SPEECH MOTOR PLANNING IN ADULTS WITH STUTTERING

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MAY 2001

Dedicated to

Respected Madam,

Dr. (Mrs) Savithri, S.R.

&

Dear Parents

Certificate

This is to certify that the Dissertation entitled ***"Speech** Motor Planning in Adults with Stuttering"* is the bonafide work done in part fulfillment of the degree of Master of Science (Speech and Hearing) of the student (Register No. M 9922).

Mysore

May 2001

Director
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Certificate

This is to certify that the Dissertation entitled ***"Speech Motor Planning in Adults with Stuttering"*** **has** been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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This dissertation entitled ***"Speech Motor Planning in Adults with Stuttering"*** is the result of my own study under the guidance of Dr. S. R. Savitri, Reader and Head, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any other University for the award of any Diploma or Degree.

Mysore

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CHAPTER I

INTRODUCTION

[According to Wingate (1964). the term "stuttering" means:

1. (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. These disruptions (c) usually occur frequently or are marked in character and (d) are not readily controllable.

2. Sometimes the disruptions are (e) 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.

3. Also, there are not infrequently (f) 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, (g) The immediate source of stuttering is more in-coordination expressed in the peripheral speech mechanism; the ultimate cause is presently unknown and may be complex or compound.

In the scope of this definition, stuttering is considered as a motoric disturbance that results in a broad spectrum of dysfluencies. Until the middle of seventies, stuttering was explained mostly from a psychological point of view and learning principles were seen as the major factors in the development of the problem (Bloodstein, 1995). However, research on speech anxiety and emotional factors showed that stutterers and nonstutterers have the same levels of arousal in the anticipation of as well as during speech situations (Peters & Hulstijn, 1984). These results lead to an increasing interest in explaining stuttering from a speech motor perspective. A major line of research over at least three decades has investigated the possibility of a motor control disorder as at least one component (Ingham, 1998; Peters, Hulstijn & Van Lieshout, 2000). Speech motor control (SMC) perspective on stuttering has been largely responsible for promoting the view that stuttering is best understood as a neurophysiological disorder that directly affects the speech motor system. It has also generated a massive amount of research, most of which has been directed at the level of control that stutterers exert over motor behaviours in their speech, rather than towad any "underpinning" neurological variables (Peters & Hulstijn, 1987; Peters, Hulstijn & Startweather, 1989; and Bloodstein, 1995)."

According to speech motor control (SMC) perspective, stuttering was described as a disruption of coordinated muscle activity in the laryngeal system (Adams, 1974), as a discoordinated timing of articulatory movements

(Zimmerman, 1980 a, c), and as a disruption in the timing or coordination between laryngeal, respiratory and articulatory movements (Wingate, 1976; Van Riper, 1982; and Kent, 1984).

Stutterers ability to initiate phonatory and articulatory movements has been investigated in numerous reaction time (RT) studies, where RT was defined as the lapse of time between the onset of a response signal and that of acoustic speech signal. In general, the results showed that stutterers are significantly slower in initiating phonatory and articulatory movements: for single vowel productions the results were somewhat contradictory, but for more speech like stimuli (continuous speech as in words or sentences) stutterers were unequivocally found to be slower in initiating speech, with greater group differences in verbal reaction times for more complex utterances (Peters, Hulstijn & Starkweather, 1989). The results were interpreted as suggesting that stutterers may have difficulty in the motor programming speech behaviour. Similarly Postma, Kolk and Povel (1990) reported that the difference between stutterers and nonstutterers in silent speech indicates that stutterers have larger speech planning time. Kolk (1991) referred speech programming difficulties to the disturbances in phonological encoding, in which the correct phonemes for a particular word or sentence are selected in such a way that segmental and metrical word form information from the mental lexicon is integrated. A well known theory to explain stuttering is the covert repair hypothesis (Postma & Kolk, 1993), according to which repetitions, prolongations and blocking of speech sounds are by-products of covertly repairing errors in the speech plan. Several studies have found evidence to support the covert repair hypothesis (Bosshardt, 1993; Hubbard & Prins, 1994; and Wijnen & Boers, 1994).

In contrary, subsequent studies by Van Lieshout, Hulstijn & Peters (1996 a, b) did not support the hypothesis that people who stutter have a deficit in motor programming. Also studies exist which do not support the hypothesis that stuttering is caused by phonological encoding deficit (Throneburg, Yairi & Paden, 1994; and Burger & Wijnen, 1999).

The results of the reaction time studies using speech like stimuli, though suggesting an increased reaction time in stutterers, are equivocal. It is also unclear whether the increased speech reaction times seen in stutterers are caused by difficulties in the speech motor planning or by disturbance of motor initiation. In this context the present study was planned. The aim of this study was to investigate the difficulties in people who stutter may have in the planning or initiation of speech. Specifically a reaction time paradigm was used.

CHAPTER II

REVIEW OF LITERATURE

In the last two decades, there has been a growing body of research into speech motor behaviour in stuttering. This research was strongly motivated by some striking results of the Freeman and Ushijima (1978) investigation that used EMG measurements to record laryngeal and articulatory muscle activity during fluent and nonfluent speech of people who stutter. They reported a disruption of the normal reciprocity of abductor muscles in dysfluent speech utterances. These results lead to the hypothesis that stuttering might be linked to a discoordination of activity between and within the speech motor subsystems involved in speech production (Peters, Hulstijn & Van Leishout, 2000).

Large varieties of general motor explanations of stuttering were published, which can be summarized as speech motor control (SMC) perspective. All SMC theories share the common hypothesis that stutterers have difficulties in initiating and controlling speech movements in one way or another. The speech motor research into stuttering will be discussed in relation to the various stages and processes of the Van Lieshout (1995) model (c.f. Peters et al., 2000).

These stages can be further divided into a number of sub stages as in the figure 1.

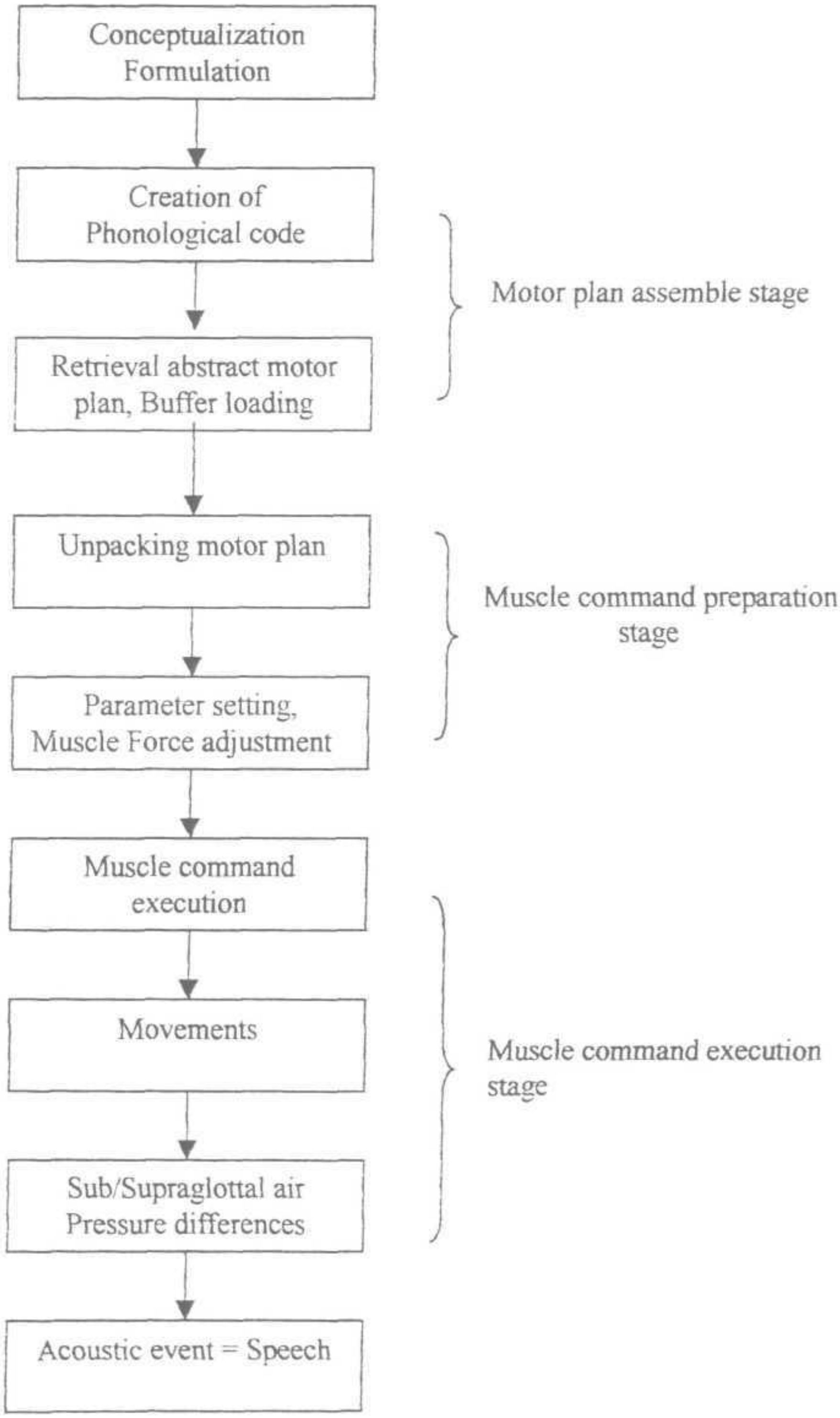

Figure 1: Stages and processes in speech motor production as described by Van Lieshout(1995)

The model consists of three main stages:

1. The motor plan assembly stage, in which an abstract motor plan is assembled,
2. The muscle command preparation stage, in which muscle commands are turned to the context of the verbal motor task, and
3. The muscle command execution stage, in which muscle commands are initiated and executed.

