A Comparative Study of Speech Motor Programming in Stutterers and Non-stutterers

Reg. No. M9501

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A DISSERTATION SUBMITTED AS PART FULFILMENT OF
FINAL YEAR M.Sc. (SPEECH AND HEARING)
TO THE UNIVERSITY OF MYSORE, MYSORE.

ALL INDIA INSTITUTE OF SPEECH AND HEARING
MYSORE - 570 006
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MAY 1997

Dedicated to

Dr. (Mrs) SAVITHRI, S.R.

A thought to prospective readers

" A little learning is a dangerous thing;
drink deep or taste not the pierian spring:
There shallow draughts intoxicate the brain,
and drinking largely sobers us again ".

Alexander Pope
(1688-1744)

CERTIFICATE

This is to certify that this disseration entitled "A COMPARATIVE STUDY OF SPEECH MOTOR PRGRAMMING IN STUTTERERS AND NON-STUTTERERS" is the bonafide work in partfulfilment for the degree of "Master of Science (Speech

and hearing)" of the student with register number M9501.

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CERTIFICATE

This is to certify that this dissertation entitled "A COMPARATIVE STUDY OF SPEECH MOTOR PRGRAMMING IN STUTTERERS AND NON-STUTTERERS" has been prepared under my supervision and guidance.

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DECLARATION

This dissertation entitled "A COMPARATIVE STUDY OF SPEECH MOTOR PRGRAMMING IN STUTTERERS AND NON-STUTTERERS" is the result of my own study under the guidance of Dr. SAVITHRI. S.R., Reader, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier at any University for any other Diploma or Degree.

Mysore
May, 1997

M9501

ACKNOWLEDGEMENT

First and foremost the investigator extends his heartfelt gratitude to his teacher and guide, **Dr. (Mrs.) SAVITHRI, S.R.,** Lecturer, Department of Speech Sciences, All India Institute of Speech & Hearing, Mysore, for her guidance, patience and inmmeasurable help. Also he would like to thank her for being a constant source of inspiration and for putting up with all his foibles.

Gratefulness is expressed to **Dr. (Miss) S. NIKAM,** Director, All India Institute of Speech & Hearing, Mysore, for permitting the investigator to take up this work.

Dr. NATARAJA, N.P. Professor and Head, Department of Speech Sciences is thanked for permitting the investigator to use the Speech Science Laboratories to conduct the study.

The investigator wishes to offer sincere thanks to **Dr. PRAKASH,** for his timely help with the statistics, and **MEGHA, S.** for her insightful reactions, comments on earlier drafts of this dissertation.

A special mention of thanks to **SPACEAGE ELECTRONIC TYPING,** for metamorphosizing the dissertation to its present delightful form.

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CHAPTER - I

INTRODUCTION

It would be unwise to discuss a formidable disorder as stuttering without a comprehensive definition. Wingate (1964) with a farsight has presented the most wholistic picture of stuttering in the perspective it needs to be understood in.

According to him, 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 some inco-ordination 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. It also unquestionably indicates that the "core" features are intricately laced with affective, linguistic and cognitive functions of the individual (Perkins, Kent and Curlee, 1991).

Stuttering as is " known" today has had its own rightful share of scientific curiosity. Wallowing through the history of research and theory on stuttering, it does not fail to surprise a curious investigator that no single theory till date has successfully "saved the phenomena" (As Perkins et al. (1991) point out in their "Neuropsycholinguistic view of stuttering). That is each theory successfully addresses only a part-of-the-whole phenomena and none explicitly accounts for all the evidence observed.

Currently stuttering is being explained from a motoric perspective (Adams, 1974; Kent, 1984). However, the portrayal of stuttering in the motoric facet has waxed and waned over the past few decades.

One of the earliest theories (Travis, 1934) postulates that an inadequate cerebral dominance produces a breakdown in the motor control of speech. In the years that followed, interest in neuro-anatomical and neuro-physiological substrates of stuttering dwindled, the reason as McFarlane and Prins (1978) point out was "partly because of the influence of Johnson's (1938, 1942, 1959) view that stuttering was a continuation of normal disfluencies and, later as a result of the rapid growth in popularity of behaviourism".

In 1960-70's, theory and research in stuttering was being focused on emotional issues (Sheehan, 1975), learning theory (Shames and Sherrick, 1963; Brutten and Shoemaker, 1967) and by the late 1970's laryngeal dynamics in stuttering gained importance and provided impetus for understanding stuttering in the speech motor control perspective (Starkweather, 1982; Zimmerman, 1980a, 1980c). However, the speech motor control perspective of stuttering is more than just one single theory or model. It encompasses at least four comprehensive motor control hypotheses proposed to fill the lacuna in the etiological domain of stuttering.

They are as follows as Ludlow (1991) summarizes: " Peters, Hutstijn & Starkweather (1989) have suggested a speech programming deficit; Harbison, Porter and Tobey (1989) and Borden (1983), have suggested that speech execution is affected; Caruso, Gracco and Abbs' (1987) results indicated that feedforward adaptation skills might be deficient; while Zimmerman (1984) proposed that hyper-reflexia and disinhibition of brainstem reflexes disrupt speech motor control during stuttering". Thus as evidenced, over the last decade, there has been a "snow ball" effect with respect to the upsurge of interest in stuttering as a disorder of motor control, in particular as a dysfunction at a level of processing preceding the overt execution of speech movements i.e, speech motor planning (Wijnen and Boers, 1994).

Recent literature indicates that amongst the different levels of speech motor programming (See Levelt (1989); Sternberg (1978)), phonological encoding (ie., mapping of lemma to lexeme) may be crucially involved in stuttering (Wijnen and Boers, 1994). According to certain authors (Postma &

Kolk, 1993) these phonological encoding errors are detected by an internal monitor and then subjected to covert/overt self repair. This very process of "self-repair" may be manifested as a clinical stuttering event.

Despite these theories and advancing state-of-the-art knowledge in stuttering research, no investigator has successfully isolated a single factor as being solely responsible for the etiology of stuttering, and probably none exists.

As I to (1982) points out, It is our limited knowledge regarding the central nervous system as a multivariable controller that constraints our understanding of the motor control system, it subservers.

In a like manner, Till, Reich, Dickey and Seiber (1983) suggest "A formidable obstacle to establishing the relative potency of neurologic and psychologic contributors to stuttering has been the relative inaccessibility of the nervous system to relevant, objective measurements". An enduring measurement technique which has been rampantly used to investigate sensory-motor events in the temporal domain is that of reaction time paradigms (Kahneman, 1973), in essence being adopted to study stuttering and driven by a fanatic hope to disambiguate the locus of lesion.

Further there is a consensus among various researchers (Peters et al. 1989) to utilize speech reaction time paradigms (SRT) (Speech Reaction Time = time interval between stimulus presentation and speech onset) with varied task complexities to study response preparation in the speech motor control perspective. It is to be understood that response complexity manipulation would enhance our perception about the multitude of processes and intrinsic variables operating during the disfluencies in speech.

Thus SRT paradigms (latency measures), not just measure differences in response between groups of non-stutterers and stutterers but also highlight the crucial processes that could be dysfunctional in stutterers.

Given this hindsight, if motor programming is aberant in stutterers and if stuttering events are manifestations of these motor programming errors, then with increasing task complexity one would expect.

(a) a greater difficulty for stutterers to plan and organize their sequences for production, the resultant of which may be a prolonged latency in speech reaction time and

(b) a proportional increase in the frequency of stuttering with task complexity.

In the past several studies have been conducted in which reaction time has been measured. (Adams, 1975, 1984; Starkweather Hirschman and Tannen baum, 1976; Starkweather, Franklin and Smigo,1984; Peters and Hulstijn and Starkweather, 1989). The results of these studies, though suggesting an increased reaction time in stutterers, are equivocal. If stuttering is viewed as a "disorder of movement" (Adams, 1975; Zimmerman, 1980a, Andrews, Craig, Feyer, Hoddinott, Howie and Neilson, 1983), then a possible disorder in advance preparation or the programming of speech motor activity in stuttering needs to be studied intensively. In this context, the present study was planned. The aim of this study was to investigate whether a longer Speech Reaction Time (SRT) in stutterers was a result of a programming disorder or whether it was caused by a disturbance of motor initiation. It should be clear that premotor planning or programming for speech is assumed to consume more time if utterances of increasing length have to be centrally organized.

In this study, length of the speech utterance was varied between a one syllabic word, a multi syllabic word and a short sentence. If stutterers encounter problems in the programming stage, then it could be predicted that the difference between stutterers and non-stuttereres in SRT would be greater in lengthy or complex utterances.

REVIEW OF LITERATURE

CHAPTER - II

REVIEW OF LITERATURE

I. Stuttering as a speech programming deficit.

The research literature on stuttering is extensive - spanning etiology, phenomenology and treatment. Meandering through this vast body of literature, one finds an ebb and flow of interest in distilling the phenomena of stuttering to a "disorder of movement" or a possible disruption in advance preparation or the programming of speech motor activity (Adams, 1975; Andrews et al. 1983).

Van Riper (1982) in his own words defined stuttering as a disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound in a word. Over the last two decades there has been a major resurgence of research interest in the speech motor control perspective on stuttering. This is mainly because the primitive descriptions based on perceptual evaluations such as repetitions of linguistically defined events (example: phonemes, syllables etc.,) led us nowhere in identifying and understanding the neuromotor production processes underlying these behaviours. As reiterated by Zimmerman (1980a, 1980c) such "descriptive vocabulary" may only "be useful in the clinic".

The central tenet of why stuttering needs to be considered as a "disorder of movement" or a disruption in the advance preparation for speech production, is to elucidate the connection between overt stuttering behaviours and the presumed underlying dysfunction of speech production mechanism.

Traditional theory and research in the field of stuttering has focused its attention on various epiphenomena rather than the underlying pathology.

Early theories for example repressed-need theories (Glauber, 1958; Travis, 1957), the approach-avoidance conflict (Sheehan 1953, 1975), the operant conditioning ((Shames and Sherrick, 1963) and the pheripheral discoordination hypothesis (Perkins, 1976, 1979; Adams, 1974, 1978), have viewed stuttering through a key hole and have falsely addressed struggle and avoidence as primary factors in the aetiology and pathophysiology of stuttering which are at best a stab in the dark.

The current arborations in stuttering research are conducive to an understanding of stuttering as a disorder of the complex neuromotor control system that subserves speech production (Zimmerman, 1980a). More recently a large amount of attention has been spent on explaining stuttering as a dysfunction of the motor execution of speech.

For the sake of parsimony, this review will confine to addressing major problems and evidences in favour of a speech planning deficit in stutterers. These approaches have in common atleast the idea that stutterers have greater difficulty than non-stutterers in initiating and controlling speech movements.

One hypothesis pertinent to motor dysfunction in stutterers is the discoordination hypothesis. It states that stuttering is presumably the result of constitutional inability to temporally co-ordinate respiratory, phonatory, and articulatory actions in speaking (Perkins, Rudas, Johnson and Bell, 1976; Caruso 1991).

This hypothesis has been deemed obsolete for two fundamental reasons.

(1) In order to conclude discoordination as a factor in etiology of stuttering it needs to be emperically demonstrated that it is ontogenitically prior to stuttering. (Wijnen and Boers, 1994).

