures (|z| = 3.57; p<0.001). On comparing the mean values, it was found that their reaction time was longer (M = 2139.05; SD = 261.18) and less accurate (M = 73.96; SD = 12.81) in phoneme monitoring task when compared to simple motor task (reaction time measure- M = 560.87; SD = 224.60; accuracy measure- M = 97.64; SD = 4.04). Among children with severe stuttering, significant difference was found between performances in simple motor task and phoneme monitoring task with respect to reaction time (|z| = 2.36; p<0.05) and accuracy measures (|z| = 3.57; p<0.05). This was indicated by comparing the mean values and it showed that they took shorter time to respond (M = 479.20; SD = 275.54) and also were more accurate (M = 99.04; SD = 2.51) in simple motor task when compared to phoneme monitoring task (reaction time measure- M = 1918.64; SD = 207.04; accuracy measure- M = 76.89; SD = 10.03).

To summarize, in simple motor task CWS took longer time to respond to onset of the target tone when compared to CNS and the difference in their performances was statistically significant. In terms of accuracy measure, CNS was more accurate than CWS but the difference was not statistically significant. The same trend was observed in auditory tone monitoring task. In phoneme monitoring task, CWS was found to be slow in monitoring the presence and absence of the target phoneme when compared to CNS. CWS was also found to be less accurate when compared to CNS. This was highlighted by statistical significance between both the groups in terms of reaction time and accuracy measures. In terms of reaction time and accuracy measures, CWS and CNS performed poorly in phoneme monitoring task when compared to auditory tone monitoring task.

Chapter V

DISCUSSION

The present study investigated the phonological encoding abilities of children who stutter and do not stutter using the phoneme monitoring process in the silent naming task. In specific, the reaction time and accuracy measures of the participants' responses were measured in three tasks such as simple motor task, auditory tone monitoring and phoneme monitoring tasks and comparison was made between the groups and within CWS group. The performances of CWS and CNS groups and CWS group alone were compared between the tasks such as phoneme and auditory tone monitoring tasks; simple motor and phoneme monitoring tasks. The results are discussed below.

Performance of CWS and CNS in Simple Motor Task

The reaction times of manual responses were found to be longer among CWS when compared to CNS and the differences in their performances were significant. The findings of the present study was supported by neuroimaging studies and studies involving non-verbal motor tasks. According to neuroimaging studies, Olander, Smith and Zelanik (2010) found that speech and nonspeech motor timing share a common neural substrate and the abnormalities in this shared neural substrate could lead to generalized motor control deficit. This generalized motor control deficit was considered as one of the causal factors for the occurrence of dysfluencies among individuals with stuttering. Luper and Crossf (1978) also found that PWS have a general motoric deficit which slowed their manual reaction time. Slowed manual reaction time could also be because of the additional muscular tension. Studies related to nonverbal motor tasks indicated that the adults who stutter were found to have a delay in motor initiation and increased motor execution times when compared to adults who do not stutter (Borden, 1983; Hulstijn et al., 1992). Timing deficits during auditory motor coupling tasks was observed among children and adolescence who stutter (Falk, Muller & Bella, 2015). Falk, Muller & Bella (2015) found that CWS have difficulties in sensorimotor synchronization compared to CNS. They suggested that stuttering is related to timing deficits found in the nonverbal domain. Among PWS, decreased accuracy was found during bimanual finger coordination tasks (Zelaznik et al., 1997) and self-paced tapping (Cooper & Allen, 1977). Persons who stutter performed poorly in synchronizing with a rhythmic auditory stimulus such as a metronome when compared to persons who do not stutter. This implies that among PWS, basal ganglia (BG) and supplementary motor area (SMA) (Goldberg, 1985), failed to produce 'internal' timing cues for the perception of beats.

On the contrary, Sasisekaran, Brady and Stein (2013) found no significant difference in the speed of motor responses between CWS and CNS groups. Though there was no significant difference between the groups, the CWS group were found to be slower than the CNS group. With respect to the accuracy measure of the present study, a significant difference was not found between CWS and CNS groups. CWS had followed the same trend as CNS though they experience a delay in initiating their simple manual responses. Therefore, in the present study, CWS may have generalized motor control deficit that is nonspeech and speech motor timing deficits since they experience deficits in the timing domain only. Thus in terms of accuracy measure, it was found that there was no influence of the participants' simple manual responses on their performance in auditory and phoneme monitoring tasks.

Performance of CWS and CNS in Auditory tone monitoring Task

In the present study, CWS were found to be slow in eliciting "Yes" and "No" responses for the presence/absence of auditory tone when compared to CNS. This was indicated by a significant difference between CWS and CNS groups in tone monitoring response time to "Yes" and "No" responses. Children who stutter were found to be slower in eliciting "Yes" and "No" responses across initial and medial positions when compared to children who do not stutter. Across both the positions, a significant difference was found between CWS and CNS groups in tone monitoring response time to "Yes" responses. Across the initial position, a significant difference was not found between CWS and CNS groups in tone monitoring response time to "No" responses whereas, in medial position, a significant difference was found. The observed differences in this task were dependent on the differences in simple motor responses which were considered as an inherent component of auditory tone monitoring task.

With respect to accuracy measure of "Yes" and "No" responses, the findings of the present study indicated no significant difference between the groups but the performances were comparable between CWS and CNS groups. With respect to initial and medial positions, the difference between both the groups in tone monitoring response time to "Yes" and "No" responses were found to be not significant. Similarly, Sasisekaran, Brady and Stein (2013) found no significant difference in the percentage of errors in eliciting "Yes" and "No" responses between CWS and CNS groups. Therefore, CWS of the present study had difficulties in monitoring tones specifically in the timing domain. The delay in auditory tone monitoring skills was not accompanied by a reduced percentage of errors. Better performance observed in terms of accuracy could be attributed to their effective working memory skills (Hampton & Weber Fox, 2008).