MOTOR PLAN ASSEMBLY STAGE

One of the arguments for attributing stuttering to a perturbation of the prearticulatory speech planning is the well established influence of the linguistic factors on stuttenng. Specifically, stuttering events frequently occur at the beginning of a word or utterance and moreover there is a greater tendency of stuttering to occur on longer rather than shorter words (Soderbeg, 1966), and sentences (Tornick & Bloodstein, 1976; and Jayaram, 1984). This in conjunction with Hulstijn's (1987) view that speech utterances are supposed to be programmed before their initiation lead to hypothesis that a programming or planning processes may be involved in or is responsible for the origin of stuttering.

Introducing simultaneous recordings of various speech physiological processes and employing systematic manipulations of speech tasks within the reaction time paradigm, Peters, Hulstijn and Starkweather (1989) tested whether stutterers have more problems in the planning processes than nonstutterers. They reported larger reaction time differences between stutterers and matched controls for longer verbal sequences, more specifically in comparing monosyllabic and polysyllabic words. These results are interpreted as suggesting that the stutterers may have difficulty in the motor programming of speech behaviour. Similarly, Aravind (1997) used a choice reaction time paradigm and studied the stutterers' programming abilities. Material consisted of 36 meaningful Kannada words varying in word length and complexity and three sentences for standard and picture sentence levels. Results showed a longer SRTs in stutterers compared to nonstutterers and an increase in SRTs with an increase in word length and word complexity with a greater effect for stutterers. This suggest that the stutterers may be endowed with inefficient motor programming capabilities.

Later studies by Van Lieshout et al., (1996 a, b) used more refined paradigm and did not show a significant interaction between the word size and group effects. These findings did not support the hypothesis that people who stutter have a deficit in motor programming. They further argued that the differences in EMG peak latency between stutterers and nonstutterers might be better understanding in terms of motor control strategies than in terms of motor control deficits. They hypothesized that people who stutter may use the feed back driven strategy to control the speech motor apparatus.

Another argument for locating the cause of stuttering in the speech planning given by the results of an experiment by Postma, Kolk, and Povel (1990). A silent speech technique was used in order to determine the relative importance of speech planning and execution in stuttering. Their results showed that stutterers are slower than nonstutterers in silent speech and to an increased degree in lipped and overt speech. The difference in silent speech suggests that speech planning is impaired in stutterers. With respect to the lipped and overt condition, the data indicated that either speech execution stage is independently impaired or that the planning defect has stronger consequences with actual speech motor movements.

In a similar study, Bosshardt (1990) found that stutterers subvocalize more slowly than nonstutterers. The stutterers silent presentation times were significantly slower than those of nonstutterers. In a subsequent study, Bosshardt (1993) found that stutterers displayed a serial short term reproduction performance inferior to that of nonstutterers. This was accounted for by assuming (a) that stutterers have slower phonological encoding and rehearsal times and (b) that they use nonphonological forms of coding to a lesser extent.

The first process in the motor plan assembly stage is that of phonological encoding, in which the correct phonemes for a particular word or sentence are selected in such a way that segmental and metrical word form information from the mental lexicon is integrated.

According to Kolk (1991), stuttering is the result of a phonological encoding problem. In phonological encoding segments (phonemes) are selected for syllable frames. Segments are considered to be nodes in an activation spreading network. Several segments may compete for a particular syllable slot. The segment that is most activated is selected. Kolk proposed that in stutterers, activation spreading is lower than nonstutterers. As a consequence, several elements that compete for the same slot are at the same level for activation for a longer period of time. This, in combination with the speaker's wish to produce speech at a "normal" speaking rate, increases the chance of segment misselection. The speech monitor detects and corrects the resulting error before it is uttered. These covertly repaired errors interfere with speech delivery and show up as disfluencies. Thus, according to this explanation, repetitions, prolongations and blocking of speech sounds are a byproduct of covertly repairing errors in the speech plan. This explanation, which relates disfluencies (including stuttered disfluencies) to repair processes during speech production, is called the covert repair hypothesis (Postma & Kolk, 1993).

Wijnen and Boers (1994) attempted to test the hypothesis that stuttering involves a perturbation of the process of phonological encoding. They combined the ideas of Kolk (1991) and Wingate's (1988) proposal, which relates stuttering to a specific problem in the computation of prosodic parameters of articulatory plan, which led to the hypothesis that stutterers have difficulty in the phonological encoding of, in particular, the rhyme (i.e., the syllable constituent that is involved in stress and accent). They compared stutterers and nonstutterers reponses in an experimental paradigm - phonological priming - that has been argued to probe this level of processing. The results suggest that phonological encoding processes in stutterers differ from those in fluent speakers.

Hubbard and Prins (1994) studied the effect of word frequency and syllabic stress pattern on stuttering frequency using specially designed sentences read orally by stutterers and nonstutterers. Their results revealed significant differences in stuttering frequency between sentences with low and high frequency words, but not between sentences with regular and irregular stress patterns. They proposed that word access and phonological encoding difficulties could be a course factor that underlies the occurrence of stutter events.

In a contradictory study, Throneburg, Yairi & Paden (1994) investigated the relation between the phonologic difficulty of words and the point at which stuttering like disfluencies occurred in the speech of preschool children identified as having a stuttering problem. The results did not show a systematic predictable relation between phonologic difficulty and the occurrence of stuttering like disfluencies at the early stage of stuttering. Such a relation may be formed as the problem progresses and becomes chronic. Hence the assertion that speech difficult)" of children who stutter may result from problems with central premotor planning of the speech act (Posma et al., 1990) is not supported by this study. And if at all, this is not aggravated by words that are phonologically more difficult.

To replicate the Wijnen and Boers (1994) study, which supports the hypothesis that stuttering is caused by a phonological encoding deficit, Burger and Wijnen (1999) replicated that phonological priming experiment with a large group of subjects and a new set of stimulus words. The results showed that nonstutterers responded faster than stutterers, as they did in Wijnen and Boer's experiment. Also homogeneous condition yielded faster reaction times than heterogeneous condition. Moreover, response words with identical initial

CV's primed better than response words with identical initial C's. However, the expected interaction of group, prime type and condition did not show up. The reaction times as a function of the interaction between prime type and condition showed the same pattern in stutterers and nonstutterers. These findings do not support the hypothesis that stuttering is the result of a phonological encoding deficit. They also examined the influence of stress upon phonological encoding in nonstutterers and stutterers. The mean reaction time for words stressed on the second syllable was significantly longer than for words stressed on the first syllable, but no significant interaction between subject group and stress position was found. These results do not support the hypothesis that stuttering is specifically related to difficulty in the phonological encoding of the stress bearing part of the syllable.

From the previous studies it can be concluded that the hypothesis that stutterers have problems in the motor plan assembly stage was not confirmed.

Measurement of Speech Motor Planning:

A popular way to investigate planning aspects in speech production is to use a speech reaction time paradigm (SRT), where SRT is defined as the time interval between stimulus presentation and speech onset. Reaction time paradigms in speech motor control research can be dichotomized as simple and choice reaction time paradigms. The differences in the performance under each, demonstrates the differences between motor response programming and execution.

In simple reaction time (considered equivalent to a "delayed" reading tasks condition) task, subjects already know what response to perform and have only to wait for the "go" signal to execute the response task, whereas in choice reaction time tasks (considered equivalent to an "immediate" reading task) subjects must wait for information, both on the response to perform and when to begin performance, requiring them to both program and execute the response, thereby causing them to respond more slowly.

In stuttering research word size is one of the main interest. The word size effects in simple and choice reaction times have their origin at difference stages of speech production (Levelt 1989). The influence of word size on choice reaction time is assumed to be related to the fact that the longer words have more units (eg: syllables or phonemes), which will affect the time needed to prepare the whole sequence in advance i.e.. greater speech motor planning time is essential if utterances of increasing length have to be centrally organized (Peters et al., 1989).

In model by Sternberg, Monsell, Knoll and Wright (1978), speech production follows in four stages viz., the programming, retrieval, unpacking and command stages. In the programming stage, an articulatory/motor plan (phonetic plan according to Levelt, 1989) is assembled by phonological encoding and stored in an articulatory buffer. The motor plan is retrieved from the articulatory buffer, unit by unit in the second stage. In the third stage, each unit is unpacked for its constituents, which are motor commands for the different phonological elements (syllables) within a unit. In the last stage, these unpacked motor commands are sent to the neuromotor system for subsequent execution. In a more recent version of the model (Levelt & Wheeldon, 1994 (c.f. Van Lieshout et al., 1996b), the output of the phonological encoding stage is followed by phonetic encoding substage. In the phonetic encoding substage the final product of phonological encoding is used to retrieve motor templates from the long term memory in syllabic units. Van Lieshout et al., (1996) addresses these two substages as a single state i.e., motor plan assembly stage.