On the contrary, Conture, Colton and Gleason (1988) found that selected temporal characteristics of coordination of speech related muscle contractions in the perceptually fluent speech of stuttering children, between 2 to 8 years of age did not differ significantly from those of their normal fluent peers. Indeed Conture later on concludes that generally voice onset times, voice initiation times, voice termination times and other measures of temporal co-ordination of respiration, phonation and articulation in stuttering children do not appear to differ from those in their non-stuttering peers. Molt (1991) in his study corroborates Conture's conclusion.

Thus, it can be inferentiaUy reasoned that the signs of motor discordination that have been found in adult stutterers are a consequence of stuttering rather than an antecedent.

(2) A second major argument to refute this discoordination hypothesis stems from its inability to account for and relate motor dysfunction to behavioural manifestations of stuttering.

As Wijnen and Boers (1994) claim " How could discoordination of respiratory, phonatory and articulatory muscles lead to a repetition and prolongation of speech sounds? " Zimmerman (1980a, 1980c) argues that discoordination results from neurophysiological instability, which also leads to oscillations and tonic behaviour. In this neuroscience view, oscillations would produce repetitions and tonicity would lead to prolongations.

However, according to Postma (1991) and Kolk (1991) it is hard to conceive how oscillations, in particular muscle groups could lead to repetitions of lingusitic events (example: syllables, linguistic segments etc.). Complex speech behaviours in stutterers are functional conglomerates of large numbers of muscles and their superordinate neural networks (Mackay, 1982) and physiological oscillations and tonicity explaining these speech behaviours are over simplistic. An alternative to the discoordination hypothesis are theories locating the central dysfunction at a level of processing preceeding the execution of speech movements i.e., speech planning. Bosshardt (1990) stated that ". . . . a strictly motoric interpretation of stuttering is insufficient if it is not supplemented by assumptions about differences in speech planning". ["motoric" according to Bosshardt is probably speech motor execution stage].

Crucial to the understanding of speech planning in the neuromotor control system for speech production is the concept of a "Program" or "motor plan" by which speech articulators are controlled. [Klapp, Anderson and Berrian, 1973; Rosenbaum, Gordon, Stillings and Feinstein, 1987).

The "motor plan" is an elaborate representation of all or most of the "intended utterance" constructed prior to the actual execution of the utterance itself (Stemberg, Monsell, Knoll and Wright, 1978; Keele, 1982; Hulstijn and Galen, 1983]. Such an advance preparation of the utterance is called motor pre-programming of speech. Although the motor preprogramming view has not been without criticism [example: Kelso, Tuller and Harris, 1983), several findings in the past seem to support the basic notion of advance response preparation (Keele, 1982; Schmidt, 1988).

Research on normal speech production, particularly with respect to "slips of-the-tongue", ""Metathesis" etc., as well as experimental analysis and studies on language pathology such as aphasia, have laid concrete evidence for the basic notion of advance preparation of speech motor movements (Laver, 1973; Dell, 1986; Levelt, 1983, 1989). Drawing largely from the concept of "advance response preparation" speech scientists have been quick to extrapolate and yoke these concepts into the field of stuttering.

In this context, skimming through a vast ocean of literature on motor pre-programming leads to an interesting proposition about the nature of stuttering.

II. Studies on Speech Motor Programming in Stutterers:

It has been often cited in literature that 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 (Soderberg, 1966), and sentences (Tornick and Bloodstein, 1976; Jayaram

1984). This, in conjunction with the assumption that utterances are supposed to be programmed before their initiation, suggests that a programming process may be underlying the aetiology of stuttering. (Hulstijn, 1987).

In the years that followed, various groups of researchers theorized, studied and emperically established impaired programming processes for speech in stutterers. Some studies have demonstrated a longer speech reaction time (SRT) associated with longer utterances, this effect being greater for stutterers than for non-stutterers (Peters, Hulstijn and Starkweather, 1989).

On comparable lines, Postma, Kolk and Povel (1990a) showed that stutterers were slower than non-stutterers in silent (sub-vocal) speech and still slower in lipped and overt speech conditions implying an increased speech planning difficulty in the former of the two groups apart from an extra amount of difficulty when motor execution is involved. In line with the foregoing surmise a succinct hypothesis has been put forward which views stuttering as a phonological encoding disorder. However, it is worthwhile to note that this concept stems from the "parental" notion of stuttering as a central programming deficit, as cited previously.

Inherent to the understanding of the above is the comprehensive knowledge of the stages involved in the speech production process and the role played by the "Formulator" (fig.l) (see Levelt 1989, for an extensive overview of the literature and a detailed model).

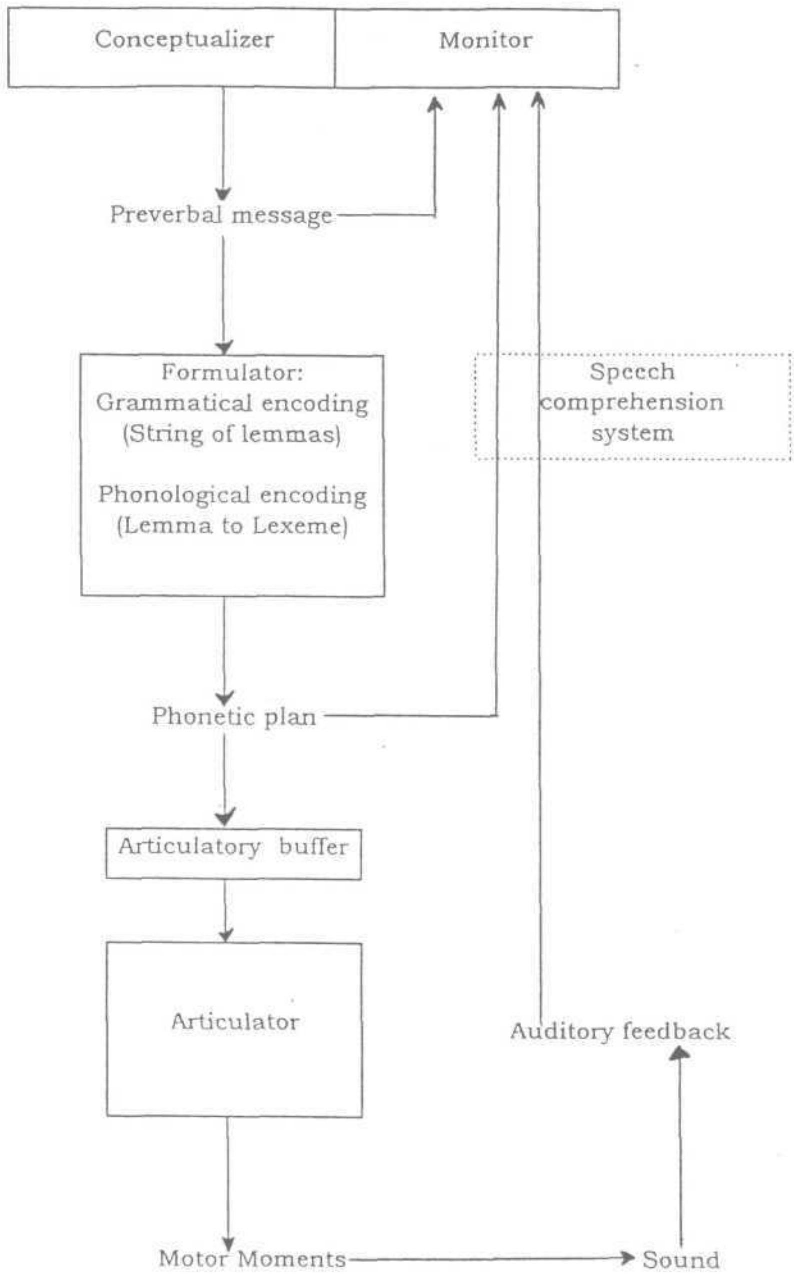

FIGURE 1. A speech production model with three Monitoring loops (adapted from Levelt, 1989).

The "formulator" recieves input from its preceeding stage the "conceptualizer" (The conceptualizer is a non-linguistic stage in which the basic topics to be expressed in an utterance are selected and represented in a preverbal, propositional code) based on which the "formulator" provides the utterance with its linguistic form.

The "formulator" has two major active subcomponents that are currently of interest to us: (1) **Grammatical encoding,** that is selecting appropriate words (lemmas) and ordering them syntactically; and

(2) **Phonological encoding,** that is elaborating the sound structure of words {to form lexeme (s)}.

The end product of "the formulator" is a phonetic or articulatory program specifying how the utterance should be pronounced (phonemes, syllables, stress etc.,). There is also a third, **"Articulator stage"** where the phonetic program is translated by the motor system into audible speech movements. But, the present discussion, will be confined to the two basic processes in the "formulator".

There is consensus among researchers that phonological encoding may be crucially involved in stuttering. A number of studies have demonstrated that stutterer's speech planning activities prior to any speech motor movement tend to deviate from normals (Peters, Hulstijn and Starkweather, 1989).

Wijnen and Boers (1994) point out that ". . . . Generally, stutterers have longer speech reaction times than non - stutterers on various tasks (see Starkweather (1987) for a good overview). Since, on the one hand, this difference is observed in tasks that apparently do not involve message generation and syntatic encoding, such as reading aloud, these processing components do not seem to be responsible. On the other hand, even in silent reading (i.e., without overt articulation), stutterers are slower than non-stutterers, which implies that the problem cannot be restricted to motor execution" , but in all probability involves phonological encoding difficulty.

It is also argued that the distributional analysis of patterns of stuttering errors in concordance with linguistic factors (i.e., repetitions, prolongations and segmental errors show a tendency to occur more frequently on consonants than on vowels, on syllable and word initial positions and on stressed syllables) relates to a phonological system involvement in these populations (interested reader may refer St. Louis (1979) for an excellent review).

Moreover, it is underscored that these stuttering errors parallel those of accidental sound errors (example: slips of the tongue, metathesis etc.,), which have been convincingly argued to arise during phonological encoding (Levelt, 1989; Postma, Kolk and Povel, 1990a). Further, the frequency of stuttering errors appears to be adversly affected by variables such as sentence length and complexity and also by the recurrance of identical or similar phonemes for example like during the production of tongue twisters (Postma, Kolk and Povel, 1990a).

Thus, from these myriad experimental findings it may be inferred that phonological encoding deficits (for example:- phonological encoding errors occuring during the mapping of lemma to lexeme) may have a considerable role to play in the aetiology of stuttering and the uncloaking of the hitherto futile search in this realm.

It is now firmly established that deficits in phonological encoding may be one of the factors in the aetiology of stuttering. This leaves us with another question to be answered:- How a dysfunction of phonological encoding account for the observed stuttering behaviours?

Postma, Kolk, and Povel (1990b) offer an explanation utilizing the "spreading activation model" (Dell, 1986). Here, the formation of lemma and lexeme can be envisioned as the spreading of activation in an intricate network of nodes, where in activation spreads down from superordinate word meaning representation [lemma (s)] nodes to the segmental level nodes to form lexeme(s) (Dell, 1986).