On comparing "Yes" and "No" responses, both the groups (CNS and CWS) took a longer time in eliciting "Yes" responses when compared to "No" responses. In terms of timing domain, both the groups followed a similar trend but the reaction time of both the responses was more for CWS than the CNS group. In terms of accuracy, the CNS group was more accurate in eliciting "Yes" responses when compared to "No" responses whereas the CWS group was more accurate in eliciting "No" responses when compared to "Yes" responses. Though the CWS group took longer time in monitoring the presence of target tone (1KHz), they were found to be less accurate in eliciting "Yes responses. Therefore, the CWS group of the present study did not exhibit speed-accuracy trade-off strategy since the slow tone monitoring reaction time was not accompanied by a reduced percentage of error rate. The speed-accuracy trade-off was exhibited by CNS group since the increased reaction time to "Yes" responses were accompanied by reduced percentage of error rate i.e. they were more accurate in eliciting "Yes" responses because they took a longer time as a result of repeated monitoring to confirm their "Yes" responses.

The reasons which could be attributed to longer reaction time and less accurate score obtained for eliciting "Yes" responses among CWS are as follows: They would have allocated more attention resources required for processing the target tone. They might have done repeated monitoring to confirm the response or the neural representation of the target tone would have less robust or they might have experienced difficulty in updating the working memory in response to the target tone or they would have been less sensitive to notice the change in the presented tone sequence or they would have poor memory traces of the target tone which was presented before presenting the tone sequence (Hampton & Weber Fox, 2008). They were fast in eliciting "No" responses because it was easier to determine the absence of the target tone and also both the tones in the tone sequence were similar.

Both the groups (CNS and CWS) took a longer time in eliciting "Yes" responses when tone occurred in initial when compared to medial position. But for "No" responses, the CNS group took a longer time in monitoring the absence of target tone in initial position whereas the CWS group took longer time in monitoring the absence of target tone occurring in medial position. The monitoring response time was more among CWS when compared to CNS though, a similar trend pattern was observed for “Yes” responses. Thus CWS were found to experience a delay in monitoring tones but not deviant from the CNS group with respect to “Yes” responses across positions. But for “No” responses across positions, CWS were found to experience a delay in monitoring tones and the trend was deviant from the CNS group. With respect to accuracy measure across positions, the CWS and CNS groups were more accurate in eliciting “Yes” responses when tone occurred in the initial position when compared to medial position. In eliciting “No” responses, both the groups were more accurate in responding when the tone did not occur in the initial position when compared to the medial position. They paid more attention in identifying whether the first tone in the tone sequence matches the initial presentation of the target tone or not and so they were more accurate in detecting the presence or absence of target tone in the initial position. Despite observing a similar trend pattern concerning positions, the percentage of error response was less for CWS when compared to CNS. Therefore, CWS were found to be less accurate in monitoring the tone but not deviant from CNS.

The findings of the present study are in partial agreement with findings of Sasisekaran, Brady and Stein (2013)’s study. They also found that children who stutter (aged between 10 and 14 years of age) were found to be slower in eliciting “Yes” and “No” responses when compared to children who do not stutter but the difference in the performance of two groups was not statistically significant. Across the four positions, the difference in the monitoring response times between CWS and CNS was not statistically significant but in the present study, a significant difference was found with respect to positions. The CWS of their study took a longer time in eliciting “No” responses when compared to “Yes” responses. With respect to accuracy measure of “Yes” and “No” responses, a significant difference was not found between CWS and CNS but on comparing the mean values, they noted that the performance of CWS in this task was found to be less accurate when compared to CNS. They also found that a significant difference was not found between the accuracy measure of “Yes” and “No” responses for CWS and CNS groups. The findings of the present study are congruous with the findings of Sasisekaran et al. (2006) study where AWS and ANS groups took shorter time in monitoring the presence of target tone occurring in the initial position when compared to medial and final positions. This finding suggests that the reaction time for monitor the target tones was sensitive to left to right positioning of the tones within the presented tone sequence. Therefore, the CWS and CNS groups of the present study had followed the sequential processing of tones when the tone sequence was presented.

There are very few studies reported in the literature regarding the performance of children who stutter in non-linguistic auditory processing tasks. The CWS group of the present study experienced delayed motor initiation and execution times while monitoring non-linguistic stimuli such as pure tones. This may imply that they could have brain stem timing deficits. Goncalves, Regina, Andrade and Matas (2015) stated that brain stem timing deficits in the CWS group may lead to poor performance in cortical processing of acoustic information. Barasch, Guitar, McCauley and Absher (2000) reported that the functional organization of the auditory cortices was found to be different in AWS when compared to fluent adult speakers. Hampton and Weber Fox (2008) found that the majority of the participants from the AWS group were fast and more accurate in responding to the target stimuli. Their performance was similar to the participants from the ANS group. But a subset of AWS was found to be slow and less accurate in responding to the target stimuli in pure tone oddball paradigm like that of children who stutter. Even for simple tonal stimuli, few of the participants belonging to the AWS group exhibited auditory processing deficits when compared to fluent adult speakers. Majority of AWS who detected the target tone with faster reaction time and high accuracy rate were found to have a larger amplitude of early cortical potentials $N100_S$, $N100_T$ and P200. This is because they had a more robust representation of the target stimulus in the auditory system. But for the subset of AWS, the amplitude of these cortical potentials was reduced. As a result of this, they had a weak representation of the target tone in the auditory system which in turn may have facilitated slower and less accurate behavioral measures. This trend pattern was not observed in fluent speakers since all the participants from the ANS group and had a larger amplitude of early cortical potentials. The P300 amplitude was reduced for all the participants belonging to the AWS group when compared to the ANS group. It is said that reduced P300 amplitude is related to poor orienting response, weak internal neural representations and lack of attentional resources in the auditory processing system required for detecting the target tone. Fluent speakers had a larger P300 amplitude which in turn had enhanced their working memory performance attributing to faster reaction time and high accuracy rate. But AWS were found to be inefficient in updating the working memory in response to the target tone. The performance of AWS was found to be heterogeneous in non-linguistic auditory processing task. Hence, the CWS group of the present study could have been inefficient in enhancing their working memory performance in response to the target tone or the representation of the target tone in the auditory system would have been less salient or they might have experienced difficulties in orienting or advocating attention resources to respond to the target tone. All the other above mentioned factors can also be attributed to their delayed reaction time and less accurate behavioral measures in auditory tone monitoring tasks.