The effects of word size in choice reaction time are believed to have their origin mainly at this stage (Levelt 1989). Since longer words or more complex words have more syllables or sounds, which according to the model, will take more time to encode phonologically and also to find all the corresponding motor templates (stored as syllabic units) in the syllabary.

For people who stutter, the model as described above would predict that if they have problems in processing information at the motor plan assembly stage (Bosshardt, 1990, 1993; Hubbard & Prins, 1994; Posma & Kolk, 1993; and Wijnen & Boers, 1994), the increase in planning demands for longer words would increase the difference in choice reaction time between themselves and those who do not stutter. In other words, choice reaction time show an interaction between group word size and complexity effects.

Moreover, stuttering literature suggests that time pressure influences the frequency of stuttering (Healey, Mallard & Adams, 1976). It is assumed that under high time pressure, stutterers might lack the ability to program adequately the required speech motor sequences (Kolk, 1991). Considering these in the present, it was decided to investigate the effects of word motoric complexity, word length on choice reaction time i.e., immediate reading task. Word motoric complexity was manipulated by selecting stimuli that varied in terms of ontogenetic acquisition of speech sounds. Word length was manipulated by alterations in the number of syllables in a word, in view of estimating the effects of sequence length on motor planning.

MUSCLE COMMAND PREPARATION STAGE

This stage involves two substages. First, there is the retrieval of the motor plan: well learned motor plans are retrieved from short term memory. During the last few years, the notion that stuttering has its origin in motor learning failures resulting in inefficient plans (Peters et al., 2000).

Second stage involves the parameter setting. Individual movement characteristics such as stress, loudness, rate (all variables related to the actual speech situation) are added to the motor plan. The selection of the proper values requires the processing of sensory information or sensory afference. At this level, stutterers experience some problems. Neilson and Neilson (1991). and Pindzola (1987) hypothesize that people who stutter may have difficulty in interpreting sensory information for the control of movement. De Nil (1994) study reports that adult stutterers have been less proficient than nonstutterers in making very fine movements with oral articulators when relaying on proprioceptive feed back information. Furthermore, the deficiency is related to movement speed and stuttering severity. Severe stutterers find it difficult to use kinesthetic information quickly during the performance of small articulatory movements. They further hypothesized that deficiency in the processing of oral kinesthetic feed back during speech may be related to patterns of articulatory discoordination. Recent literature also supports this notion of limited abilities in people who stutter to process sensory information or acquiring and using sensory information for ongoing movement coordination (Archibald & De Nil, 1999).

There is also some evidence that stutterers exhibit a reduced ability in the precise regulation of speech related forces. A recent study conducted by Grosjean, Van Galen, Jong, Van Lieshout and Hulstijn (1997) (c.f. Peters et al., 2000), showed that they exhibit less strength and are more inaccurate or variable than nonstutterers when pressing their lips on a pressure transducer. From this study, it may be hypothesized that force control is less accurate in stutterers.

MUSCLE COMMAND EXECUTION STAGE:

After setting the parameter values, the new concrete program must be initiated and executed, which is done in this third and final stage. The motor units of muscles in the speech motor effector system are activated which gives rise to muscle contractions and thus to movements in the respiratory, phonatory and articulatory subsystems involved in speech production. During the last two decades, a large number of authors have pointed out defective or inefficient speech movement initiation processes in stuttering.

Zimmerman (1980a) used the high speed cineradiography to study the movement of the lower lip and jaw for CVC utterances. The results indicate that stutterers consistently show longer duration between movement onsets, achievements of peak velocity and voice onsets than normal speakers. Stutterers also show longer steady state positioning for the lip and jaw during vowel production and greater asynchrony between lip and jaw movement. These support that they may be motorically slow than nonstutterers, even during the fluent utterances.

Speech reaction time (SRT) studies using isolated vowels have often found significant differences between stutterers and nonstutterers (Adams & Hayden, 1976; Cross & Luper, 1979, 1983; Cross, Shadden & Luper, 1979; Hayden, Adams & Jordahl, 1982; and Starkweather, Franklin & Smigo, 1984), but there have also been some studies using isolated vowels in which no significant differences were found (Murphy and Baumgartner, 1981; Venkatigiri, 1981; and Watson and Alfonso, 1982).

On the other hand, in reaction time studies in which words or phrases were used, the picture is clearer. Without exception, these studies have found that stutters are slower in speech initiation than nonstutterers. Borden (1983) compared the initiation and execution intervals in the fluent utterances of stutterers with the same intervals in the utterances of the controls. They also examined the finger movements in a nonspeech serially ordered task in order to determine whether differences between stutterers and controls extend beyond the speech mechanisms. Stutterers were found to be significantly slower than control subjects in performing a speech counting task as well as counting on their fingers silently. For both counting tasks, time taken to execute the numerical series accounted for more of the difference between severe stutterers and control than the time taken to prepare and initiate the task. Also mild stutterers were not significantly slower than controls on either counting task. Similar results were also reported by many authors (see Adams, 1985; Peters et al., 1989 for review).

Pindzola (1987) measured the duration of vocalic transitions, steady states, and total vowel between stutterers and nonstutterers perceptually fluent productions of VCV bisyllables. Results showed that stutterers displayed shorter transition and spent more time in steady state position of articulators. This suggests that temporal differences exist in the fluent speech of stutterers as compared to nonstutterers.

Study by Harbison, Robert and Porter (1989) also showed that stutterers difficulties appear to lie after response initiation suggesting they have problems in coordination of gestures during execution of fluent responses. Their results indicated that stutterers were, on average, 34 msecs slower on acoustic responses than nonstutterers in a shadowing response in which speakers exactly repeated vowel sequences they heard, and a simple response in which speakers said /u/regardless of the identity of the vowel stimulus.

Studies have also been done on the effect of complexity on the simple reaction time paradigm, one such study of Peters et al., (1989). They found longer reaction time for an increased utterance length, but there was no interaction between word size and group in simple reaction time. Similar results were also reported by Dembowski and Watson (1991), who recorded the laryngeal reaction time for isolated vowels and nonpropositional VCV responses in different stimulus conditions governing response preparation.

On the contrary- to the above studies, Bishop, Williams and Cooper (1991) reported the differences between performance of stutterers and nonstutterers increased with task complexity in a simple reaction time paradigm. In their stud}', stutterers had significantly slower reaction times than nonstutterers.

Recently, Van Lieshout et al., (1996a) found that people who stutter had longer word durations than control speakers, in particular for longer words. They speculate that this effect may reflect the differences in type of motor control strategy' used by the two groups. In particular, it was hypothesized that longer word durations seen in people who stutter reflect the use of a feed back driven strategy to control the speech motor apparatus in this population. On the contrary, a subsequent study conducted by same group of researchers failed to elicit any group by word size effect for word durations when both the naming tasks (symbol and word naming) contained same number of items and repetitions per item. Based on their findings, Van Lieshout et al., (1996b) suggested that group differences in word durations found in their earlier work reflect practice effects.

Measurement of Muscle Command Preparation/Execution:

If people who stutter are different from control speakers in the way they handle the preparation of muscle commands, it seems likely that group differences will also exist at the stage of muscle command execution, since the borderline between both stages is rather vague. Preparation and execution will follow each other very quickly and to some extent the execution of ongoing muscle commands will coincide with the preparation of the muscle commands next in line (Van Lieshout et al., 1996b). Delay that arises at the muscle command preparation stage could thus hamper ongoing muscle command execution. Also people who stutter may have significant delays in initiating speech. Van Riper (1982) mentioned that it may lead to stuttering, because "when a person stutters on a word, there is temporal disruption of the simultaneous and successive programming of muscular movements required to produce one of the word's integrated sounds, or to emit one of its syllables appropriately or to accomplish the precise linking of sounds and syllables that constitutes the motor pattern.'[1] Given the above mentioned problem in creating a meaningful temporal distinction between the preparation and execution of muscle command, Van Lieshout et al, (1996b) addresses them both as a stage by using the term "muscle command preparation/execution stage."

The effects of word size in simple reaction times are assumed to have their origin at the muscle command preparation stage (the term used by Van Lieshout et al.. 1996b, to address the "retrieval" and muscle command" parameterization stages), since longer or more complex words have more muscle commands and this will affect the time to complete the unpacking and muscle command parameterization substages (Levelt, 1989). If people who stutter are different from control speakers the way they prepare muscle commands, the simple reaction time would show an interaction between group-word size and complexity effects.

Here, in the present study, it was decided to investigate the effects of word motoric complexity, word length on simple (delayed reading task) reaction time with high time pressure. Word-motor complexity and word length was manipulated similar to that of choice reaction time task, in the view of estimating the effects of these changes on the muscle command preparation/execution stages.

CHAPTER III

METHODOLOGY

Subjects: Nine adult male native speakers of Kannada who stutter (16-29 years, mean age = 22.6 years) and nine adults who do not stutter (18-30 years, mean age = 23.8 years) matched for native language served as subjects for the study. None of the persons had been in treatment over at least one year preceding the experiment.

Stuttering severity was determined by speech-language pathologist using the stuttering severity instrument (SSI, Riley, 1986) scores on oral reading and conversational speech. Of those who stutter, two were classified as very mild, four as mild and three as moderate. No subject had any history of visual, hearing or neuromotor disorders. Subject details are in table 1.