They assume that slowing down or a delay in the activation of these phonological segments disrupts the appropriate selection of these segments. As a rule, selection of segments for phonological encoding follows the "most - primed - wins" principle (see Mackay, 1982), if either priming, activation or linkage strength is aberrant in an "intended" to be activated node, then there is an increased tendency for misselections / errors to occur in the "articulately plan" that follows.

Kolk (1991) proposes that typical stuttering behaviours arise when the stutterer detects these misselections / errors through the "internal monitor" prior to overt execution of the utterance.

However, error detection interrupts speech flow and one or several attempts to revise and reoutput the articulatory plan produces overt repetitions and "holding" of the output until an appropriate articulatory plan is revised and selected, leads to prolongations. Internal monitoring, repair strategies etc., will be dealt in detail in the succeeding sections of this review.

In a similar vein, Wingate (1988) proposes a perturbation in the preparation of the articulatory program in stutterers. According to Wingate stuttering involves a specific difficulty in the computation of the prosodic parameters of the articulatory plan. Further, Wijnen and Boers (1994) assume that the "encoding problem is permanent" but overt stuttering ensues "only when the speaker asks too much of the 'weak' encoding mechanism".

III. Measurement of speech programming:

In the previous sections of this review, models and a number of studies are dealt with suggesting a central programming deficit in stutterers. One measurement technique in stuttering literature which has been utilized extensively to study the central programming of events is the reaction time paradigm. Utilizing this, there have been a surge of vocal reaction time studies beginning in the early 1970's (Adams, Freeman and Conture, 1984). The majority of these studies have recorded slower reaction times for stutterers than for non - stutterers.

A growing body of litereature suggests increased reaction time or latency when longer or more complex movements have to be initiated. Although substantiaal evidence is available in favour of the relationship between movement complexity and reaction time, there are innumerable controversies about the optimal paradigm to study programming.

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" task condition) task, subjects already know what response to perform and have only to wait for the "go" signal to execute a response task.

In choice reaction time tasks 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 (Klapp, Wyatt and Lingo, 1974) thereby causing them to respond more slowly.

Arguments on these lines about the optimum paradigm to be used in the study of programming leaves us at the famous "Klapp - Steinberg controversy" (see Hulstijn, 1987). On condensation and pooling in of the vast research data available, it is to be inferred that both these paradigms unequivocally test different types / levels of programming.

In this context, Hulstijn (1987) proposes 2 levels of programming :... the low level programming of relatively novel movements and the high level programming in which particularly the order of the units are planned. The units in such a plan can only be well learned movement sequences like letters or words". He suggests that a distinction between these levels of programming can bring together the different views on the optimal paradigm to Study programming.

In one of the best known Klapp's experiments (Klapp and Wyatt, 1976), the subjects had to press a morse code key either for a short - 'dit' or long 'dah'. However, in this study stutterers were slower than their non - stuttering counterparts on the choice reaction time task and not on the simple reaction time task.

Thus in light of these findings Hulstijn (1987) suggested that "recently - learned reactions like 'dit' - 'dah' key presses can be better studied in a choice reaction time paradigm, since their simple reaction time does not reveal their low level programming . . . However, the process called high level programming can probably better be studied, using a simple reaction paradigm with long sequences of well learned elements". Peters et al.'s (1989) study to an extent corroborates these speculations.

Nevertheless, Hulstijn (1987) in an ambitious overextension of these interpretations, suggests that in all probability it is the low level, motor command programming that is non - optimal in stutterers. But, in the following years van Lieshout, Hulstijn and Peters (1991) utilized a choice reaction time paradigm to study the effects of word size and word complexity on speech reaction times.

In contrast to Hulstijn's previous work, the latter study incorporated the idea that an immediate or choice reaction time task, where in the subjects were required to both construct a program and execute the same, was indeed a better central programming estimation tool than the simple reaction time paradigm. In simple reaction time tasks, the motor program / phonetic plan may have well been assembled at a higher level prior to the 'go' signal and thus on most accounts may not in actuality reveal programming processes such as phonological encoding.

However, reaction time paradigms are no means to an end in stuttering research. Some recent researchers working on reaction time paradigms have agreed upon the fact that subcomponents of reaction time (namely stimulus recognition, input processing, planning and motor execution) are not clearly delineated on such tasks (Peters et al. 1989 ; Postma, Kolk, and Povel, 1991).

As Till and co-workers (1983) note: "studies which measure total response time are difficult to interpret unambiguously because the locus or loci of the apparent delay in information transmission, processing, or execution cannot be inferred". In fact Peters et al. (1989) suggest that some variables such as input processing may also contribute to the observed delays in stutterers.

In simplistic terms for complex stimuli, more time is required for a more intense sensory analysis there by this factor would indirectly affect response latencies. With similar caution, Postma et al. (1991) acknowledge that "planning time" as well as "execution time" may be longer in stutterers which means that reaction time paradigms may obscure critical issues.

Despite the criticisms and pitfalls, some groups of enthusiastic researchers have tried to overcome the fundamental problem in reaction time paradigm studies by two "controversial" approaches.

1) Till et al. (1983) have cited in their paper a means to identify the locus of the stutterers problem by utilizing Netsel and Daniel's (1974) approach - conventionally utilized to study voluntary response to a reaction time stimuli. According to them, the total time required to initiate and complete a voluntary response to a reaction time stimulus is believed to consist of **(a) neural** and **(b) mechanical response times.**

Accordingly, **(a) Neural response time** can be subdivided into its constituent times of : **(1) sensory, (2) central organizational** and **(3) motor time.**

(1) Sensory Time:— Assumed to be the time interval between the stimuli / response cue and electroencephalographic (EEG) evoked potential at the sensory cortex.

(2) **Central Organizational Time** :-- Presumably the time interval between evoked sensory potential and motor potential or pyramidal tract discharge.

(3) **Motor Time** :— The time interval between the motor cortex discharge and the onset of first (electromyographic - EMG) muscle activity.

(b) **Mechanical Response Time** :-- The time interval between the onset of first EMG activity to the initiation or completion of the required movement (Netsell and Daniel, 1974).

Unfortunately, on reviewing literature, there has been no study undertaken comprehensively utilizing Netsell & Daniel's paradigm to analyse stutterer's reaction times because of questionable practicality of the same. But the idea of utilizing "muscle potential - EMG" latencies as a indicator of

"Organic - physiological" delay in stutterers is old, and in the speech motor control research area, well accepted. Several studies (for eg: McFarlane and Prins, 1978) have measured Neural response time (NRT) [NRT is defined as the time interval between stimulus offset and the onset of EMG activity from speech related musculature] in stutterers, and have found that stutterers in general were slower in NRT when compared to controls.

Nonetheless, most of these studies failed to manipulate response complexity to study speech motor pre - programming deficits in stutterers. Perhaps the 'orphan' study that utilizes various physiological events to understand and delineate pre - programming and motor initiation times is the one by Peters and Hulstijn (1987) .

They, by simultaneous recording of responses in laryngeal (surface EMG electrodes on laryngeal area and electroglottographic assessment), articulatory (surface EMG electrodes on orbicularisoris and musculus masseter) and acoustic domains (tape recording) divided output preparation time into programming and initiation times (Figure 2).

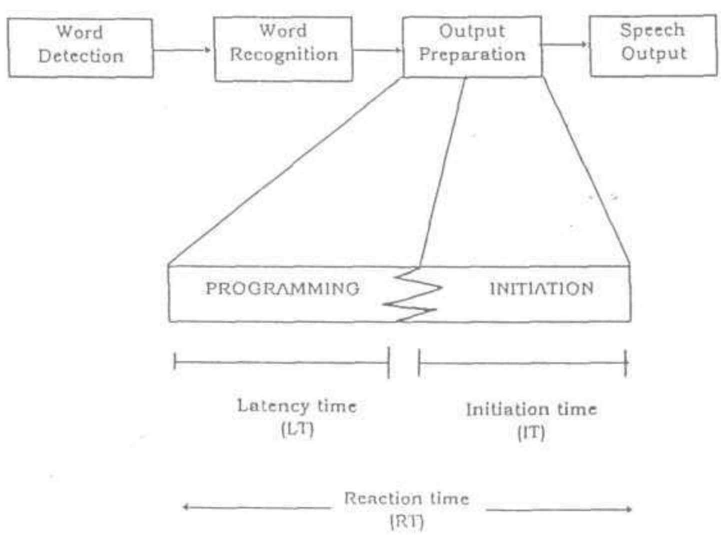

FIGURE 2. Schematic representation of programming and initiation of speech utterances in reading (cf. Peters and Hulstijn, 1987).

In the above Latency time (LT) is the interval between the response signal and the first manifestation of physiological activity (on EMG) and initiation time corresponds to the interval between the start of the first physiological activity and the onset of speech.

They assume that a lengthened latency time might reveal programming difficulty, if any, while a lengthened initiation time might give insighr into initiation problems mainly pertaining to co-ordination of muscle events - in a wholistic sense a "motoric" difficulty. As expected, the stutterers had longer latency times before the initiation of speech and more so with increases in utterance length (the independent variable in the study).

Ironically, the stuttering group also had longer initiation times for laryngeal and articulatory behaviours, suggesting that the output speech reaction times are a "combined effect" of programming and increased motoric difficulty.

Despite the potential inferential value of such EMG studies Starkweather, Franklin and Smigo (1984) caution the use of EMG recordings in the study of latency in SRT paradigms. Since EMG is dependent upon baseline muscle activity, high muscle activity levels in stutterers could produce artifactual EMG latency responses.

2) A second approach to emperically study the dependent variable (acoustic reaction time or speech reaction time) was to presumably manipulate the independent variable (reaction time stimulus). Here one assumes that by

varying the complexity of the reaction time stimulus the motor programming can be differentially varied.

For example: for speech it was found that by increasing the size of a word by altering number of syllables normal speaking subjects showed longer SRT's (Klapp et al. 1973; Klapp and Wyatt, 1976) [i.e., speech motor preprogramming is assumed to consume more time if utterances of increasing length have to be centrally organized].

A major question arising from the preceeding corpus of speech reaction time research is that :- How are the independent variables (reaction time stimuli) and dependent variables (SRTs) related? In other words, at this nebulous juncture, we need to understand in the first place why linguistic/ motoric complexity should influence SRT? Secondly, of immense interest to us is the reason why this effect is greater for stutterers than for non - stutterers?

Basic to the understanding of the above paradox, are the models for speech motor control. Thus, in this purview one needs to amalgamate various approaches to the modeling of motor control processes to study normal speech motor control and the underlying dysfunction in stutterers.

However, for reasons of brevity, the review in the following sections will be limited to some models, that comprehensively cover the basic essentialities that one needs to understand to cohesively study the speech motor control processes and derive its dysfunctional states.

IV. Models on speech motor **programming:--** The first and probably the most crucial model for understanding speech motor programming and answering our former question is by Sternberg et al. (1978) and was proposed in view of explaining the basic unit of the speech motor plan. (Fig. 3).

(a) Model for speech motor control by Sternberg et al. (1978).