In the year 2010, Kaganovich, Hampton and Weber Fox found no difference in the early cortical potentials P1 and N1 between CWS and CNS in response to pure tones. They also found no difference between CWS and CNS in the MMN task i.e. to change in pure tone. This is because the neural processes involved in creating and maintaining a memory trace for recently presented stimulus and also for detecting stimulus change were efficient for CWS and CNS groups. Among children who stutter, the authors observed that deviant tones failed to elicit P3. This finding implies that processes involved in allocating attention resources and updating the working memory in response to stimulus change were found to be less robust in CWS. This finding is incongruous with the findings of Hampton and Weber Fox (2008)'s study and also supports the finding of the present study. The heterogeneity of the performance in the auditory tone monitoring task was also observed among children who stutter. The multifactorial model of stuttering (Smith, Kelly, Curlee & Siegel, 1997) assumes that with respect to different factors' contribution to stuttering, the factors are weighed heterogeneously in different individuals. Thus this model supports the inconsistencies in the literature stating that children who stutter experience auditory processing difficulties in terms of timing domain.

Sussman and Mac Neilage (1975) found that persons who stuttered experienced difficulties in integrating auditory information with the motor output. They have difficulties in detecting the change in the frequency of the target tone. Thus, the CWS group of the present study must have faced the same problem which had led to poor performance in this task when compared to CNS. PWS were found to be poor in detecting the presence of auditory targets. Neilson and Neilson (1987) suggested that they were slow in developing a mental auditory-motor model of the relationship between their movements of the cursor control (i.e. pressing the cursor) and the resulting sound change (i.e. detecting the presence of target tone). Nudelman et al. (1992) measured how quickly PWS could change their humming to match the changing pitch of the auditory target tone. They observed that PWS were slow in detecting the changes in the target's frequency when compared to fluent speakers. This implies that they need more time to process auditory signals. Thus PWS were found to have difficulty in performing auditory processing tasks.

Performance of CWS and CNS in phoneme monitoring Task

In the present study, CWS were found to be slow in eliciting "Yes" and "No" responses when compared to CNS and also across initial and medial positions. This was indicated by a significant difference found between CWS and CNS groups. This finding proves that children who stutter experience difficulties to encode phonologic units. The central capacity required for this task was assumed to be reduced among CWS which in turn impedes their performance in phoneme monitoring task (Neilson & Neilson, 1987). In this task, the differences observed in terms of timing domain were dependent on the differences in simple motor responses which were considered as an inherent component of the phoneme monitoring task. The speed of monitoring to elicit "Yes" and "No" responses were found to be slow in the CWS group of the present study. This implies that to make a "Yes" decision, children who stutter experience a delay in achieving a higher activation level of the target phoneme. It can be assumed that when they hear the target phoneme, they tend to perform a post lexical search strategy in order to confirm the response which explains the delay. To make a "No" decision, it can be assumed that there is a delay in retrieving and activating the phonemes present in the name of the target picture. The findings of Sasisekaran, Brady and Stein (2013) study is in partial agreement with the findings of the present study where the participants from their CWS group were found to be slow in eliciting "Yes" responses only. In the present study, the "Yes" and "No" responses were minimally affected by prediction bias (since the target picture is presented twice, the response obtained in the first encounter could predict the response on the second encounter) whereas in Sasisekaran et al. (2013) study, the "Yes" responses were minimally affected and "No" responses were affected to a maximum extent. In Sasisekaran et al. (2013) study, children who stutter do not have general monitoring deficits whereas they have deficits in specific to phonological encoding process. On the contrary, the CWS group of the present study experience general monitoring and phonological encoding deficits. This finding is supported by another study by Darshini and

Swapna (2015) where they found that Kannada AWS experienced a delay in encoding phonologic codes of their own speech and also in the speech generated by others. So they also experience delays in the auditory perception task. Therefore, AWS had deficits in both phonological encoding and general monitoring abilities.

Many models and theories support the findings of the present study that the monitoring time of children who stutter were slow when compared to children who do not stutter. EXPLAN theory (Howell, 2004) states that children tend to stutter when there is a temporal asynchrony in encoding phonologic codes during motor planning and execution. Based on WEAVER $^{++}$ model (Ramus et al., 2010), it can be stated that the CWS group of the present study may have experienced a delay in activating and retrieving the required phonologic codes at the lexical level. According to influential model (Dell, 1986), children who stutter take a longer time to activate the appropriate phonologic segment nodes which leads to delay in the generation of phonologic elaboration of the metrical frame. This explains the slow monitoring time observed among children who stutter in the current study. Based on the neurolinguistic model, Perkins, Kent and Curlee (1991) attributed the present study's finding to inefficiency in processing segmental units which are commonly observed among children who stutter. The spreading activation model [Dell, 1986; Dell & O' Seaghdha, 1991] supports the findings of the present study that among children who stutter, the time taken for the target phonologic units to reach the highest level of activation was found to be delayed when compared to children who do not stutter. Children who stutter tend to be hyper-vigilant in monitoring the errors in their motor plan and the threshold to initiate covert repairs was reported to be less (vicious circle hypothesis; Vasic & Wijnen, 2005). Thus, this reason could be accounted for slow reaction time in monitoring the target phonemes which was observed among the CWS group of the present study when compared to CNS.