Subject Number	Age/Sex	Total score on SSI	Severity of Stuttering
1	16y/M	24	Moderate
2	24 y/M	13	Very mild
3	22y/M	18	Mild
4	29 y/M	17	Mild
5	16 y/M	20	Mild
6	24 y/M	26	Moderate
7	28 y/M	12	Very mild
8	25y/M	22	Moderate
9	20 y/M	18	Mild

Table 1. Subject details.

Material: Word list based on syllable length and complexity formed the material. Material prepared by Aravind (1997) was used in the present study. The stimuli consisted of 36 meaningful Kannada words varying in word length (monosyllabic, bisyllabic, trisyllabic and polysyllabic) and motoric complexity (Complexity A: words with phonemes /b/, /t/, */k/,* /m/, /g/; complexity B: words with phonemes *ldz/,* /s/, /r/, */l/* and complexity C: words with clusters /sk/, /sl/, /bl/, /kr/, /bhr/, /gr/, /pr/. Table 2 shows the experimental stimuli. For practice trials additional three words were used. Each stimulus was written on a card measuring five inches by four inches.

Procedure: The experiment utilizes a reaction time paradigm with high time pressure and no feed back on reaction time. Each subject was measured in two different tasks - choice reaction time task (i.e., choice reaction time task) and simple reaction time task (simple reaction time task). In the first task, the subject was required to respond immediately after presentation of the stimulus. In the second task, the stimulus word was presented for the subject to read, followed by a pause before presentation of the signal to respond.

The subjects were first tested in choice reaction time task followed by simple reaction time task in a sound treated room. In the choice reaction time task, each stimulus card was slid into the manual slot machine (figure 2) and

		REACTION TIME (in msec)			REACTION TIME (in msec)			REACTION TIME (in msec)	
Complexity / Word Length	Complexity A	Immediate	Delayed	Complexity B	Immediate	Delayed	Complexity C	Immediate	Delayed
Mono Syllabic	/ba:/ ಬಾ /ta:/ ತಾ /ki:/ ಕೀ			/tʃa:/ ಚಾ /zu:/ ಜೂ /si:/ ಸೀ			/sku:l/ ಸ್ಕೂಲ್ /sleiṭu/ ಸ್ಲೇಟು /bleiḍu/ ಬ್ಲೇಡು		
Bi Syllabic	/məne/ ಮನೆ /ka:lu/ ಕಾಲು /bi:ga/ ಬೀಗ			/su:dʒi/ ಸೂಜಿ /la:ri/ ಲಾರಿ /səra/ ಸರ			/kra:nti/ ಕ್ರಾಂತಿ /bhrəʃṭa/ ಭ್ರಷ್ಟ /grəntha/ ಗ್ರಂಥ		
Tri Syllabic	/iruve/ ಇರುವೆ /agəsa/ ಅಗಸ /erəḍu/ ಎರಡು			/sarəsa/ ಸರಸ /rəŋgo:li/ ರಂಗೋಲಿ /tʃəppəli/ ಚಪ್ಪಲಿ			/kshəmisi/ ಕ್ಷಮಿಸಿ /ʃrəvəṇa/ ಶ್ರವಣ /kshətri:ja/ ಕ್ಷತ್ರಿಯ		
Poly Syllabic	/bi:gədəkəi/ ಬೀಗದ ಕೈ /ga:ḷipəṭa/ ಗಾಳಿಪಟ /kənnəḍəka/ ಕನ್ನಡಕ			/so:məva:ra/ ಸೋಮವಾರ /ra:ma:jəṇa/ ರಾಮಾಯಣ /tʃəndama:ma/ ಚಂದಮಾಮ			/kra:ntivi:ra/ ಕ್ರಾಂತಿವೀರ /grənthəgəḷu/ ಗ್ರಂಥಗಳು /pra:ntgəḷu/ ಪ್ರಾಂತಗಳು		

Table 2. Experimental stimuli-word list.

the subject was instructed to read the visually presented word as quick)} as possible.

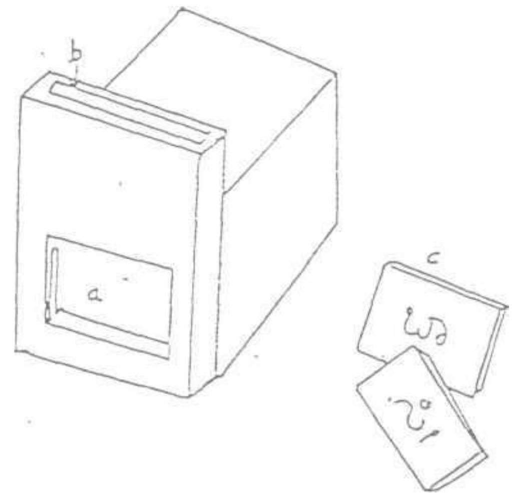

Figure 2: Manual slot machine: reading window (a), slot (b), stimuli on cards (c).

In the simple reaction time task, the presentation of the stimulus was followed by variable fore period of 2 to 5 sec. and then response signal was presented through a simple sound making device (figure 3). The subject was instructed to read as soon as possible after the presentation of the response signal.

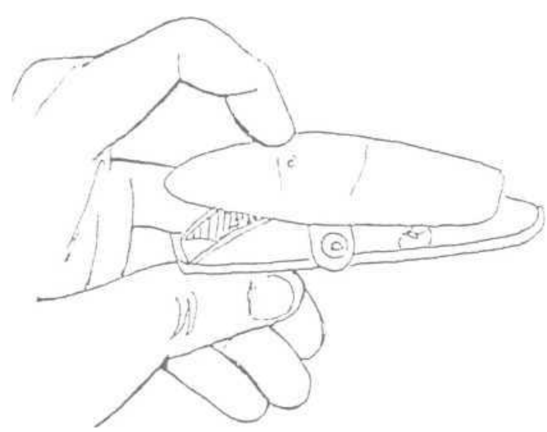

Figure 3: Sound making device used in simple reaction time task.

Instrumentation: The subject utterances and transient stimuli (noise of the card sliding through the slot machine in the choice reaction time task and sound generated by simple sound making device in simple reaction time task) were transduced by a microphone (Legend HD800) placed at equidistance from subject mouth and slot machine or sound making device.

The signal was then amplified by an audio-amplifier (Philiamp 60) and sent to the stereo cassette recorder (Sony TC-FX 170). The recorded utterances were then line fed from cassette deck into the computer memory with an analog to digital converter, digitized at 10 kHz sampling rate and 12 bit quantization. All the utterances were analyzed using CSL 50 (Computerised Speech Lab, Kay Elemetrics Corp.), speech analysis system for the measurement of speech reaction time (SRT) [Figure 4].

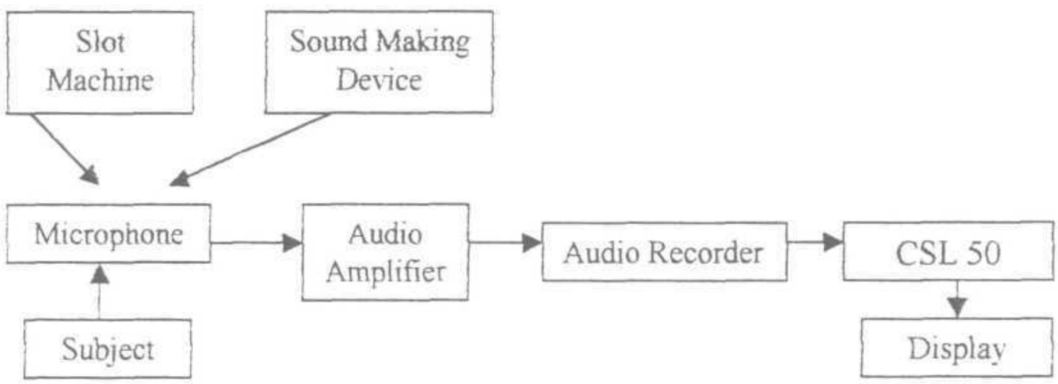

Figure 4: Schematic diagram of instrumentation set up during experiment.

Analysis: The speech reaction time was measured by the waveform display on the CSL. The time interval between onset of the transient stimulus presentation noise (generated by the fall of the card through the slot machine) and speech onset in acoustic domain was considered as SRT in choice reaction time task (figure 5). In the simple reaction time task. SRT is the time interval between the onset of transient stimulus generated by the sound making device and speech onset (figure 6). The SRTs were measured using time cursors on the waveform display program (CSL 50), to the nearest whole millisecond.

For this study, only those speech utterances judged to have been spoken fluently were analyzed. In order to be accepted as fluent, an utterance had to satisfy two criteria:

1. There should no visual signs of struggle in the subject's face or body just before or during the token. The experimenter took note of these visual signs of dysfluency during the recording session.

2. The utterances should not contain audible hesitations, prolongations and repetitions. These acoustic signs of dysfluency were judged by the experimenter from an audio recording of the subject' s speech.