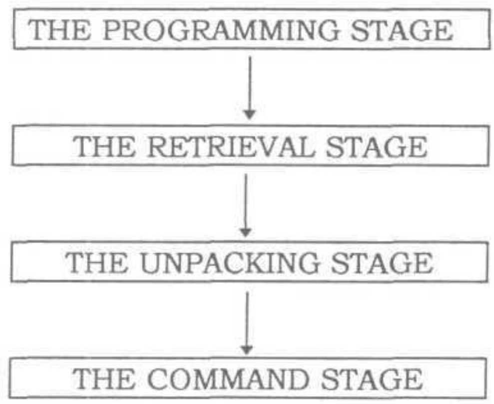

FIGURE 3. Model for speech motor control by Sternberg etal.(1978**).**

Stage I:

THE PROGRAMMING STAGE:

An articulatory/motor plan {phonetic plan (Levelt, 1989)} is assembled by phonological encoding. Each articulatory plan consists of sub units or sub programs in terms of words or stress groups. The total articulatory plan can be stored temporarily in an articulatory buffer awaiting further processing.

Stage II:

THE RETRIEVAL STAGE:

The motor plan is retrieved from the articulatory buffer, unit (sub-program) by unit. The retrieval takes more time if there are more units in the motor plan.

Stage III

THE UNPACKING STAGE:

Unpacking is done for each unit or sub program, for its constituents, which are motor commands for the different phonological elements (Syllables etc) within a unit. The unpacking takes more time if the unit is more complex, as defined by its size.

Stage IV

THE COMMAND STAGE:

Each individual motor command is sent to the neuro-motor system and subsequently executed.

(**Note:** The total time needed to prepare a response is an additive composition of each time interval resulting from separate stages, since different stages are considered to be independent from each other)

As lucidly illustrated in the figure 3, the I stage is the motor-programming stage, where a motor plan is assembled and stored in an articulatory - memory- buffer. In the retrieval stage or second stage, the articulatory/motor plan is retrieved from the articulatory memory-buffer, wherein the time for retrieval is influenced by the number of units (stress groups) in the buffer.

In the third/unpacking stage, each unit is unpacked or fractionized into smaller sub units (syllables, articulatory gestures, sounds). Here the processing time depends on the size of the motor plan unit as determined by, for example the number of syllables in a word or stress groups. (Sternberg et al., 1978; Levelt, 1989) which are then transferred to the fourth/neuro-motor command stage. In neuromotor command stage each sub-unit results in neuromotor system actions and execution of intended movements.

On the assumptions of this model, one can illuminate the intricate factors, that are responsible for increasing speech reaction times, with increasing response complexity.

In a nutshell the factors can be summarized as follows:

(1) In the light of Sternberg et al.' s model (1978), any increase in word length would have a direct effect on any of the four stages, that he proposes.

(a) In the first stage, presumably the phonological encoding comprises the creation of a fully specified articulatory program. Phonological encoding entails three sub processes (i) Selection of segments for a word or word(s); (ii) sequencing these segments to within syllable frames; and (iii) the fixation of intonational and temporal parameters for each syllable (Levelt, 1989). Each of this sub-process consumes greater time for a larger articulatory program that is required to be constructed for a larger word. Inductively reasoning from another facet, the number of nodes required to be organized in the phonological system are greater for longer utterance (Mackay, 1982).

(b) Along similar lines, the retrieval and unpacking stages are also adversly influenced by increasing response complexity.

(2) It is important to note that this model is limited, since it "does not add much to the understanding of specific speech motor production factors at the

level of motor execution" (van Lieshout et al. 1991). However, one can logically extrapolate relevant information from Mackay's (1982) node-structure theory at muscle movement (system) level to account for increase in SRT's by the number of muscle movement nodes required to be organized and activated for a complex utterance.

Having inferred, why SRT increases with increase in linguistic/motoric complexity., one should be in an advantageous position to answer the latter part of the question: as to why there is a greater increase in SRT's for stutterers than non-stutterers for increasing reponse complexity. As cited earlier, facts strongly suggest an aberrant speech planning organizational deficit in stutterers (e.g. Phonological encoding difficulty) (Peters et al. 1989; Postma et al. 1990).

Several studies from a developmental perspective have also shown that a considerable number of child stutterers have phonological problems (St. Louis, 1991; Louko, Edwards and Conture 1990) . Although these studies are not decisive per se, they strongly support the idea that the emergence of stuttering is correlated with an inability to appropriately phonologically encode an utterance to be spoken.

Thus from a clear minded anastamosis of the foregoing findings, it is evident that certain aspects of linguistic planning, and in particular the phonological encoding processes may be aberrant in people who stutter (Postma and Kolk, 1993) .

Now bearing in mind what has been discussed above and extrapolating the answer offered by the proponents of "covert-repair" hypothesis (Postma and Kolk, 1993), one can comprehensively derive an answer to the latter question. A corollary of "covert-repair" hypothesis is that, stutterers fluency problems originate from a deficit in the phonological encoding of an utterance. This deficit makes the phonetic plan vulnerable to phonemic and phonetic distortions. In turn these distortions or errors in programming are detected by internal monitoring loops and thereby provide many opportunities for covert self repair (covert self repair means the repair process that is initiated on detection of an error in the linguistic or phonetic program prior to overt articulation).

However, covert self repair or pre-articulatory editing is not easily done. The self repair (error detection, interruption, repair proper (or) correction) process is assumed to require a complete halt/interruption of the ongoing speech, and to one or several attempts to revise and reoutput the articulatory plan.

Essentially, people are thought to have two ways to covertly correct a detected speech programming error (Postma and Kolk, 1993). One way is called the 'restart' strategy (i.e., restart of the phonetic plan from a retraced position) and the other way is referred to as the postponement strategy (postponement strategy does not involve any retracing, but only revision of the not yet-executed part of the phonetic plan). Both these strategies have their equal share in overt stuttering manifestations (see table I).

Internal error	Covert repair	Disfluency
	Restart Strategy	
Semantic/ syntactic error	Restart phrase.	(1) Phrase repetition.
Lexical error	Restart previous word.	(2) Word repetition.
Phonemic error	Restart interrupted syllable from beginning.	(3) Blocking.
Phonemic error	Restart interrupted syllable from beginning.	(4) Prolongation.
Phonemic error	Restart interrupted syllable from beginning.	(5) (Sub) Syllabic repetition.
	Postponement strategy	
Semantic/Synthactic/lexical error	Hold execution, reformulate.	(6) Silent pause (> 200 msec.)
Phonemic error	Prolong current sound until proper continuation found.	(7) Prolongation of syllable non initial sounds (drawls).
Phonemic error	Hold execution next sound until proper continuation found.	(8) Blocking in the midst of a syllable (broken words).

Table I. Depicts the relation between internal error, covert repair and overt manifestation of disfluencies (cf. Postma and Kolk, 1993).

Thus, if a researcher needs to analyse programming difficulties per se in stutterers, then repair strategies also need to be incorporated into the test paradigm. One method of doing so is inclusion of stuttering errors (covert + overt repair times) in general SRT paradigms. In a similar vein, increased SRT in stutterers may be viewed as an attempt to 'hold' execution until an appropriate phonetic plan is selected.

Assuming that (Kolk, 1991; Postma, Kolk, & Povel, 1990b) phonological encoding is error prone in stutterers (in comparison to normal non-stiutterers) and the fact that a single covert repair cycle does not guarantee success, it would follow quite logically that they need multiple repairs in succession to achieve a correct program relative to a non-stutterer, thereby producing an increased latency, effect in SRT.

Directly in line with the foregoing are a myriad of studies that convincingly demonstrate that both speech error and disfluency frequencies increase with speaking rate (Mackay, 1971; Adams, Lewis and Besozzi, 1973; Perkins, Bell, Johnson and Stocks, 1979; Andrews, Howie, Dozsa and Guitar, 1982; Postma and Kolk, 1990). Speeding up speech tempo is thought to cause more planning lapses, (i.e., internal speech errors) that provides greater occasion for covert repair and would thus elevate overt error rate (Dell, 1986; Postma and Kolk, 1990a, 1990b). On parallel lines one might construe from the aforementioned, an analogus "time stress" (during the SRT task, wherein immediate response to stimuli is emphasized) situation that forces the stutterer to generate a phonetic plan at a very short notice which may be assumed to be equivocal to a speech motor plan that is generated when speeding up speech tempo.

Indeed from the assumption that stutterer's speech motor plans are error prone in the first place, it would be quite reasonable that they need more time (or as reflected in increased SRT's) especially under time stress situations for accurate covert repairs than other wise. However, it would be a pretentious task to deduce inferences from the foregoing by the very fact that with time stress there may also be a lessened accuracy demand in that condition (well known speed-accuracy trade off - for an explanation see Peters and Boves, 1988) or in other words a greater lapse in the internal and external monitering system i.e., the tendency to correct an error (eg., covert repair) will supposedly be less when speed of production is of concern and not accuracy (Postma, Kolk, and Povel, 1991) and this in a sense may conversely decrease SRT.

But for the present study we will capitalize on the posit that under time stress speech motor programming errors increase which are in concordance with increase in covert repair time as evidenced by increased latency in speech reaction times.

b) Spreading Activation Model:

The "spreading activation" model (Rumelhart and Norman, 1982; Dell 1986; Mackay, 1987) should be considered for its pertinence to the above mentioned issue. This model envisions speech production as a spread of activation amongst content nodes in a heirarchical network, descending from the sentential system through the phonological system and finally to the muscle movement system.

Here, the content nodes are present at each level and are represented as different functional entities at different levels. For example: content nodes within the muscle movement system represent muscle specific patterns of movement involving the respiratory, laryngeal and articulatory organs and at the phonological and the sentential levels represent cognitive units for controlling the movements making up a preprogrammed sequence such as a word or a phrase. Kolk (1991) argues that the buildup of activation of phonemic control elements are too slow in stutterers and that consequently, under time stress, there is an increased risk of choosing an incorrect element because of an elevated degree of response competition of alternative elements. On probing into the spreading activation or connectionist models of speech production (Dell, 1986; Mackay, 1987) it can be further speculated that the presence of elevated degree of response competition of alternative elements during phonological encoding as seen in the previous excerpt may hypothetically be attributed to an unusually rapid decay of an elements activation level or due to other hypo/hyper active self inhibitory processes in the nodes themselves (Mackay, 1987). Thus in order to produce error free speech, the stutterers should either speak at a lower pace or consciously/unconsciously permit more time for selection of appropriate speech motor programs.

At this juncture, one cannot take an adequately substantiated position on another controversy of conscious/controlled versus unconscious /automatic self-repairing. As Berg (1992) points out both of them are equally possible and have equivocal results on SRT paradigms.

V. Factors affecting speech reaction time:

Whether addressed directly or indirectly, another major underlying issue in speech motor programming is the influence of task complexity on SRT.

(Task complexity or varying the number of elements in a response sequence is often referred to as manipulating the response complexity (Schmidt, 1988).

Various researchers have attempted to manipulate task complexity (independent variable) at different levels. This digression follows three basic levels of framework viz.,

(1) Information processing level.

(2) Programming level: (response complexity manipulation by sequence length)

(3) Production level:

(1) Task complexity manipulation at information processing level:

Webster and Ryan (1991) studied stutterers' reaction times from an information processing perspective. In this purview, complexity was conceptualized in terms of decision making on simple 2-choice and 4-choice reaction time tasks. Unfortunately their results pointed to the well known fact that reaction time differences between stutterers and non-stutterers were independent of decision complexity.