A significant difference was found between CWS and CNS groups in terms of phoneme monitoring accuracy measure of “Yes” and “No” responses and also across initial and medial positions. The percentage of errors in eliciting “Yes” and “No” responses were found to be more among CWS when compared to CNS. The same was observed across both the positions. On the contrary, Sasisekaran, Brady and Stein (2013) found that both the groups were comparable in the accuracy measure of “Yes” and “No” responses but the difference was not statistically significant. They reported that the participants of their CWS group experienced encoding difficulties in time domain only and it was not accompanied by a reduced error rate. But in the present study, for the CWS group, the slow monitoring time was accompanied by an increased error rate.

The findings of the present study are incongruous with the findings of Darshini and Swapna (2015). AWS performed poorly in phoneme monitoring task when compared to ANS. This was indicated by observing a significant difference between both the groups with respect to reaction time and accuracy measures. The AWS group took a longer time in eliciting “Yes” responses when compared to the ANS group. They were also less accurate in eliciting “Yes” responses. They had attributed this finding to the mismatch between the activation levels and the retrieval of the phonemes. Even in their study, AWS performed poorly in monitoring the phonemes occurring in initial, medial and final positions when compared to ANS. Among AWS, they found that they took longer time in monitoring the presence of phoneme occurring in initial, medial and final positions but they were found to be less accurate in monitoring the phonemes occurring in medial and final positions. Thus for AWS, increased reaction time was accompanied by a reduced error rate during monitoring the presence of target phoneme in initial position. According to the covert repair hypothesis (Kolk & Postma, 1997) and spreading activation model (Dell, 1986; Dell & O’ Seaghdha, 1991) rationales, the initial syllable gets activated appropriately though it gets activated slowly. But there is a deficit in encoding the remaining portion of the word in their own formulated speech since the time taken to activate the medial and final syllables was found to be slow which was accompanied with diminished accuracy.

Sasisekaran et al. (2006) also found that AWS were found to be faster and more accurate in encoding the phonemes occurring in the initial position when compared to medial and final positions. This implies that they were sensitive to the sequential encoding of speech. AWS performed poorly in phoneme monitoring task when compared to ANS. This group difference was attributed to the difficulties faced by AWS in storing and retrieving the speech plan from the speech buffer as opposed to delays in the activation and selection of phonemes during phonological encoding.

Many models and theories support the findings of the present study that children who stutter were less accurate in self-monitoring skills when compared to children who do not stutter.

Based on the spreading activation model (Dell, 1986; Dell & O' Seaghdha, 1991), the findings of the present study imply that CWS were less accurate because the competing phonologic units might have more activation strength than the target phonologic node. The probable reasons for the competing phonologic unit to get activated could be because of the residual activation where it would have been recently selected and the activation has not decayed yet or faulty activation of the units. As suggested by the Cover Repair Hypothesis (Postma & Kolk, 1993), the CWS group of the present study exhibited increased error rate in phoneme monitoring task and this could be their failed covert attempts to correct the errors in the phonologic encoding of an utterance. Phonologic encoding deficits are observed among the CWS group of the present study that supports this theory. With respect to Cover repair hypothesis (Postma & Kolk, 1993) theory, the present study findings imply that CWS experience difficulty in selecting the appropriate phonemes required for the name of the target picture and their self-monitoring system fails to correct these errors covertly which leads to increased error rate in phoneme monitoring task. Due to repeated covert repairs, the correct portions of the plan become temporarily unavailable which results in slowed monitoring time and less accurate. The finding of the present study is supported by the Vicious circle hypothesis (Vasic & Wijnen, 2005) where it states that the ability to encode phonologic sequences is impaired among CWS. Vasic and Wijnen (2005) stated that hyper-vigilant monitoring system results in recurrent repairs of even minor sub-phonemic irregularities resulting in unnecessary reformulations of the speech plan ultimately resulting in a "vicious circle" which explains the slowed reaction time and increased error rates observed among CWS group of the present study. Increased error rate observed among CWS of the present study could be because of asynchrony in the assembly of phonologic units (Fault line hypothesis, Wingate 1988). According to the Neuropsycholinguistic model, Perkins, Kent and Curlee (1991) stated that stuttering occurs due to delay in linguistic processing which is because of segmental processing inefficiency or due to ineffective activation of the components that contribute to the final act of speaking. This explains why CWS were found to be delayed and less accurate in encoding phonologic codes.

On comparing the reaction time in eliciting "Yes" and "No" responses, CWS and CNS took a longer time to elicit "No" responses compared to "Yes" responses. This reflects hyper-monitoring that is they could have done repeated monitoring to ensure that the heard phoneme is not in the presented picture of the target word. Both the groups have followed a similar trend in timing domain but the CWS group took longer reaction time in eliciting “Yes” and “No” responses. Therefore, the CWS were found to be delayed in encoding phonemes but they were not deviant when compared to the CNS group. In terms of accuracy, both the groups were more accurate in eliciting “No” responses when compared to “Yes” responses. Less error rate in eliciting “No’ responses could be attributed to slow reaction time. There is no deviancy in the trend pattern but the CWS group was found to be less accurate when compared to the CNS group.

In terms of positions, CWS and CNS groups took a longer time to monitor the presence of the target phoneme occurring in medial positions when compared to the initial position. Both groups had followed a similar trend in the timing domain. Thus there is no deviancy between the groups in terms of timing domain. In terms of accuracy, CWS and CNS were more accurate in eliciting “Yes” responses when phoneme occurred in the initial position when compared to medial position and vice versa for “No” response. In terms of accuracy measure of “Yes” and “No” responses, both the groups followed a similar trend but the CNS group were more accurate than the CWS group.

Based on MacKay and Macdonald (1984)’s model rationale, phonologic time nodes connected to phoneme nodes of the phonologic system generates fewer pulses per second for activating the phonemes in medial and final position of the words whereas it generates more pulses per second for activating the initial phoneme of the word. The activation level of the initial phoneme doesn’t get self inhibited and as a result of this, the medial phonemes do not get activated under the most primed win principle (the target which is primed with the highest level of activation). This can be attributed to longer reaction time and less accuracy rate in monitoring the phonemes occurring in the medial position of the word.