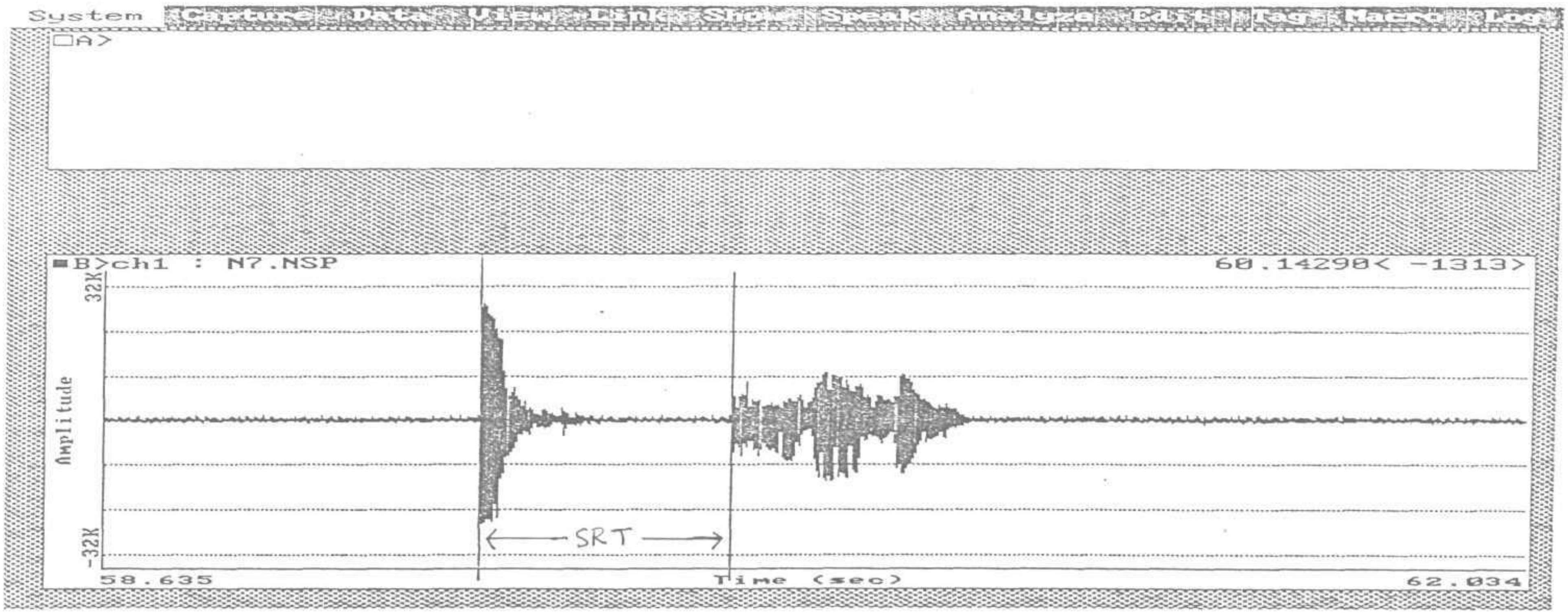

Figure 5: Depicts the measurement of SRT for the word /rəngoli/ in choice reaction time task.

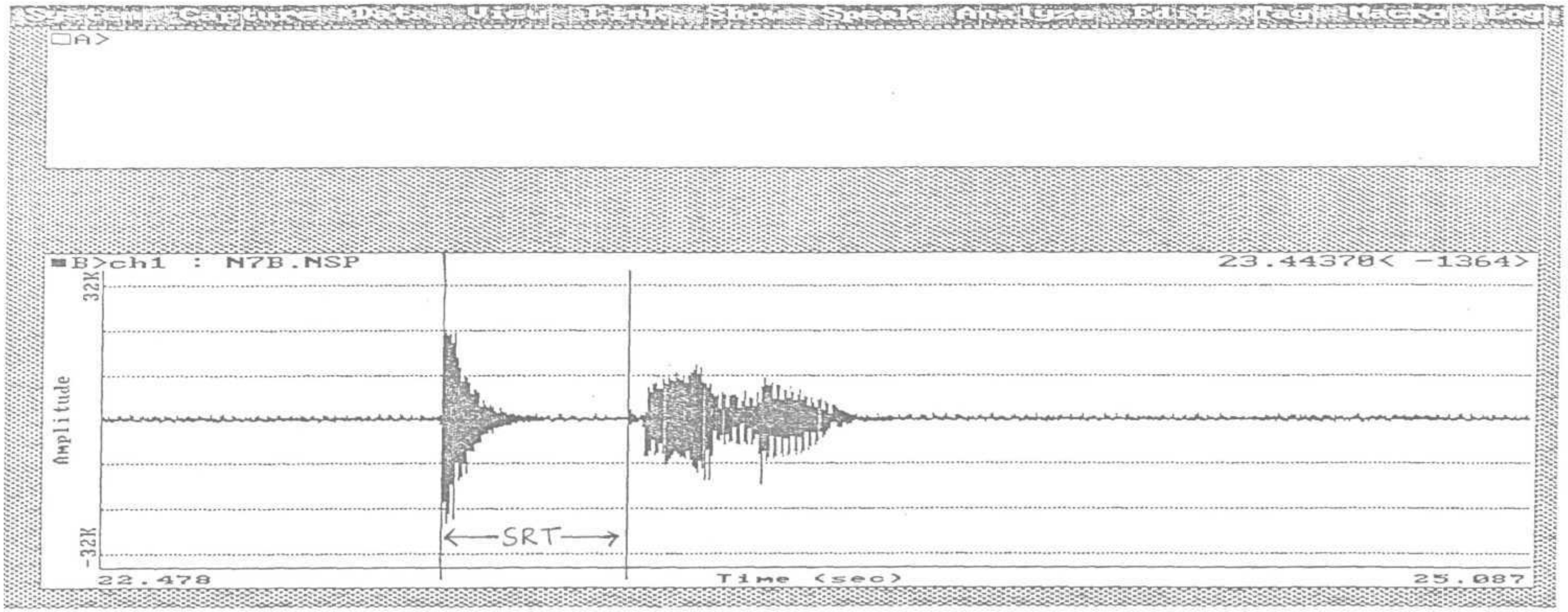

Figure 6: Depicts the measurement of SRT for the word /ka:lu/ in simple reaction time task.

One-factor analysis of variance (ANOVA) was carried out on speech reaction time data with length and complexity as within group comparison and three-factor analysis of variance (ANOVA) was carried out with length and complexity as between group comparison to find the interaction effect among them. This was followed by Duncan post hoc test to identify the locus of significant difference. The analysis was carried out separately in simple as well as choice reaction time paradigm.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

The results of the present study are presented in two major sections. The first section presents the SRT (Speech Reaction Time) data for the choice reaction time task (i.e., immediate reading task). The second section presents the SRT data for the simple reaction time task (i.e., delayed reading task).

CHOICE REACTION TIME TASK

1) Mean SRT's for varying word length and complexities

Table 3, 4 and 5 show the mean speech reaction times and standard deviation for stutterers and normals for four levels of word lengths and three levels of complexities.

	Stutterers		Normals	
Word length	Mean	SD	Mean	SD
Monosyllabic	586	84	517	87
Bisyllabic	608	103	515	62
Tri syllabic	607	146	523	123
Polvsvllabic	719	126	619	113

Table 3. Means and standard deviation of SRTs (in msec) of stutterers and normals for four levels of word lengths at complexity 'A' condition.

Word length	Stutterers		Normals	
	Mean	SD	Mean	SD
Monosyllabic	670	130	562	100
Bisvllabic	659	123	584	85
Tri syllabic	654	105	569	96
Polysyllabic	738	104	608	96

Table 4. Means and standard deviation of SRT's (in msec) of stutterers and normals for four levels of word lengths at complexity 'B' condition.

Word length	Stutterers		Normals	
	Mean	SD	Mean	SD
Monosyllabic	602	119	578	85
Bisvllabic	667	101	578	71
Tri syllabic	667	129	565	111
Polv svllabic	765	166	650	103

Table 5. Means and standard deviation of SRTs (in msec) of stutterers and normals for four levels of word lengths at complexity 'C' condition.

The results indicated that stutterers had longer speech reaction times and greater deviations compared to normals for all the levels of length and complexity.

Figure 7 indicates the effect of world length and complexity on the speech reaction times of stutterers and normals.

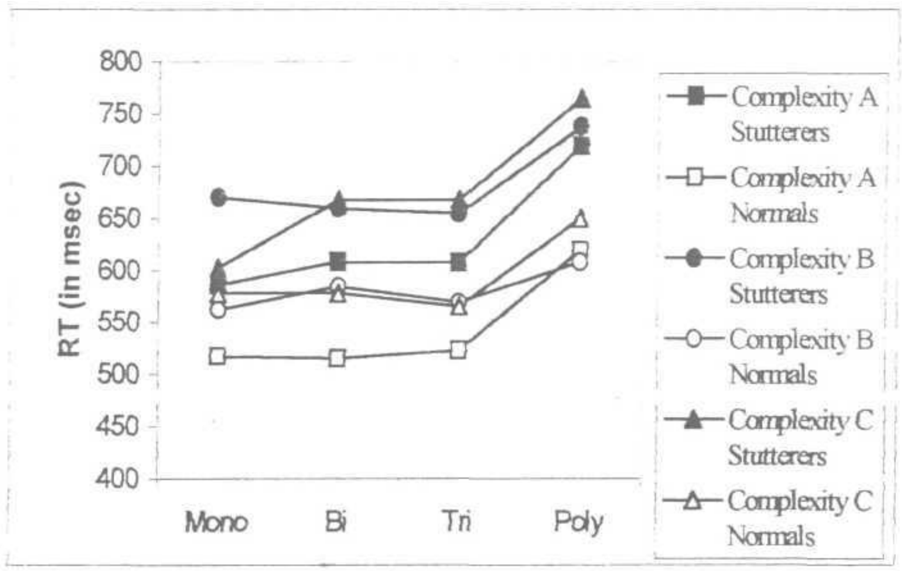

Figure 7. Mean SRTs across words varying in word length and word complexity among stutterers and normals.