Nevertheless, it paved the way for another interesting hypothesis that what ever planning and organization deficits there may be in stutterers (Webster, 1986b) will be manifest in the realm of motoric complexity.

Reverting to the discussion on task complexity at information processing level, an ambitious group of Dutch researchers (van Lieshout et al. 1991) studied the effects of lingusitc complexity (from an information processing perspective) on SRT (between stutterers and non-stutterers). They used a novel picture naming task along side with a word naming task, for two basic reasons. (1) In a picture-naming task, owing to a different order by which semantic and phonological codes are accessed, more considerable and diverse linguistic processing is needed than in word naming (van Lieshout, et al. 1991; Smith and Magee, 1980). (2) It successfully circumvents, implicit speech and reading differences that may be present in a word naming task (Klapp et al. 1973).

Their results indicated an increase in SRT in stutterers in the picture-naming task. On one hand, interpretation of this finding suggests that the latency effect in SRT could be the result of processes involved in retrieval of semantic information. However, on the other hand, one cannot conclude based on this evidence alone that affected semantic retrieval systems are present in stutterers.

As van lieshout et al. (1991) and Peters and Starkweather (1990) point out (fundamentally based on the "Interference hypothesis") an alternative explanation to the observed phenomena, could possibly be attributed to the disruption caused by parallel processing of language formulation and motor programming in these (stuttering) populations.

(ii) Response complexity manipulation by sequence length

The nature of research corpus in this affair is contentious for the reason that it is still unclear as to what is the minimal unit of speech motor control. Therefore, the concept of increasing programming length by just adding syllables and assuming that it, in turn, would increase response preparation or programming difficulty, is ill-founded and arbitrary. Substantiative evidence in this regard is found in van Lieshout et al.'s (1991) study, wherein no word size differences in SRT between stutterers and non-stutterers were found by manipulating the response-complexity in terms of merely increasing number of syllables in a word.

It is surprising to note that two decades ago Sternberg et al. (1978) questioned the assumption of syllables forming the basic unit of speech motor plan, however, Steinberg's vision was realized in the years that followed with collosal research and indepth theoretical study.

van Lieshout et al. (1991) explicity state that the simple addition of syllables may not reveal any programming deficits of stutterers, even if present, and agree to the point made by Sternberg et al. (1978) that varying the number of words or stress groups (a segment of speech associated with a primary stress) may indicate programming deficits if any, but at another level of speech motor control (namely the retrieval stage), wherein the word size in terms of number of syllables would influence the time flow in the unpacking stage.

An excellent example for the proposition made in the preceeding paragraph is the approach by Bishop, Williams and Cooper (1991). They investigated age and task complexity variables in a simple reaction time paradigm. For our purpose we will restrain ourselves to listing vocal tasks of increasing complexity which were actually manipulated interms of number of words.

The speech tasks they utilized were production of vowel 'a' (level I), the works "a cow" (level II) and the words "a cow boy" (level III), correspondingly their study potrayed a significant difference between the performances of stutterers and non-stutterers on the aforementioned tasks of increasing complexity which could have possibly influenced time flow in the retrieval stage.

(iii) Production level - Production complexity or motoric complexity:

In general, the term "complexity" is ill defined As seen previously the entity of "complexity[1]' can be approached at different levels. Thus, the notion of "complexity" needs to be more clearer and tenable.

The foregoing outline is nicely pointed out by van Lieshout et al (1991), " ... interpretation of complexity is ambigious. For example, it is generally agreed that words are more complex than single vowels (Peters et al. 1989; Starkweather, 1987; Till, Reich, Dickey and Seiber, 1983), but in what dimension, in number of elements (sounds, articulatory gestures etc) that have to be executed or in specific characteristics of the execution itself (movement speed, force etc)? And in addition to this, what is it that makes longer words more difficult than shorter ones ? Longer words not only have more syllables, they also have more sounds, and they might easily have more complex sound clusters".

Thus, in this regard, by motoric complexity it means a production complexity contrived from a large number of motor neuron pools, muscle groups, physiological subsystems and articulators contributing to the movement per se. Indeed this concept has so captured the imagination of some researchers including speech physiologists that there have been various attempts to explain stuttering based on production complexity variables (for example: Till et al. 1983).

Unfortunately progress in this area has been crystallized " because of the unavoidable inertia that often slows assimilation of new findings from one area of scientific endeavour to another " (Abbs and Cole, 1982). Despite this confused state of affairs and omnipresent obstacles regarding "complexity, it would be worthwhile to deduce an agreement as to what exactly should be varied when motoric complexity is being manipulated.

Extrapolating information from the related fields of child language development and linguistics, it is apparent that a child's preferances, and the related preferences in language inventories {the term "markedness" has been utilized by linguists to refer to these "preferences" (Jakobson, 1968)} have a motor bias. The term "motor bias" encompasses the peripheral structures and the motor system constraints within which the speech production apperatus functions (MacNeilage, 1982).

Drawing this a little further, with increasing age, the child develops superior production skills which account for the shift in consonant production preferances. Gracco (1991) points out that when such a "shift" occurs, new characteristic neuromotor and neuromuscular patterns become established in the childs sensori motor repertoire as retrievable elements.

Thus capitalizing on these assumptions one could possibly vary motoric complexity by ontogenetically selecting the stimuli.

For example: Increasing motoric complexity could mean

Level I |p|, |b|

Level II |t |, |r|

Level III |bla|, |cla| (Clusters)

Scientific inquiry in this "lesser-known" territory has been enthusiastically initiated and quickly applied to the field of motor dynamics in stuttering.

Webster and Ryan (1991) suggested "It will be of significance to determine in future research if reaction time differences between the groups" - (non-stutterers versus stutterers) - " diminish with a simpler motor response and increase as the response is made more complex in terms of spatially and temporally co-ordinated elements".

Logically progressing, the next expected question would be: Is it that in stutterers the articulatory system (neural mechanisms involved in speech production and peripheral articulators) cannot handle the required sequences of motor commands involving peripheral inertia and kinematic interaction? If one intends to answer the above question then pursuing Zimmerman's trial would be the superlative choice. Research on speech movement control has and will heavily rely on the neuro-muscular anatomy and physiology of the speech production apparatus.

According to the proponent of reflexiological underpinnings in stuttering aetiology (Zimmerman, 1980a, 1980c) stuttering can be viewed as a distruption in the patterning of movements in time and space (ie., spatial and temporal organization) leading to reflexiological oscillations and tonicity that characterize the disorder.

In a nutshell, Zimmerman argues that when a person speaks, he usually operates the speech production subsystems (respiratory, phonatory etc.,) within certain ranges of variability. That is, the speaker usually maintains a certain range of limit for velocities, displacement, accelerations and interarticulatory spatial and temporal relationships. "When these normal ranges are exceeded the afferent nerve impulse generated are presumed to increase the gains of the associated brainstem relfex pathways. If excitation reaches a "threshold" level, oscillations and tonic behaviours occur."

With parallel impetus Saltzman (1991) derives similar explanations from the roots of the Task dynamic" model of production. According to him, stuttering behaviours are analogus to the well know "Bifurcation phenomena". As expounded by Saltzman (1991) "....a qualitatively different dynamical pattern produced by the speech production system when the system crosses over into a particular region of its space of control parameters. Stuttering is the "normal" behaviour for the system in this region... the way to avoid acute instances of stuttering is to avoid crossing over into the stuttering region of the relevant parameter space."

Further a vast repertoire of research suggests that for speech sound production the nervous system does not explicity manipulate/control the action of an individual muscle or articulator (Saltzman, 1986; Caruso, Gracco and Abbs, 1987) but rather operates on a co-ordinative structure principle (example: combined actions of the articulators may be represented as the motor plan for oral closure) or in other words "goal-directed" speech motor planning.

Zimmerman (1980a) suggests that in such co-ordinative structures, interaction exists among articulators and if "normal limits" for velocity, displacement etc., are exceeded then the resultant could be a disruption in co-ordinative structure functioning. **(Note:** Zimmermen views the co-ordinative structure system as the pivot for organization of fluent articulatory processes and also, apparently the substrate for fluency disruptive processes).

As previously seen this results in afferent information which leads to an instability in the afferent-efferent system. In line with this reasoning, it is possible to speculate that increased motoric complexity would result in increased variability in the movement parameters and soforth. In conclusion, more motorically complex sound utterances might influence reaction times because of (a) differing demends on co-ordination or (b) as van Lieshout et al. (1991) points out from Kombrot's (1989) study, by the way in which subjects orgnanize the number of units within a motor plan depending on how they organize and structure the motor task they have to perform. In this posit, the same number of syllabels per word/phrase can have differential effects on SRT according to the manner in which individual syllables are grouped together at a superordinate organizational level (e.g., with respect to manner, place, feature of articulation). The number of nodes at this level dictates the reaction time. Thus, to an extent individual motor control strategies govern SRTs.

Apart from the above factors that affect speech reaction times certain authors have suggested tangential but practical considerations to bear in mind while interpreting SRT results. Peters and Hulstijn (1987) point out that, reaction time " in the immediate task condition is strongly influenced by letter and word recognition processes" and that "these input - processes will understandably consume more time for longer utterances", also as mentioned earlier in the immediate/choice reaction time task, SRT effects may be speculated as arising from interference between simultaneous higher level linguistic processing and lower level speech motor programming as highlighted by the "Interference hypothesis" (Peters & Starkweather, 1990).

The same authors suggest that when stutterers perceived a more difficult task (e.g., increased length of utterance) they may have slowed down production in order to speak more fluently, which indirectly affects SRT. It is well known that sutterers disfluences occur more on some sounds, syllables, words and phrases (Johnson and Brown, 1935; Taylor, 1966; Starkweather, Hirschman and Tannen baum, 1976) than others, it is not clearly known as to whether, and to what degree, linguistic and/or motoric complexity play a precipitating role in the occurance of disfluencies (Soderberg, 1967; Soderberg, 1971; St. Louis, 1979).

More over, stuttering literature suggests that time pressure influences the frequency of stuttering (Healey, Mallard, and Adams, 1976). Speaking in low time pressure conditions enhances fluency and vice versa (Adams, Lewis and Besozzi, 1973).

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 study, it was decided to investigate the effects of word-motoric complexity, word length and linguistic complexity on stuttering frequency and on speech reaction times.

A (time stress) choice reaction time paradigm (with the idea that it best indicates response preparation by alterations of dependent variable - SRT), to determine the effects of three independent variables namely word-motoric complexity, word length and linguistic complexity has been used in the present study.

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 programming.

The study also incorporates a picture-sentence reading task and a sentence reading task to estimate the effects of linguistic complexity on SRT, since van Lieshout et al. (1991) have shown that a picture-naming task is more representative of an extensive linguistic processing than just word naming, also an implicit reading difference that can be present in a word naming task is circumvented in picture naming - tasks.

The rationale of the study carried out was that, if stuttering depends on motor programming, then one would expect the differences in reaction time between stutterers and non-stutterers to be greater when longer, linguistically/motorically more complex stimuli are used. That is, effect of "complexity" would be greater for stutterers than for non-stutterers.