Both the groups have followed sequential encoding of speech. These findings imply that children who stutter experience difficulties in encoding phonemes occurring in medial positions when compared to the initial position. They might find it easier to plan the initial phonemes when compared to phonemes occurring in the medial position as suggested by EXPLAN model. The finding can be interpreted through EXPLAN model. CWS group of the present study might be inefficient in segmenting the later portion of the word. As suggested by the EXPLAN model, they might have a sub-conscious default setting i.e. they assume that the target phoneme for which they are monitoring occurs only in initial position not in the latter portion of the word. Because of this, their reaction time to monitor the target phoneme in the medial position is delayed and less accurate. The reasons for CWS group to be less accurate in monitoring phonemes occurring in medial position could be because of delay in retrieving the appropriate phoneme as the threshold required for activation of appropriate may be increased (Dell 1986; Dell & O' Seaghdha, 1991) or more effort is required since the latter portion of the word becomes temporarily unavailable (as suggested by EXPLAN model) or mismatch between the retrieved and activated phoneme or segmental inefficiency. Levelt and Wheeldon (1995) also reported that monitoring latencies of their CWS group gradually increased along with the serial position of the segments within the target word. The findings of the present study suggest that children who stutter may have an unstable language planning system and this could be attributed to strong linguistic differences in certain aspects of phonological encoding.

Performance in phoneme monitoring task Vs auditory tone monitoring task

There was a significant difference between their performance in auditory and phoneme monitoring tasks, "Yes" and "No" responses, initial and medial positions and performances of children who stutter and do not stutter. It was found that there was no group influence on the tasks, response and position. With respect to reaction time measure for both the groups (CNS and CWS), the phoneme monitoring response time to "Yes" and "No" responses were longer than tone monitoring response time to "Yes" and "No" responses and it was statistically significant. Across initial and medial positions, the speed of monitoring the presence and absence of target tone was faster than the monitoring speed of the presence and absence of target phonemes. In terms of accuracy measure, the participants of both the groups were more accurate in eliciting "Yes" and "No" responses in auditory tone monitoring task when compared to phoneme monitoring task and it was statistically significant. Across the initial position, the participants of both the groups were more accurate in monitoring the presence and absence of target tone when compared to phoneme and it was statistically significant. With respect to the medial position, the CNS and CWS were more accurate in monitoring the presence of target tone when compared to phonemes. A comparison between these two tasks was not reported in the literature. With respect to reaction time and accuracy, the findings of the present study imply that CWS and CNS groups have performed better in auditory tone monitoring task and poorer in phoneme monitoring task since the auditory tone monitoring task does not involve speech stimuli and the latter is limited to monitoring verbal stimuli. Phoneme monitoring task can be considered as cognitively more demanding since it requires children to covertly monitor the presence or absence of target phoneme in their own speech whereas auditory tone monitoring task is less cognitively demanding since it requires them to monitor the presence and absence of target tones in the presented tone sequence. Phoneme monitoring task involves processes such as activation of appropriate phonemes and retrieving the phonologic representation of the target word once they see the target picture whereas in auditory tone monitoring task, the tone sequence is already presented and they just have to monitor the presence and absence of target tones. This explains the poor performance in the phoneme monitoring task. Compared to the auditory tone monitoring task, the phoneme monitoring task requires more effort i.e. the amount of resources allocated for monitoring and selective focus of monitoring i.e. looking out for the presence of target phoneme in the name of the presented picture which could occur in initial/medial position.

Performance in phoneme monitoring task Vs performance in simple motor task

The performances of both the groups in phoneme monitoring and simple motor tasks were compared and found a significant difference between their performances in simple motor task and phoneme monitoring task in terms of reaction and accuracy measures. This finding suggested that both the groups (CWS and CNS) took a longer time to elicit phoneme monitoring responses. In terms of accuracy measure, both the groups were found to less accurate in phoneme monitoring task though their reaction time was slow. Simple motor task is considered as a less cognitively demanding task and it does not involve speech stimuli. In this task, the participants are required to be vigilant enough to respond as soon as they hear the target tone. Since it does not involve additional cognitive or linguistic processing, they have performed better in simple motor task when compared to phoneme monitoring task. General monitoring deficits could also influence their poor performance in phoneme monitoring task. Compared to simple motor task, phoneme monitoring task involves cognitive processing (such as selective attention where they have to selectively look for the presence of the heard phoneme in the name of the target picture, meta-linguistic skills i.e. covert monitoring, phonologic working memory i.e it requires more effort for them to retain the phonologic code in memory for segmentation process and judgment) and linguistic processing (such as activation and retrieving the phonologic codes of the target word, sequential encoding of speech and segmentation process). This explains for their longer reaction time and poor accuracy scores in phoneme monitoring task.

In summary, both the groups' i.e. CWS and CNS have performed better in non-linguistic tasks when compared to linguistic tasks. The CNS group had followed the same trend as that of the CWS group though they were fluent in speaking. This implies that the CNS group also experienced difficulties in phoneme monitoring task but less when compared to the CWS group. On analyzing the performance of CNS in linguistic and non-linguistic tasks separately, it was noted that their monitoring reaction time was faster and more accurate when compared to the CWS group. The Non-linguistic tasks used in this study involve the perception of external stimulus whereas the linguistic task used in this study involves the perception of self-generated speech. In the auditory tone monitoring task, the target tone is already presented and they just have to check if one of the tones in the tone sequence matches the target tone. In simple motor task, they have to be vigilant enough to respond to the onset of the target tone. These two tasks require updating the working memory in response to the target tone, allocating attention resources in the processing system for processing the target tone and retrieving the memory trace of the previously presented target tone. The processing takes place at the perception level. The performance in these non-linguistic tasks reflects the enhanced performance of the auditory processing system. Overall, these tasks involve general monitoring skills and also indicate the presence or absence of motoric control deficits coupled to stimuli presented auditorily. Thus, they have performed better in auditory tone monitoring and simple motor tasks.