It was found that

a) there was a definite increase in SRTs between mono and polysyllabic words for normals and stutterers. However, there was no clear trend between mono, bi and trisyllabic words in both groups.

b) Stutterers and normals had longer speech reaction time for complexity 'C compared to complexity 'A' condition. However, there was not much difference between complexity 'B' and complexity 'C' condition for both the groups.

2) Within group comparisons

(a) Word length: Results showed a significant difference in speech reaction time for increasing word length across complexity A, B, C in both the groups (Table 6).

	Complexity	F-test	P values
Normals	A	6.598	0.000*
	B	1.174	0.324
	C	4.465	0.005*
Stutterers	A	6.872	0.000*
	B	2.931	0.037*
	C	6.704	0.000*

* Significant at 0.05 level

Table 6. Results of ANOVA: F-test and P values depicted for increasing word length for different complexity conditions.

A post hoc analysis indicated that in stutterers, only the mean SRTs between monosyllabic vs polysyllabic, bisyllabic vs polysyllabic and trisyllabic vs polysyllabic word levels were significant across complexity A, B and C conditions. In comparison, normals showed a similar effect except at complexity 'B' condition, where there was no significant difference across the various word levels (Table 7).

	Stutterers			Normals		
	A	B	C	A	B	C
Mono Vs. Bisyllabic	21	11	65	2	↑ No significant difference ↓	0
Mono Vs. Trisyllabic	22	16	75	8		11
Mono Vs. Polysyllabic	132*	68*	163*	104*		77*
Bi Vs. Trisyllabic	1	5	10	6		13
Bi Vs. Polysyllabic	111*	79*	98*	102*		77*
Tri Vs. Polysylalbic	110*	84*	88*	96*		85*

* Significant at 0.05 level.

Table 7. Results of the Duncan post hoc analysis of mean speech reaction time differences (in msec) for increasing word length across complexities within a group.

(b) <u>Word complexity"</u> Table 8 shows the interactive effects of different complexity conditions as a function of an increasing word length.

	Word length	F-test	P value
Stutterers	Mono	4.409	0.015*
	Bi	2.239	0.98
	Tn	1.960	0.148
	Poly	0.759	0.472
Normals	Mono	3.262	0.044*
	Bi	6.283	0.002*
	Tn	1.411	0.250
	Polv	1.152	0.321

* Significant at 0.05 level.

Table 8. Results of ANOVA: F-test and P values depicted for increasing complexity for various word length conditions.

Post hoc analysis indicated that under most conditions, there was no significant mean SRT difference between simple and complex words. However, in stutterers, significant SRT differences between complexity 'A' vs complexity 'B' and complexity 'B' vs complexity 'C' at monosyllabic level.

In comparison, in normals as well, there were no significant mean SRT differences between simple and complex words at tri and polysyllabic word levels. However, at mono and bisyllabic levels, significant differences in SRT was observed between complexity 'A' vs complexity 'B' and complexity 'A' vs complexity 'C' conditions (table 9).

<table>
<tr><th rowspan="2"></th><th colspan="4">Stutterers</th><th colspan="4">Normals</th></tr>
<tr><th>Mono</th><th>Bi</th><th>Tri</th><th>Poly</th><th>Mono</th><th>Bi</th><th>Tri</th><th>Poly</th></tr>
<tr><td>Complexity 'A' Vs. Complexity 'B'</td><td>86*</td><td colspan="3" rowspan="3">No significant difference</td><td>45*</td><td>60*</td><td colspan="2" rowspan="3">No significant difference</td></tr>
<tr><td>Complexity 'B' Vs. Complexity 'C'</td><td>68*</td><td>16</td><td>03</td></tr>
<tr><td>Complexity 'A' Vs. Complexity 'C'</td><td>18</td><td>61*</td><td>63*</td></tr>
</table>

* Significant at 0.05%

Table 9. Results of Duncan post hoc analysis of speech reaction time differences (in msec) for increasing complexities across word length within group.

3) Between group comparisons

Between group speech reaction time, means were analyzed using three-way ANOVA. Table 10 shows the F test and P values for various interactions.

Results indicated that the three way interaction of length x complexity x group failed to reach the significance. Other interactions that failed to reach significance were word length x group, word complexity x group and complexity x length. However, the stutterers had a significantly longer speech reaction time compared to normals. Also, the effects of length and complexity were significant.

	F-test	P values
Group	106.766	0.000*
Complexity	12.596	0.000*
Length	25.282	0.000*
Group x complexity	0.282	0.755
Group x length	1.268	0.284
Complexity x length	1.100	0.361
Group x complexity x length	0.767	0.596

* Significant at 95%

Table 10. Results of three-way ANOVA. F-test and P values depicted for interactive effects of word length and complexities between groups.

Post hoc analysis for word length indicates that polysyllabic words had a longer speech reaction time compared to mono, bi and trisyllables. The later three levels failed to reach the significance (table 11).

Length	No. of samples	SRT	
		Subset 1	Subset 2
Mono	162	586	
Bi	160	602	
Tri	157	598	
Poly	155		685
Significance		0.217	1.000

Table 11. Duncan post hoc analysis of speech reaction time (in msec) for various word lengths.

Post hoc analysis for word complexities indicates that complexity 'B' and complexity 'C had significantly longer speech reaction times compared to complexity 'A' but there was no difference in SRTs between complexity 'B' and complexity 'C conditions (table 12).

Word complexity	No. of samples	SRTs	
		Subset 1	Subset 2
Complexity 'A'	213	586	
Complexity 'B'	211		631
Complexity 'C'	209		631
Significance		1.000	0.687

Table 12. Duncan post hoc analysis of speech reaction times (in msec) for various word complexities.

To summarise, the results of choice reaction time task revealed:

(1) Significant differences in SRTs between normals and stutterers with longer SRTs in stutterers.

(2) Significant differences between the SRTs of monosyllabic vs polysyllabic, bisyllabic vs polysyllabic and trisyllabic vs polysyllabic across complexity A, B and C.

(3) There was no significant mean SRT difference between simple and complex words except at monosyllabic level in stutterers, wherein significant difference was noticed between complexity 'A' vs complexity 'B' and complexity 'B' vs complexity 'C conditions.

(4) There was no significant interaction between group x length x complexity, group x length and group x complexity. However, length and complexity effects were significant.

SIMPLE REACTION TIME TASK

1) Mean SRTs for varying word lengths and complexities

Table 13, 14 and 15 show the mean speech reaction time and standard deviation for stutterers and normals for four levels of word lengths and three levels of complexities.

Word length	Stutterers		Normals	
	Mean	SD	Mean	SD
Mono svllabic	326	58	265	61
Bi svllabic	313	84	269	62
Tri syllabic	295	68	256	65
Polv svllabic	327	73	277	60

Table 13. Means and standard deviation of SRTs (in msec) of stutterers and normals for various word lengths at complexity 'A' condition.

Word length	Stutterers		Normals	
	Mean	SD	Mean	SD
Mono syllabic	308	65	272	60
Bi syllabic	302	59	261	59
Tri syllabic	312	77	270	62
Poly syllabic	330	55	270	55

Table 14. Means and standard deviation of SRTs (in msec) of stutterers and normals for various word lengths at complexity 'B' condition.

Word length	Stutterers		Normals	
	Mean	SD	Mean	SD
Mono syllabic	325	85	285	71
Bi syllabic	322	*69*	270	62
Tri syllabic	320	71	279	66
Poly syllabic	335	87	270	61

Table 15. Means and standard deviation of SRTs (in msec) of stutterers and normals for various word lengths at complexity 'C' condition.

Results indicated that stutterers had longer speech reaction times compared to normals for all the levels of length and complexity.

Figure 8 shows the effects of word and complexity on speech reaction times.

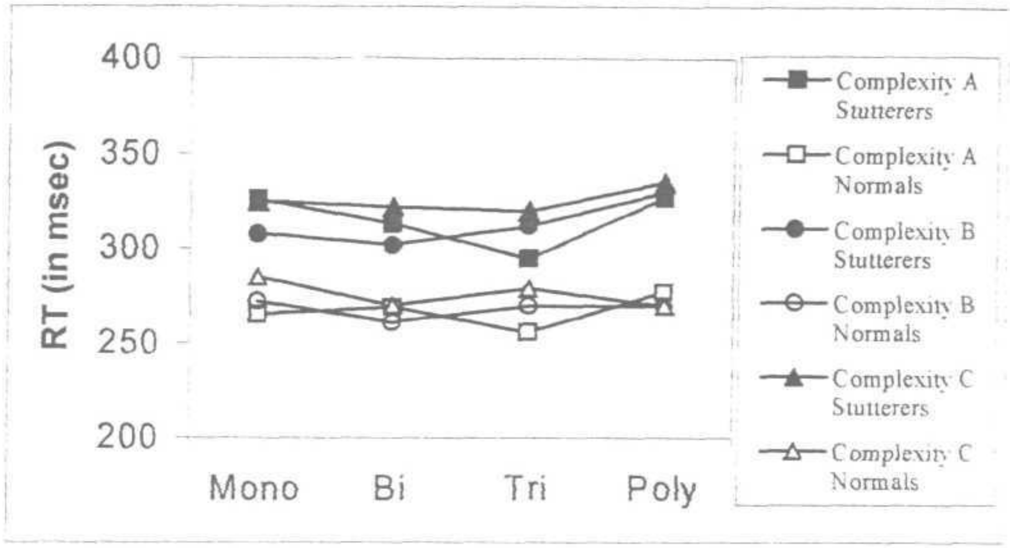

Figure 8. Mean SRTs across words varying in length among stutterers and normals.