METHODOLOGY

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CHAPTER-III

METHODOLOGY

Subjects: Ten male stutterers and ten normal speakers matched for age and educational level served as subjects. All the subjects were proficient in reading, writing and speaking Kannada and had normal hearing and vision with no background of any neuromotors disorders.

The stutterers were selected from those enrolled in the therapy clinic of All India Institute of Speech and Hearing and consisted of those without therapy, those who had undergone therapy previously and those who were recieving therapy. No attempt was made to systematically control the degree of stuttering nor the treatment variables. Table II shows the subject details.

Subject Number	Age/sex	Severity of stuttering	Number of therapy sessions attended	Family history of stuttering	Handedness
1.	18 yrs. M	Severe	On discharge	-	Right
2.	23 yrs. M	Moderate	-NIL-	+	Right
3.	24 yrs. M	Moderate	2 *	-	Right
4.	25 yrs. M	Mild	7	+	Right
5.	18 yrs. M	Moderate	3	-	Right
6.	22 yrs. M	Severe	5	-	Right
7.	40 yrs. M	Severe	On discharge	-	Right
8.	24 yrs M	Severe	-NIL-	-	Right
9.	18 yrs. M	Moderate	3 *	-	Right
10.	25 yrs. M	Moderate	1	+	Right
Mean age	Stutterers = 23.7 yrs.				
Mean age	Normal Controls = 21.6 vrs.				

Note: * refers to those who had undergone therapy previous

Table II: Subject details.

Materials: (a) Word list based on syllable length and complexity formed the material. The words in the list were taken from either the Kannada Articulation test (Mohan Babu, Ratna and Bettageri, 1972) or were based on familiarity as assessed by three native Kannada speakers. The list included three words each in monosyllabic, bisyllabic, trisyllabic and multisyllabic levels. Monosyllabic words were borrowed from English. All these had three complexity levels; - viz. A, B and C, which was based on the age of acquisition of phonemes in Kannada (Tasneem Banu, 1977). Table III shows the phoneme type selected for the three complexity levels and table IV shows the word list .

<table>
<tr><th>Complexity</th><th>Age of acquisition in years</th><th>Initial sounds/clusters</th></tr>
<tr><td>A
(Simple)</td><td>3.5 years</td><td>|b|, |t|, |k| , |m|, |i|, |a|, |g|</td></tr>
<tr><td>B
(Compound)</td><td>3.5 to 5 years</td><td>|t |, |dz|, | s | , |r|, |l|</td></tr>
<tr><td>C
(Complex non-gemminate clusters)</td><td>> 5 years</td><td>|sk|, |sl|, |bl|, |kr|, |bhr|, |gr|, |k |, \ r\, |pr|</td></tr>
</table>

Table III: Phonemes and clusters selected for the three complexity levels based on the age of acquisition.

(b) Apart from the words, sentences were also selected. Three to four word simple sentences were used. This had two levels; viz., standard sentences and picture-sentences. In the standard sentence, three sentences as written one each on a card formed the material and for picture-sentences, three sentences (one with three words and the rest with four words) represented by orthographic, numeric and pictorial items (sequenced to form a sentence) were used.

SUBJECT No.: ____________ NAME: ______________________ CASE No. __________ PROVISIONAL DIAGNOSIS: ______________

Date :
Age :

Complexity / Word length	A	T_1	T_2	Avg.	B	T_1	T_2	Avg.	C	T_1	T_2	Avg.
Mono Syllabic	1 ಬಾ /ba:/ 2 ತಾ /ta:/ 3 ಕೀ /ki:/				1 ಚಾ /tʃa:/ 2 ಝೂ /zu:/ 3 ಸೀ /si:/				1 ಸ್ಕೂಲ್ /sku:l/ 2 ಸ್ಲೇಟು /sleiṭu/ 3 ಬ್ಲೇಡು /bleiḍu/			
Bi Syllabic	1 ಮನೆ /mɔne/ 2 ಕಾಳು /ka:ḷu/ 3 ಬೀಗ /bi:ga/				1 ಸೂಜಿ /su:dʒi/ 2 ಲಾರಿ /la:ri/ 3 ಸರ /sɔra/				1 ಕ್ರಾಂತಿ /kra:nti/ 2 ಭ್ರಷ್ಟ /bhrɔʃṭa/ 3 ಗ್ರಂಥ /grɔntha/			
Tri Syllabic	1 ಇರುವೆ /iruve/ 2 ಅಗಸ /agɔsa/ 3 ಎರಡು /erɔḍu/				1 ಸರಸ /sɔrɔsa/ 2 ರಂಗೋಲಿ /rɔŋgo:li/ 3 ಚಪ್ಪಲಿ /tʃɔppɔli/				1 ಕ್ಷಮಿಸಿ /kshɔmisi/ 2 ಶ್ರವಣ /ʃrɔvɔṇa/ 3 ಕ್ಷತ್ರಿಯ /kshɔtri:ja/			
Poly Syllabic	1 ಬೀಗದ ಕೈ /bi:gɔdɔkɔi/ 2 ಗಾಳಿಪಟ /ga:ḷipɔṭa/ 3 ಕನ್ನಡಕ /kɔnnɔdɔka/				1 ಸೋಮವಾರ /so:mɔva:ra/ 2 ರಾಮಾಯಣ /ra:ma:jɔṇa/ 3 ಚಂದಮಾಮ /tʃɔndama:ma/				1 ಕ್ರಾಂತಿವೀರ /kra:ntivi:ra/ 2 ಗ್ರಂಥಗಳು /grɔnthɔgɔḷu/ 3 ಪ್ರಾಂತಗಳು /pra:ntgɔḷu/			

SENTENCE LEVEL STIMULI

SENTENCES	T_1	T_2	Avg.
1 ಅವರು ಕ್ಷಮಿಸಿ ಎಂದರು /avɔru kshɔmisi endɔru/			
2 ಕರ್ಣನ ಕವಚ ವಜ್ರದ್ದು /kɔrṇɔn kɔvɔtʃ vɔdʒrɔddu/			
3 ಸತೀಶ ಮಧ್ಯಾಹ್ನ ಹೋದನು /sɔti:ʃ mɔdhja:nha ho:dɔnu/			

PICTURE - WORD STIMULI	T_1	T_2	Avg.
1 ಇದು /idu/ + 1 + 			
2  + ಮೇಲೆ /me:le/ +  + ಇದೆ /ide/			
3  +  + ಕೆಳಗೆ /keḷɔge/ + ಇದೆ /ide/			

TABLE IV. Experimental stimuli - word list

Thus the materials consisted of 36 words and 3 sentences each for standard and picture-sentence levels. Three words and two similar sentences were additionally prepared for practice trials. All words and sentences were written one each on a card.

Method: A manual slot machine was devised through which a stimulus card could be inserted (figure 4). The cards were slided through the slot, the noise of which would be picked up by a microphone (Aud-535 Ms-undirectional-Imp 600 - 50 kΩ placed on the table.

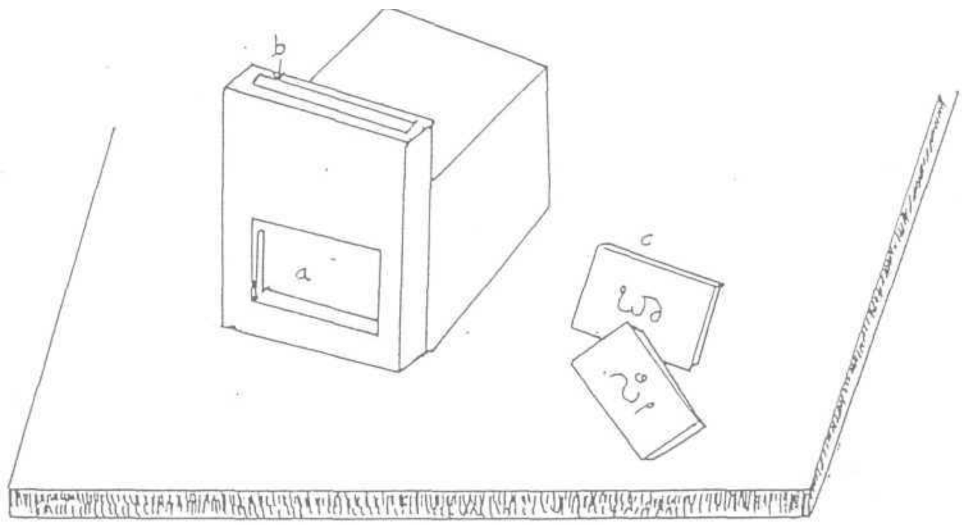

FIGURE 5. Manual slot machine: Reading window (a), slot (b), stimuli on cards (c).

The experiment utilized a choice reaction time paradigm with high time pressure and no feedback on individual reaction times. All subjects, both stutterers and normals, were given the following instructions verbally which were repeated if necessary:

This is a scientific study, wherein we are interested to measure how fast one can read visually presented stimuli (words). We are only interested in finding out how quickly one can say the word after it appears through the stimulus window, and not the manner in which you say the word.

During the experiment you could get small words, large words, sentences or even picture-sentences, which you have to say as fast as possible. To familiarize you with the procedures, I will give you a few practice or trial runs".

Also, stutterers were instructed not to use fluency-enhancing techniques during the test as this would have interfered with the task demands. Following this, the trial followed by the experimental stimulus was started. The stimulus cards were randomized and iterated twice and the responses were audio-recorded.

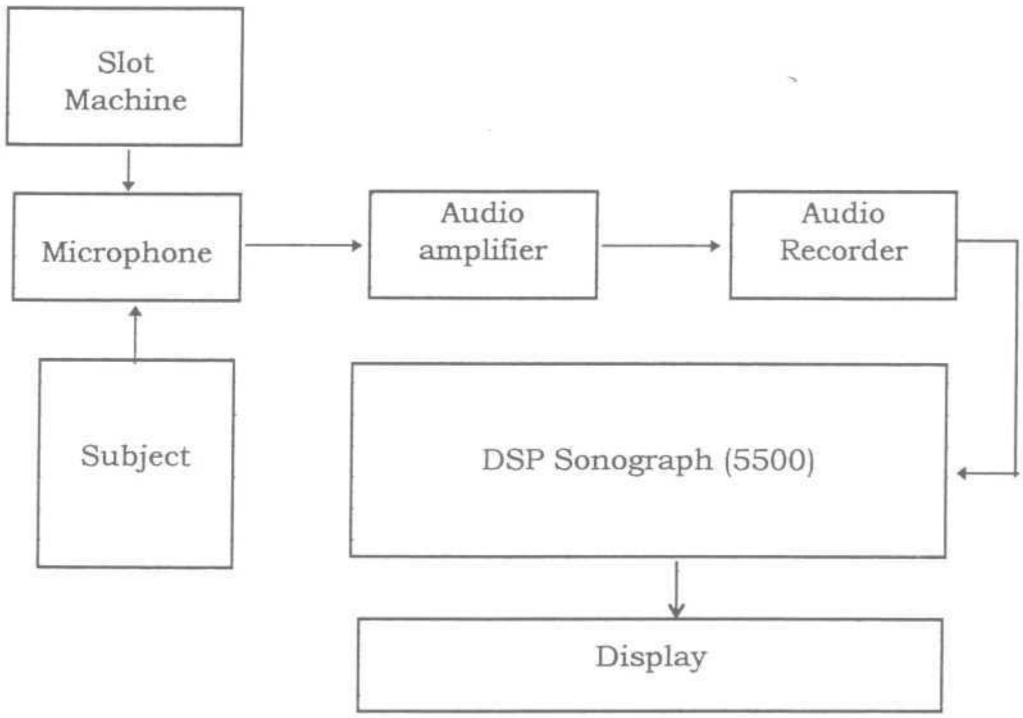

FIGURE 5. Schematic diagram of instrumentation set-up during the experiment.