Compared to these non-linguistic tasks, the phoneme monitoring task is considered a complex task for both the groups. In the phoneme monitoring task, on seeing the picture, they have to monitor for the presence of heard phoneme in their self generated speech. In this task, first, they have to retrieve and say the name of the picture (which they were familiarized earlier) covertly. Next, the phonemes present in the target word will get retrieved and activated and then they have to segment the word in order to identify the presence of heard phoneme. This task involves working memory to enhance the segmentation process. Post lexical search strategy is advocated for them to confirm the response. It employs sequential encoding to identify the presence of phoneme in the medial position other than the initial position. It also involves the use of feedforward and feedback loops. It involves a lot of cognitive and linguistic processes. Poor performance in this task could be because of more demand on working memory or retrieving memory traces of the target word or retrieving and activating the phonologic representation of the target word or getting feedback of their speech.

Slow performance in phoneme monitoring task implies that they take a longer time to update the underlying sensory-motor model (Andrews et al., 1983). Based on the rationale of the demand capacity model, the demand imposed on this task is more when compared to non-linguistic tasks and it might have exceeded their capacity to perform in this task. Thus they might have performed poorly in phoneme monitoring task. The phoneme monitoring task involves processing at the central level rather than at the peripheral level where the inner production loop plays a role in activating, programming and monitoring the phonologic codes and thus it can be attributed to longer reaction time in phoneme monitoring task. In the phoneme monitoring task, the reaction time was longer because more time is required for them to suppress the competing phonologic units and activate the required ones whereas, in the auditory tone monitoring task, they just have to detect the presence of target tone based on frequency change. And also, they undergo self-monitoring process where the sublexical units, rimes, and phonemes are accessed and identified in order to elicit “yes” or “No” responses. Liberman, Shankweiler, Fischer and Carter, (1974) reported that phoneme segmentation was considered to be a difficult task when compared to syllable segmentation task. Thus they took longer time to monitor phonemes compared to tones. They depend upon phonologic working memory to perform in phoneme monitoring task. The reaction time and accuracy measures of this task depend upon whether the correct phonologic codes are stored in phonology memory. The processing speed was more in phoneme monitoring task because it involves greater shorter memory capacity and attention resources like selective attention and inhibitory control. Treiman, and Zukowsk, (1966) noted that the mean amplitude of the ERP component parietal positivity elicited by S1 (S1-P3) was smaller in AWS than in AFS, which implies that AWS may have deficits in investing working memory on phonological programming.

The performances of simple motor, auditory tone monitoring and phoneme monitoring tasks across children with mild, moderate and severe stuttering

With respect to reaction time and accuracy measures of “Yes” and “No” responses, a significant difference in the performance of all three tasks was not found across these three severity groups although the performances of three severity groups were comparable. There are no studies reported in the literature considering the influence of severity on their performances in all three tasks. Because of the less and unequal sample size in each severity group, the influence of severity on general and phoneme monitoring abilities cannot be validated significantly. Further, it is warranted that this finding can be validated by carrying out this study on a larger population. On comparing the performances of children with mild, moderate and severe stuttering between simple motor and phoneme monitoring tasks, a significant difference was found with respect to reaction time and accuracy measures. When their performances were compared between auditory tone and phoneme monitoring tasks, the differences in their performances between these two tasks were found to be significant with respect to reaction time measure of "Yes" and "No" responses and also across initial and medial positions. In terms of accuracy measure of "Yes" and "No" responses and also with respect to positions, a significant difference was not found but for children with moderate stuttering significant difference was found.

Reliability

For CWS and CNS groups, the reliability of phoneme monitoring task in measuring phoneme monitoring time for "Yes" responses was found to be excellent, acceptable for "No" responses, good for "Yes" initial responses, acceptable for "Yes" medial responses and good for "No" initial responses and "No" medial responses. With respect to accuracy measure in phoneme monitoring task it was found to be excellent for measuring "Yes" responses, good for measuring "No" responses, acceptable for measuring "Yes" initial responses, excellent for measuring "Yes" medial responses and acceptable for measuring "No" initial and medial responses accurately. In auditory tone monitoring task, the reliability was found to be acceptable for measuring tone monitoring time for "Yes" and "No" responses, good for measuring tone monitoring time for "Yes" initial responses, acceptable for measuring tone monitoring time for "Yes" medial responses, good for measuring tone monitoring time for "No" initial responses and acceptable for measuring tone monitoring time for "No" medial responses. With respect to accuracy measure in auditory tone monitoring task, the reliability was found to be good for measuring "Yes" and "No" responses, acceptable for measuring "Yes" initial responses, acceptable for measuring "Yes" medial responses, acceptable for measuring "No" initial responses and good for measuring

“No” medial responses accurately. For simple motor task, the reliability of reaction time and accuracy measures was found to be good. Thus these three tasks are sensitive to assess the presence of general monitoring and phonologic encoding deficits among children who stutter of the Indian context. It would be beneficial for a holistic therapeutic approach where the clinician would work on their speech, linguistic and Motoric aspects.

To summarize, the CWS group performed poorly than the CNS group in simple motor task, auditory tone and phoneme monitoring tasks in terms of timing domain. In terms of accuracy, CWS and CNS performed similarly in simple motor and auditory tone monitoring tasks. But in the phoneme monitoring task, the CNS group performed more accurately than the CWS group. Therefore, CWS as a subgroup have general monitoring difficulties and in specific, they exhibit phonologic encoding difficulties also.