There was not much difference in speech reaction times across various word lengths and complexity conditions.

2) Within group comparison

a) Word length: Table 16 shows the interactive effects of difference word lengths as a function of increasing complexity.

	Complexity	F-test	P values	Significant/ Non-significant
Stutterers	A	0.511	0.676	NS
	B	0.186	0.906	NS
	C	0.362	0.781	NS
Normals	A	1.145	0.335	NS
	B	0.891	0.448	NS
	C	0.204	0.893	NS

NS: Not significant at 0.05 level

Table 16. Results of ANOVA. F-test and P values depicted for increasing word lengths across different complexity conditions.

Results indicated that in stutterers and normals, there was no significant differences in SRTs between mono. bi. tri and poly syllabic word levels across three complexity A, B and C conditions.

b) Word complexity: Table 17 shows interactive effects of different word complexities as a function of various word lengths.

	Word length	F-test	P values	Significant/ Non-significant
Stutterers	Mono	0.579	0.563	NS
	Bi	0.521	0.596	NS
	Tri	0.581	0.562	NS
	Poly	0.091	0.913	NS
Normals	Mono	0.684	0.508	NS
	Bi	0.578	0.562	NS
	Tn	0.837	0.432	NS
	Poly	0.130	0.878	NS

NS: Not significant at 0.05 level

Table 17. Results of ANOVA. F- test and P values depicted increasing word lengths across different complexity conditions.

Table 17 reveals that at all levels of word length, there was no significant mean SRT difference between simple and complex words in both the groups.

3) Between group comparison:

Three-wav ANOVA was carried out to see the interaction effect of length x complexity x group.

	F-test	P values
Group	80.258	0.000*
Complexity	1.502	0.224
Length	1.312	0.269
Group x complexity	0.068	0.934
Group x length	0.503	0.680
Complexity x length	0.506	0.804
Group x complexity x length	0.245	0.961

* Significant at 0.05 level.

Table 18. Results of three way ANOVA. F-test and P values depicted for interactive effects of length and complexity between the groups.

The results of three way ANOVA showed that there was no interaction between group x complexity, group x length, complexity x length and group x length x complexity. The length and complexity does not yield in any change in speech reaction time. The only difference is that stutterers as a group had a longer speech reaction time compared to normals (table 18).

To summarize, the results of simple reaction time task revealed:

(1) Stutterers, as a group had longer speech reaction time compared to normals.

(2) The speech reaction time did not increase with increase in word length or complexity" in both groups.

(3) There was no significant interaction of group x length x complexity.

DISCUSSION

The present study was set up to find evidence that people who stutter differ from control speakers in the way that they process information at the stage of motor planning or muscle command preparation/execution.

The results of the speech reaction times in choice and simple reaction time paradigm are discussed separately.

Choice Reaction Time Paradigm

The results of the present study revealed slower speech reaction times in stutterers as compared TO normals. This is in line with other findings (Peters et al., 1989; Van Lieshout et al, 1996a, b; and Aravind, 1997). This supports the well established notion of slower speech reaction times in stutterers compared to normals. The manipulation of word length and complexity has some significant results. Speech reaction time was significantly longer for polysyllabic words compared to mono, bi and trisyllabic words within the groups as well as between the two groups, i.e., SRTs increased as a function of word length in both stutterers and normal control subjects. The equal amount of difficulty in both groups for increasing word lengths is due to an increased programming time required to centrally organize utterances of increasing length (Klapp & Wyatt, 1976; Peters et al., 1989; and Van Lieshout et al.,1991).

On closer inspection, results revealed an increase in speech reaction time (17 msec) between mono and bi syllabic words and also between tri and poly syllabic words (80 msec), but no clear difference between bi and tri syllabic words.. However, statistically significant difference was not found between mono, bi and trisyallabic words but all these three levels differed significantly from polysyllabic words. This effect was not seen in normals at complexity 'B'. Similar results were obtained by Aravind (1997) who used the same material.

On contrary, Van Lieshout et al., (1996b) showed a clear difference in reaction time between monosyllabic and bisyllabic words, however, adding an extra syllable to a word that already had more than one syllable did not automatically increase the choice reaction time. They explained that by assuming that for words with more than two syllables, the subject could choose to start executing these first two syllables whereas the remaining syllables are processed in parallel at earlier stages. Klapp and Wyatt (1976) already mentioned this possibility and more recently by Verway (1994) [c.f. Van Lieshout et al., 1996b].

The differences in these studies can be explained by extending the Kombrot (1989) view, revealing that the effect of number of units that have to be prepared within a single motor plan, will depend on the way in which subjects can organize the motor task they have to perform. So the same number of syllables per word can have different effects on SRT, according to the way in which at a higher organizational level, individual syllables can be grouped together, eg., with respect to the place and manner of articulation. The number of nodes at the highest level determines the reaction time.

Another possible explanation for differences could be due the subject variables that could, influence the reaction time. These include speed of individual's central nervous system preparation processing (Watson & Alfonso, 1983; and Peters & Hulstijn (1987), as well as preparatory posturing of responsive peripheral structures (Watson & Alfonso, 1983). In the present study, the subject variables were not controlled, whereas in Van Lieshout et al., (1996b) study, they instructed the subjects to inhale following the warning signals.

Some amount of increase in speech reaction time for polysyllabic words could be attributed to the subjects reading the stimulus (Peters et al., 1989). Longer words may take longer to read and may also have lower word frequencies. Also, lexical access and retrieval times may also influence the reaction time.

With respect to the word complexity manipulation, the complexity- 'B' and complexity 'C' showed significantly longer speech reaction times compared to complexity 'A' but there was no differences in SRTs between complexity 'B' and complexity 'C' (between group comparison results). This supports the fact that complex words in general, were produced much slower than simple words and it indicates that they were more difficult to articulate.

However, within group comparison results revealed that complexity' effects were evidenced for complexity A vs B and B vs C only at monosyllabic word level in stutterers and complexity' A vs B and A vs C at mono, bisyllabic word levels in normals. Although simple words were not statistically different from complex words, they showed greater SRT for complex words. In comparison, Van Lieshout et al., (1991) did not find significant difference between simple and complex words at bisyllabic word levels.

The most important aspect of this all is the fact that in the present study group differences, word size and word complexity showed no significant interaction in the choice reaction time. Apparently, people who stutter processed the information for longer and more complex words in the same way and in the same time scale as control speakers. Thus, the present findings do not support the hypothesis that persons who stutter have a deficit in assembling motor plans (or speech planning), as was claimed by number of authors (Peters et al., 1989; Bosshardt, 1990, 1993; Postma & Kolk, 1993; Hubbard & Pnns, 1994; Wijnen & Boers, 1994; and Aravind, 1997).

The present study supports the previous findings by Van Lieshout et al., (1996a, b), in which persons who stutter and their matched controls also failed to show a differential effects for word size. This also seems in line with the findings of a recent study by Thronburg, Yairi and Povel (1994), in which stuttering children (with and without accompanying phonological deficits) showed no effect of phonological difficulty on their stuttering frequency.

A serious limitation in the significance of not finding a group by word size and complexity interaction effect may be found in the severity ratings for the stuttering subjects that were used in the present experiment. According to the SSI scores, there was only three moderate rating and other six subjects had relatively mild ratings. Dembowski and Watson (1991) have reported that word size effects people with severe stuttering more than people with mild stuttering. In this respect the present study comprised of subjects with a mild and moderate severity of stuttering than contradictory studies (Peters, et al., 1989; and Aravind, 1997) which had more subjects with a severe degree of stuttering. Therefore, the present data might not have shown word effects.

Another possible explanation might be found in the type of stimuli, Peters et al., (1989) used in their experiment. In contrast to the present study, the stimuli were one-syllable words, three to four syllable words and sentences of about 10 syllables with different number of words in a sentence. With respect to the model of Stemberg, et al., (1978), this would have effected two different stages. Word size in number of syllables would influence the time flow in the unpacking stage, whereas utterance length in number of words or stress groups would influence the time flow in the retrieval stage. Therefore, their claim that stutterers have problems in programming speech motor sequences needs to be differentiated with respect to the programming phase (retrieval or unpacking or both).

Finally, the present study used only a word naming task, thereby introducing the problem of creating differences at other levels than just response preparation. The possible disturbing influences in this respect may arise from implicit speech and reading time variations (Klapp, et al.. 1974). Therefore, word size differences in SRT in word naming tasks must be taken with much caution.

In summary, the data of the present stud)' do not show evidence that persons who stutter have problems in processing information at the stage of motor plan assembly.