The subjects utterance and transient stimulus presentation noise (produced by the falling stimulus card through the manual slot machine) were transduced by a condensor microphone (Aud - 535 MS - unidirectional - Imp 600 - 50 kΩ) placed equidistance from the subjects mouth and the manual slot machine (about 5 inches from subjects mouth). The signal was then amplified by an audioamplifier (Philiamp 60) and sent to a stereo cassette recorder (Sony-TC-FX 170). The cassette recorder was connected to the DSP Sonograph (Kay Elemetrics-model 5500) through the line input and speech reaction time (henceforth SRT) was measured by the "Wave form display" on the DSP Sonograph (5500) (Fig. 5) . The time axis was set to 200 msec to aid the analysis.

The time interval between onset of transient stimulus presentation noise (generated by the fall of the card through the slot-machine) and speech onset in the acoustic domain was considered as speech reaction time (figure 6). The SRT's were measured using time cursors on the wave form display program (DSP Sonograph - 5500), to the nearest whole milli second.

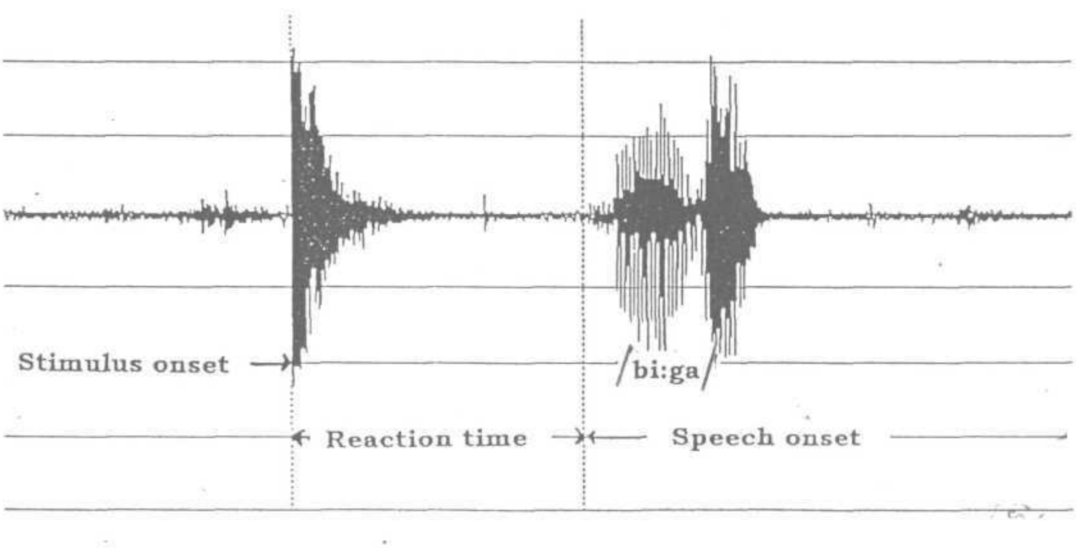

FIGURE 6. Depicts measurement of SRT

All speech utterances, both fluent and disfluent, were considered for SRT measures. However, an utterance in order to be analyzed, had to satisfy two criteria.

(1) There should be no -visual signs of speech related struggle involving the speech apparatus, related or unrelated body movements just before or during the test token presentation.

(2) All disfluent blocks >1.5 seconds were eliminated from data analysis.

No utterance was analyzed when it was (a) accompanied by inappropriate movements (eg: inspiratory gasp, swallowing etc.,) or (b) premature, as judged by the experimenter.

Analysis: The speech reaction time data was subjected to a one factor analysis of variance utilizing a repeated measures design, to find out within group differences with respect to word length and word complexity variables. This was followed by a Fisher PLSD Post hoc test to identify the locus of significant difference between the means. Between group comparison (Stutterers vs Normals) was carried out separately for each word length and word complexity variable, using a one factor analysis of variance (without repeated measures). To study the linguistic complexity variable, within and between group comparisons for standard sentences and picture-sentences were carried out using paired and unpaired t-test respectively.

RESULTS
&
DISCUSSION

CHAPTER - IV

RESULTS AND DISCUSSION

RESULTS

1) Mean SRT's for varying word length and complexity:

The first purpose of the study was to examine the SRT's for varying word length and complexity. The thesis being that, if stuttering is a speech motor programming error, then (1) stutterers should show longer SRT's compared to normals and (2) stutterers should show an increase in SRT with an increase in the word length and complexity. Tables V, VI and VII show the mean SRT and standard deviations for stutterers and normals for four levels of word length and three levels of complexity. The results reveal that:-

(1) Stutterers exhibit longer SRT's than normals for all word lengths and complexities. Also, standard deviations were higher in stutterers than in normals.

(2) Among normals and stutterers SRT's increase with increase in word length (except for complexity ' A' and 'C in normals and bisyllabic words in complexity 'A' and complexity ' B' in stutterers).

(3) Among both the groups, SRT's increased with increase in complexity (figure 7 and 8) except for multisyllabic words in complexity 'B' among stutterers and normals and monosyllabic words in complexity "A" among normals. However, this increase was more prominent among stutterers than in normals especially for the trisyllabic words.

STUTTERERS			NORMALS	
Word length	Mean	Standard Deviation	Mean	Standard Deviation
Monosyllabic	622	148	534	62
Bisyllabic	619	141	517	42
Trisyllabic	657	139	541	44
Multisyllabic	769	178	616	107

Table V: Means and standard deviations- of SRT's (in msec) of stutterers and normals for four levels of word length at complexity ' A' condition.

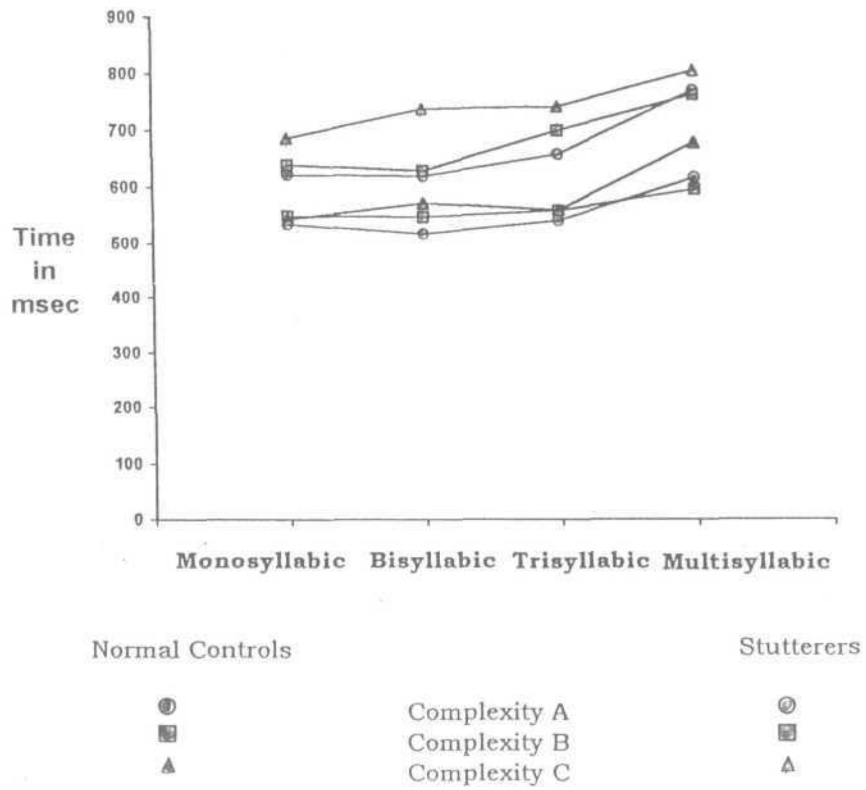

Figure 7. Mean SRTs across words varying in length among stutterers and nonstutterers.

STUTTERERS			NORMALS	
Word length	Mean	Standard Deviation	Mean	Standard Deviation
Monosyllabic	639	142	549	70
Bisyllabic	629	144	547	61
Trisyllabic	699	17	559	85
Multisyllabic	762	161	596	70

Table VI: Means and standard deviations of SRT's (in msec) of stutterers and normals for four levels of word length at complexity ' B' condition.

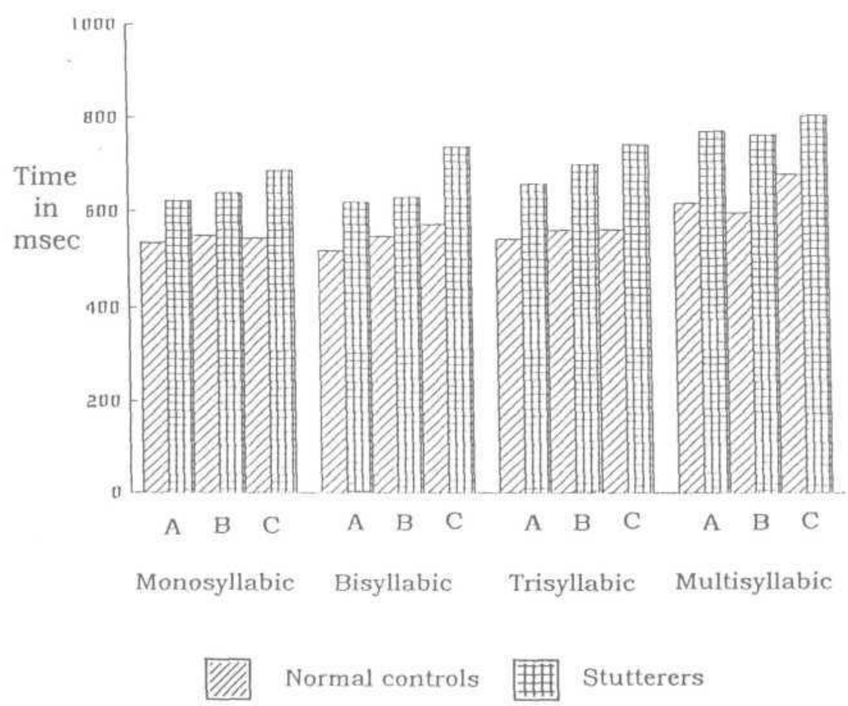

FIGURE 8. Mean SRTs across words varying in complexity among stutterers and non-stutterers

STUTTERERS			NORMALS	
Word length	Mean	Standard Deviation	Mean	Standard Deviation
Monosyllabic	686	199	543	97
Bisyllabic	737	219	572	76
Trisyllabic	741	234	560	72
Multisyllabic	804	210	677	134

Table VII: Means and standard deviations of SRT's (in msec) of stutterers and normals for four levels of word length at complexity 'C' condition.