Chapter VI

Summary and Conclusions

Wingate (1964) refers stuttering to as a (a) disruption in the fluency of verbal expression, which is (b) characterized by involuntary, audible or silent, repetitions or prolongations in the utterance of short speech elements, namely: sounds, syllables, and words of one syllable. Peters and Starkweather, (1990) believed that stuttering is associated with a lack of balance between the linguistic and motoric systems involved in speech production. Literature also supports the idea of phonological encoding deficits in adults and children with stuttering. According to Levelt (1989)'s speech production model, persons with stuttering have a problem at the output level of phonological process which could be attributed to their self monitoring deficits of their inner speech. It is said in the literature that the process of phonological encoding is obscured from direct observations since it is deeply embedded in the process of language formulation and on the western forefront there are very few direct sources of evidence which supports the fact the children who stutter were found to have phonological encoding deficits. But on the Indian forefront, no direct source of evidence was found to support this above mentioned fact. Though studies have been conducted in western context, the results cannot be generalized to other languages since English is stress timed and Kannada is syllable timed. Thus the need arose to investigate phonological encoding skills in children who stutter aged between 8 and 12 years of Indian context. The main aim of the study was to check the difference in phonological encoding using phoneme monitoring in silent naming task and to compare between children with stuttering and children with no stuttering. The objectives of the study were as follows: a) difference in reaction time and percentage of error response (accuracy) in phoneme monitoring, auditory tone monitoring and simple motor tasks b) difference in the performances between auditory tone and phoneme monitoring task c) difference in the performances between simple motor and phoneme monitoring task. The performances were compared across CWS and CNS and within CWS group.

Thirty Four children in the age range of 8 to 12 years who were diagnosed as having stuttering with a severity of mild and above degree of stuttering comprised the clinical group. Thirty Four age and gender matched children with no stuttering comprised the control group. All the participants were native speakers of Kannada and right handed. All the children were ruled out for neurological, intellectual, sensory (vision and hearing) or communication disorders and also other related medical problems.

The experiment of the present study included three major tasks namely,Simple Motor task**,** Phoneme Monitoring taskand Auditory Tone Monitoring task. The present study was conducted in two phases: 1) Stimulus Preparation and Task Design Programming 2) Administration of the tasks on Children who stutter (CWS) and Children who do not stutter (CNS) groups.

Phase 1: Stimulus preparation and Task Design Programming

Simple motor task was designed to assess the time taken to perform simple manual responses by the participants of both the groups. 500 Hz pure tone of duration of 550 ms was considered as the stimulus for this task. The participants were asked to indicate to the onset of the target tone through "Yes" response, by pressing the "key 1".. Picture familiarization and naming task was done to familiarize the participants with 34 target pictures and their names that were considered for the phoneme monitoring task. Seventeen phonemes (/t/, /d̪/, /r/, /v/, /p/, /d/, /dʒ/, /g/, /ʃ/, /k/, tʃ, /s/, /n/, /t̪/, /m/, /b/, /h/) were selected based on the mean percentage of highly dysfluent phonemes (Sangeetha & Geetha, 2015). Thirty Four Kannada bisyllabic nouns (CVCV) with a frequency value of below 10 were considered. The target phonemes occurred in initial and medial positions of the target words. In this task, thirty four target pictures were randomly presented manually on the computer screen and the participants were asked to name the pictures overtly.

Phoneme monitoring task was designed to measure the participants' response time in ms and accuracy in monitoring the presence or absence of target phonemes during silent picture naming. In this task,thirty four pictures from the picture familiarization and naming task were used in order to elicit phoneme monitoring responses. The seventeen target phonemes were presented along with vowel /a/ but the subjects were asked to monitor the target phoneme irrespective of the sound preceding or following it. The target pictures were presented in two blocks. In the first block, thirty four pictures occurred twice (once with the phoneme as a target, thus requiring participants to provide a "Yes" response and once without the phoneme as a target requiring a “No” response). In the second block, twenty target pictures were randomly presented (the pictures represent the ten target words having the phoneme as the target requiring a “Yes” response and ten without the phoneme as a target requiring a “No” response). If the target phoneme was present in the target word, the subjects were asked to indicate through a “Yes” response and “No” in case if the target phoneme was not present in the target word.

Auditory tone monitoring task was designed to measure participant’s response time in ms and accuracy in monitoring the presence of target tone that is 1 KHz in the presented tone sequence. For this task, 1 KHz and 500 Hz pure tones were used. Twenty trials were presented in both the blocks where ten in each. The target tone selected for this task was 1 KHz. In each block, half of the trials i.e. five of the trials had tone sequences comprising of 1 KHz and 500 Hz tones. The position of 1 KHz tone was distributed across initial and medial position of two tone sequence (e.g. 1 KHz, 500 Hz; 500 Hz, 1 KHz). These tone sequences required a “Yes” response from the participants indicating the presence of the target tone i.e. 1 KHz. The other five trials had tone sequences comprising of two 500 Hz tones (e.g. 500 Hz, 500 Hz). These tone sequences required a “No” response from the participants indicating the absence of the target tone.

Phase 2: Administration of the tasks on CWS and CNS groups

For the participants of both the groups, the testing protocol was initiated with the random presentation of three tasks such as simple motor task, auditory tone and phoneme monitoring tasks with an exception that the picture familiarization task was always presented prior to phoneme monitoring task.

In ***Simple Motor task***, the participants were instructed to respond to the onset of the target tone by pressing “**key 1**” (programmed specifically on the laptop keyboard) as quickly as possible. In ***Picture Familiarization task***, first, the participants were familiarized with the thirty four target pictures that were considered for the phoneme monitoring task and later these target pictures were randomly presented on the laptop screen for them to overtly name it. In case of any errors made by the participants, a corrective feedback was provided i.e. the naming errors were corrected by the tester and verbal cue was also provided in order to guide the subject to arrive at the target word. Two to three attempts were provided to the participants until they correctly name the target pictures which were named incorrectly in the first attempt. In ***Phoneme monitoring***

task, the participants were instructed to press **"key 1"** if they identify the heard phoneme in the target word indicating **"Yes"** and if the heard phoneme is not in the target word, they were asked to press **"key 2"** indicating **"No"**. In ***Auditory Tone monitoring task,*** The participants were asked to press **"key 1"**indicating **"Yes"** if the first tone that they hear is in the two tone sequence irrespective of its position and press **"key 2"** indicating **"No"** if the target tone is not in the tone sequence.