Simple reaction time paradigm

Stutterers in the present study exhibited significantly slower reaction times compared to normals. Similar results were obtained by many studies who used the speech stimuli for measurement (Starkweather, Hirschman & Tannenbaum, 1976: Steinberg, Monsell, Knoll & Wright, 1978; Reich, Till & Goldsmith, 1981; Till, Reich, Dickey & Seiber, 1983; McKnight & Cullinan, 1987; Peters et aL, 1989; Bishop, Williams & Cooper, 1991; and Dembowski & Watson, 1991). The results of the present study support the notion that stutterers are slower in speech initiation than normals.

Word size and word complexity manipulation did not effect the reaction times in both the groups. The speech reaction time in the present study did not increase with increase in word length or word complexity. However, the literature examining the effects of response complexity on both stuttering and normal population was with some inconsistent results.

On one hand, some studies suggest that syllable number does not influence the reaction time (Eriksen, Pollack & Martague. 1970; Klapp & Wyatt, 1976; and Starkweather et al., 1976). On the other hand, other studies indicate that syllable number significantly influences reaction time (Sternberg et al., 1978; Reich et aL, 1981; Watson & Alfonso, 1982; Till et al., 1983;

McKnight & Cullinan, 1987; Peters & Hulstijn, 1987; Peters et al., 1989; Bishop et al., 1991; and Dembowski & Watson, 1991).

The inconsistent findings among reaction time studies examining response complexity effects may have resulted in part from failure to control utterance initial phonetic features and propositionality, both of which significantly influence reaction time results (Starkweather, et al., 1976). This was further supported by Kornbrot (1989). Also the reaction time differences as a function of complexity may be influenced by preparation time. The preparation time may be increased by response complexity (response variables) and by relative inefficiency of control and peripheral physiologic process (subject variables as discussed in the previous section) or combination of these. Other variables which can effect the preparation time include fore period duration (the time between warning and response signals), and the fixed or random structure of fore periods and inter trial intervals (ITIs). The present study used the fore period of 2-5 sec. and used a variable inter trial interval. Further, differences in the results could be attributed to material used by different authors. Most of the authors who reported an increased speech reaction time with increased length compared the single vowel with the words or phrases, whereas the present study used only words varying in the number of syllables. This is in consonance with the results of Starkweather et al.,(1976) who used the similar type of stimuli. Their results showed no significant difference in reaction time between mono and bisyllable words. In some studies, word size effect was observed only either of the stutterers group or normal group but not for both the groups.

According to Sternberg, et al., (1978), the whole motor sequence is prepared in advance, before the "go" signal and stored in the motor buffer. After the go signal has been detected, this motor buffer is searched for the correct unit. If there are more units in the motor buffer, this search is assumed to take more time, which explains the greater reaction time found in longer sequences (more number of words or stress groups). But the present study used a single unit, which is why the difference in reaction time was not found. After this retrieval stage, the unit has to be translated into movement commands. Sternberg uses the term 'unpacking'. This second unpacking stage takes little bit longer if there are more syllables or constituents in a unit. According to this polysyllabic words should show a greater reaction time compared to mono, bi and trisyllabic words. But the results of the present study were contrary to this. The reason could be attributed to the variability in the reaction times between the stimuli. One can also speculate with caution that the unpacking may be taking place simultaneously for all the syllables in a word.

Since word length and complexity does not show any significant differences in speech reaction times for both the groups, the interaction effect between group x length x complexity was also not found. This supports some of the previous studies which did not find any interaction between group and word size (Starkweather, et al., 1976; Reich et aL 1981; Watson & Alfanso, 1982; McKnight & Cullinan, 1987; Peters, et al., 1989; and Dembowski & Watson, 1991). On contrary, some studies found a significant interaction between group and word size (Till et al 1983; Peters & Hulstijn. 1987: and Bishop et al., 1991) indicating that people who stutter (children or adults) have problems in muscle command preparation stage reporting a greater simple reaction time differences than normal speakers for longer (or more complex) words. However, the present study do not support the view that stutterers differ from normals at the muscle command preparation stage.

Between simple and choice reaction times

Differences in speech reaction times between normals and stutterers were calculated for both simple and choice reaction paradigms (Table 19).

Complexity / Word length	Simple reaction time			Choice reaction time		
	A	B	C	A	B	C
Mono	61	36	40	69	108	24
Bi	44	41	52	93	75	89
Tri	39	42	4	84	85	102
Poly	50	60	65	100	130	115

Table 19. Mean reaction time differences (in msec) between normals and stutterers in simple and choice reaction times.

Table 19 reveals that differences in choice reaction time between normals and stutterers was more in the choice reaction time paradigm compared to simple reaction time paradigm.

Peters, et al., (2000) suggested that subjects who have programming related deficits will have normal RTs in a delayed reading task (i.e. simple reaction time paradigm) and relatively longer RTs in the immediate reading task (i.e. choice reaction time paradigm). Keeping this assumption in mind, the results of the present study do not support exclusively programming related deficits. There can be possibility that more than one process may be involved. Postma et al., (1990) propose an impairment on similar lines. According to them, stutterers may have an impaired execution stage in addition to planning deficit. Their data indicates that either speech execution stage is independently impaired or that a speech programming defect is aggravated by tasks involving actual motor execution of speech. However, present study measured reaction times only in the acoustic domain, in the absence of simultaneous gathering of physiological data, it is difficult to answer the differential involvement of programming and execution stages in normals and stuttering groups. Involvement of more than one speech motor processed in stutterers indicates the sub grouping in the stutterers.

Another speculation could be a common factor which may affect these motor processes. One such can be a peripheral afferent information during movement execution. Recent research has shown that such a feedback *is* important not only in the programming, but also during the execution of articulatory gestures. Moreover, anatomical evidence has shown that certain components of speech mechanism, such as the messeter, perioral, and tongue muscles are richly endowed with receptors that provide important kinesthetic feed back. Pindzola (1987) hypothesized that people who stutter may have difficulties in interpreting sensory information for the control of movement. This was supported by many of the recent studies (De Nil, 1994; and Archibald & De Nil, 1999).

Another explanation for slower speech reaction time in both paradigms could be that people who do and who do not stutter differ in their preferred type of motor control strategies, that is in the way they set their muscle force parameters to control movement speed. Further, Van Lieshout, Alfonso, Hulstijn and Peters (1994) [c.f. Van Lieshout et al, 1996b] reported consistent asynchronies across people who stutter in the timing of peak velocity of lips and jaw, which seems to provide experimental evidence from an articulatory kinematics perspective as a control strategy' wherein feed back plays a major role.

In summary, in simple and choice reaction time paradigms, the results do not support the view that stutterers have problems either at motor plan assembly stage or muscle command preparation stage. However, when we compare the two groups between simple and choice reaction time paradigm, results showed a multiple process involvement in stutterers i.e., some amount of programming as well as execution.

CHAPTER V

SUMMARY AND CONCLUSIONS

In the last three decades, stuttering has been viewed as a disorder of speech motor control (Adams, 1974; Kent 1984; and Ludlow, 1991). However, the speech motor control perspective of stuttering is more than just one single theory or model. Some of the suggested etiologies for stuttering behaviours include speech motor programming deficits (Peters, Hulstijn & Starkweather, 1989), deficits in speech execution (Borden, 1983, Harbison, Porter & Tobey, 1989), deficient feed forward adaptation skills (Caruso, Gracco & Abbs, 1987), hyperreflexia and disinhibition of brainstem reflexes (Zimmermann, 1984). Hence the present study was planned to investigate whether the difficulties in people who stutter are in planning or initiation of speech. Specifically a reaction time paradigm was used.

Subjects consisted of nine adult male native speakers of Kannada who stutter (16-29 years, mean age = 22.6 years) and nine adults who do not stutter (18-30 years, mean age = 23.8 years). The stimuli consisted of 36 meaningful Kannada words varying in word length (monosyllabic, bisyllabic trisyllabic and polysyllabic) and motor complexity (complexity A: words with phonemes /b/, /t, /k/, /m/, /g/, complexity B: words with phonemes /dz/, /s/, /r/, */l/* and complexity C: words with clusters: /sk/, /sl/, /bl/, /kr/, /*bhrl, /gr/,* /pr/). Each subject was measured in two different tasks. Immediate (analogous to choice reaction time task) and delayed (analogous to simple reaction time task) reading of the stimulus. In the first task, each stimulus card was slid into the manual slot machine and the subject was instructed to read the visually presented word as quickly as possible. In the second task, the presentation of stimulus was followed by vanable fore period of 2 to 5 sec. and the subject was instructed to read as soon as possible after the presentation of the response signal. All the utterances were analyzed using CSL 50 (Computerized Speech Lab, Kay Elemetrics Corp.), speech analysis system for the measurement of speech reaction time i.e.. the time interval between stimulus presentation and speech onset.

The results showed an increased speech reaction time (SRT) for stutterers as compared to normals in both simple as well as choice reaction time paradigm. The effect of word length and complexity was found only in the choice reaction time task, and there was no interaction of group x length x complexity in both the tasks.

Differences in SRT between normals and stutterers in simple and choice reaction time task do not support the view that stutterers exhibit difficulties at the level of motor plan assembly stage or muscle command preparation stage. However, differences between simple and choice reaction time tasks may indicate multiple process involvement in stutterers.

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