The results of the present study revealed that in simple motor task, CWS took longer time to respond to onset of the target tone when compared to CNS and the difference in their performances was statistically significant. In terms of accuracy measure, CNS was more accurate than CWS but the difference was not statistically significant. The same trend was observed in auditory tone monitoring task. In phoneme monitoring task, CWS was found to be slow in monitoring the presence and absence of the target phoneme when compared to CNS. CWS was also found to be less accurate when compared to CNS. This was highlighted by statistical significance between both the groups in terms of reaction time and accuracy measures. In terms of reaction time and accuracy measures, CWS and CNS performed poorly in phoneme monitoring task when compared to auditory tone monitoring task. When compared to simple motor task also, both the groups performed poorly in phoneme monitoring task in terms of reaction time and accuracy measures. With respect to reaction time and accuracy measures of "Yes" and "No" responses, significant difference in the performance of all three tasks was not found across these three severity groups although the performances of three severity groups were comparable. There are no studies reported in the literature considering the influence of severity on their performances in all three tasks. Because of the less and unequal sample size in each severity group, the influence of severity on general and phoneme monitoring abilities cannot be validated significantly. On comparing the performances of children with mild, moderate and severe stuttering between simple motor and phoneme monitoring tasks, significant difference was found with respect to reaction time and accuracy measures. When their performances were compared between auditory tone and phoneme monitoring tasks, the differences in their performances between these two tasks were found to be significant with respect to reaction time measure of "Yes" and "No" responses and also across initial and medial positions. In terms of accuracy measure of "Yes" and "No" responses and also with respect to positions, significant difference was not found but for children with moderate stuttering significant difference was found.

Based on the finding of simple motor and auditory tone monitoring tasks, it can be suggested that children who stutter may have generalized monitoring deficit that is non speech motor timing deficits since they experience deficits in the timing domain only. CWS of the present study performed poorly in phoneme monitoring task. Among children who stutter, the time taken for the target phonologic units to reach a highest level of activation was found to be delayed when compared to children who do not stutter.Children who stutter tend to be hyper vigilant in monitoring the errors in their motor plan and the threshold to initiate covert repairs was reported to be less (vicious circle hypothesis; Vasic&Wijnen, 2005). Therefore, these reasons could be accounted for slow reaction time in monitoring the target phonemes which was observed among CWS group of the present study when compared to CNS. Perkins, Kent and Curlee (1991) attributed the present study's finding to inefficiency in processing segmental units which is commonly observed among children who stutter. This is because they might still retain the immature holistic phonologic representation of the word. With respect to Covert repair hypothesis (Postma&Kolk, 1993) theory, the present study findings implies that CWS experience difficulty in selecting the appropriate phonemes required for the name of the target picture and their self monitoring system fails to correct these errors covertly which leads to increased error rate in phoneme monitoring task. Due to repeated covert repairs, the correct portions of the plan become temporarily unavailable which results in slowed monitoring time and less accurate. In the present study, Children who stutter experience difficulties in encoding phonemes occurring in medial position when compared to initial position. They might find it easier to plan the initial phonemes when compared to phonemes occurring in medial position as suggested by EXPLAN model. CWS group of the present study might be inefficient in segmenting the later portion of the word. It can be concluded that overall CWS of the present study experience general monitoring deficits and in specific they experience deficits in phonologic encoding process.

Clinical Implications

- The simple motor, auditory tone and phoneme monitoring tasks are sensitive to assess the presence of general monitoring and linguistic (phonologic encoding) deficits among children who stutter of Indian context.
- The present study adds on to the theoretical knowledge on nature of stuttering in children, especially supporting the multifactorial model of stuttering.
- It would be beneficial for holistic therapeutic approach where the clinician would work on their speech, linguistic and motoric aspects.

Limitations

- The same study has to be carried out on larger sample size to validate the findings of the present study.
- Since the auditory stimulus is presented in simple motor and auditory tone monitoring tasks, visual stimuli could have been presented in simple motor task in order to clearly demarcate their performances in both the tasks and also it would be helpful in arriving at a decision whether they have problem related to motoric or auditory processing aspects.
- The present study could have focused on higher linguistic abilities (lexical retrieval/ parsing/ grammatical encoding/ semantic encoding) i.e. the level beyond phonologic encoding process.
- The present study failed to compare the performance in encoding phonologic codes across different age groups in order to arrive at a conclusion whether they have delay or deficit in segmenting the phonologic representation of the word.

Future directions

- The study can be carried out on larger sample size of CWS in the age range of 8-12 years.
- To compare the performance in encoding phonologic codes across different age groups to study the developmental trend.
- The study can be focused on meta-linguistic abilities such as lexical retrieval, parsing, grammatical encoding, semantic encoding, monitoring and self-monitoring.

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Appendix I

/ṭo:pi/	
/lo:ṭa/	
/d̪o:se/	
/gad̪e/	

/ra:dʒa/	
/a:ru/	6
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/pu:ri/	
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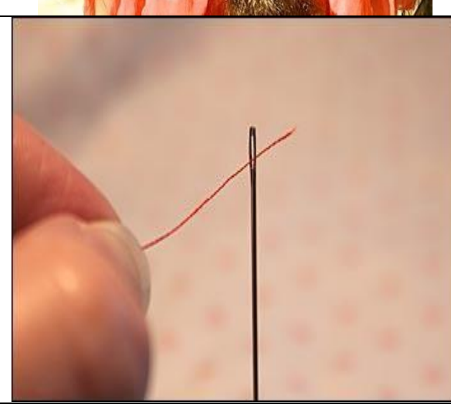
/su:dʒi/	

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