2) Within Group Comparisons:

(a) Word length: Results of (one factor) analysis of variance (repeated measures) indicated a significant interaction effect between word length and complexity, within the two groups (table VIII).

	Complexity	F-test	P value	Significant/ Not significant.
Stutterers	A	19.655	.0001	Significant
	B	9.955	.0001	Significant
	C	5.965	.0029	Significant
Non-stutterers	A	9.104	.0002	Significant
	B	1.816	.1681	Not significant
	C	11.848	.0001	Significant

TABLE - VIII. Results of ANOVA: F-test and P values are depicted for increasing word length for different complexity conditions.

A post hoc analysis indicated that in stutterers, only the mean SRT's between monosyllabic vs multisyllabic, bisyllabic vs multisyllabic and trisyllabic vs multisyllabic word levels were significant across all three complexity conditions, whereas other significant interaction effects between word length and complexity were found only for complexity ' B'. SRT differences between monosyllabic vs bisyllabic levels failed to produce any significant effects across complexity conditions (Table DC).

STUTTERERS				NORMALS		
Word length	A	B	C	A	B	C
Mono vs Bisyllabic	.046	.057	.057	0.42		.051
Monosyllabic vs Trisyllabic	.046	.057*	.057	.042	Not significant	.051
Monosyllabic vs Multisyllabic	.046*	.057*	.057*	.042*	F= 1.816 P > .05	.051*
Bysyllabic vs Trisyllabic	.046	.057*	.057	.042		.051
Bisyllabic vs Mutisyllabic	.046*	.057*	.057*	.042*		.051*
Trisyllabic vs Multisyllabic	.046*	.057*	.057*	.042*		.051*

*Sgnificant at 95%

TABLE - DC. Results of Fisher PLSD Post hoc analysis of speech reaction time differences for increasing word length across complexities within group.

In comparison, the same interaction effects between word length and complexity were obtained for normals except for complexity ' B' condition, wherein word length manipulation failed to produce any significant effects.

A decision was made to compare all SRT means between picture-sentence, standard (3-word simple) sentence and multisyllabic words, for both the groups using the t-test. The results of this comparison are presented in table X and XI which show critical difference comparisons of means revealing within-group differences across task complexity. Picture-sentences yielded significantly longer SRT's than standard sentences and the latter had significantly larger SRT's than multisyllabic words. This increasing SRT effect with increasing complexity was greater for stutterers than for normals. Also, the standard deviations were higher for stutterers when compared to normals.

	STUTTERERS		NORMALS	
	Mean	S.D.	Mean	S.D.
Multisyllabic	778	168	630	91
3 word simple sentence	1073	399	728	112
Picture-sentence	1296	336	1030	118

TABLE - X. Mean and standard deviations of SRT's for stutterers and normals for various tasks (SRT in msec).

	Stutterers	Non-stutterers
Multisyllabic vs Simple sentence	t = 3.244 P<.05 Significant	t = 5.859 P<.05 Significant
Simple sentence vs Pic-sentence	t =-3.65 P< .05 Significant	t-value = -8.13 P(2-tail) <.05 Significant

Table XI. Results of paired t-test (2 tail) between multisyllabic word level vs simple sentences and simple sentences vs picture-sentences, for stutterers and non-stutterers.

Word Complexity:

Table XII represents interactive effects of different complexity conditions as a function of increasing word length.

	Monosyllabic	Bisvllabic	Trisyllabic	Multisyllabic
Complexity A, B, C	F test = 3.017	F test = 10.09	F test = 3.318	F test = .61
	P = .0741 P = >.05	P = .0012* P = <.05	P = .0593 P = > .05	P = .554 P=>.05

* Significant at 95%

TABLE - XII. Results of ANOVA - Within group comparison: In sutterers F-test and P values are depicted for increasing complexity for various word length conditions.

Comparison	Fisher PLSD
Complexity A, - Bisyllabic vs Complexity B- Bisyllabic	.061
Complexity A, - Bisyllabic vs Complexity C- Bisyllabic	.061*
Complexity B, - Bisyllabic vs Complexity C- Bisyllabic	.061*

* Significant at 95%

TABLE - XIII. Results of Fisher PLSD Post hoc analysis of spech reaction times for increasing complexity with constant word length among stutterers.

Results of (One factor) ANOVA-with repeated measures, followed by post hoc analysis indicated that under most conditions SRT's of simple words were not significantly different from those of compound or complex words. However in stutterers significant interaction effects were obtained only for SRT means between complexity ' A' vs ' C and complexity ' B' vs' C at bisyllabic word level (Table XIII).

	Monosyllabic	Bisyllabic	Trisyllabic	Multisyllabic
Complexity A,B, C.	F test = .397	F test= 10.63	F test = .55	F test = 3.69
	P value =.6779 P >.05	P value = .0009* p > .05	P Value =.5861 P >.05	P Value =.0453* P<.05

*Significant at 95%

TABLE XTV. Results of ANOVA for within group comparison in normals: F-test and P values are depicted for increasing complexity for different fixed word length conditions.

Comparison	Fisher PLSD
Complexity A - Bisyllabic vs complexity B - Bisyllabic	.025*
Complexity A - Bisyllabic vs complexity C - Bisyllabic	.025*
Complexity B - Bisvllabic vs complexity C - Bisyllabic	.025
Complexity A Multisyllabic vs Complexity B-Multisyllabic	.065
Complexity A Multisyllabic vs Complexity C-Multisyllabic	.065
Complexity B Multisyllabic vs Complexity C-Multisyllabic	.065*

*Significant at 95%

TABLE XV. Results of Fisher PLSD post hoc analysis of SRT's for increasing complexity with constant word length for normals.

In normals similar results were obtained (Table XIV and Table XV) wherein simple words were not significantly different from compound or complex words, but interestingly mean SRTs between complexity 'A' vs ' B' and complexity 'A' vs ' *C* revealed significant effects at bisyllabic word level. In addition, mean SRT's between complexity ' B' vs ' C elicited siginificant effects at multisyllabic word level.

3) Between-group comparisons:

Between group speech reaction time means (table XVI) were analysed using (one factor) ANOVA, wherein group x complexity interaction effects were significant but with two exception as follows:

(1) At monosyllabic word level (across complexity A,B> C) no significant difference between groups were obtained.

(2) No significant interaction effects were obtained between the groups for bisyllabic words in complexity ' B' condition and multisyllabic words in complextity ' C condition.

Word complexity/ Word length.	A	B	C
Monosyllabic	F(l,18)=3.03 P = .0988 P>.05	F(l,18)= 3.224 P= .0894 P > .05	F(l,18)=4.177 P = .0559 P > .05
Bisyllabic	F(l,18) = 4.813 P=.0116* P<.05	F(l,18) = 2.759 P= .114 P> .05	F(l,18) = 5.048 P = .0374* P<.05
Trisyllabic	F(l,18) = 6.409 P = .0209 P < .05	F(l, 18) = 5.476 P= .031* P< .05	F(l,18) = 5.484 P = .0309* P< .05
Multisyllabic	F(l, 18) = 5.406 P = .032* P<.05	F(l,18) = 8.991 P = .0077* P <.05	F(l,18)= 2.61 P=.1236 P > .05

Significant at 095%

TABLE XVI. Results of ANOVA for between group Comparison across all task conditions.

Further an unpaired t-test was performed to compare SRT means between the stutterers and normals across the two task conditions, viz., picture-sentence standard sentence.

	t-value	Prob. (2.tail)
Sentence	3.481	.0029*
Picture - sentence	2.233	.0393*

* Significant at 95%.

TABLE XVII. Depicting t value and probability. Comparison betwen stutterers and non-stutterers on mean speech reaction time for sentence and picture sentence task condition.

The results of the test are in table XVII which indicated a significant difference between the groups across the two task-conditions.

4) Frequency of Stuttering event as a function of task complexity.

As expected, the experimental manipulations of independent variable did influence the subjects speech motor programming and hence the occurrance of stuttering events.

Word complexity / Word length	A	B	C
Monosyllabic	0%	66.6%	66.6%
Bisyllabic	8.3%	33.3%	25%
Trisyllabic	11.1%	5.5%	22.2%
Multisyllabic	20.8%	41.6%	29.1%
Sentence naming task			55%
Picture naming task			59%

TABLE - XVIII. Percentage of stuttering events for stutterers across all tasks/ conditions.

Table XVIII shows the percent of stuttering events across word length and word complexity for stutterers. Percentage of stuttering instances (PSI) was calculated. The results revealed that stuttering events increased with task complexity. However, it was interesting to find a gradual increase in the percentage of stuttering events with increase in word length for complexity ' A' and a varied but greater percentage of stuttering events across complexities ' B' and ' C. Also, stuttering events were greater for picture sentence naming task when compared to standard sentence naming task.

To summarize, the results revealed :

(1) Significant differences in SRT's between normals and stutterers with longer SRT's in stutterers.

(2) Increase in SRT's with increase in word length and complexity among stutterers.

(3) Significant differences between the SRT's of monosyllabic vs multisyllabic, bisyllabic vs multisyllabic and trisyllabic vs multisyllabic words across all complexities in stutterers.

(4) Significant differences between the SRT's of simple vs picture sentences and multisyllabic vs simple sentences in stutterers.

(5) Significant differences between the SRT's of complexity ' A' vs complexity ' B' and ' *C* only in bisyllabic condition.

(6) Increase in percentage of stuttering events with an increase in word length for complexity ' A'.

DISCUSSION

The objective of the present study was to examine speech reaction times from a speech motor control perspective in stutterers and non-stutterers. This research was a fledging attempt to identify motor programming deficits that could contribute to the aetiology of stuttering. To do so, the investigator compared speech reaction time responses of stutterers and normals under a multitude of experimental manipulations of the independent variable.

The independent variable was manipulated in terms of word length and motoric complexity. The experimental manipulations resulted in some interesting and important effects, though not always in the expected direction.

In general, the findings supported a well established notion of slower speech reaction times in stutterers than in non-stutterers. (Peters et al. 1989). Furthermore as response complexity increased, stutterers had longer SRTs and a greater percentage of disfluencies when compared to control subjects.

For the sake of parsimony, the effects of the independent variable, under two separate headings, viz:- within group differences and between group differences will be discussed.

Within group variations:

As proposed, the manipulation of word length had some significant results. In general, multisyllabic words required greater SRTs than words with fewer syllables. That is SRTs increased as a function of word length, in both stutterers and normal control subjects. However, word length manipulation by simple addition of syllables has been treated with skepticism in speech motor control research. On one hand Klapp (1974), Klapp & Wyatt (1976) and van Lieshout et al. (1991) have shown that increasing the size of a word in terms of number of syllables elicited longer SRTs even in normal speaking subjects. On the other, increasing the size of a word in terms of number of syllables has also failed to produce any significant effects between stutterers and normal controls.

Thus it is not surprising as to why van Lieshout et al. (1991) has espoused Steinberg's (1978) view against the syllable forming the basic unit of speech motor plan and cautioned its use in speech motor control research on stuttering. Despite the skeptical thoughts of various researchers, the results of this study strongly indicate that for longer words stutterers, in comparision to normal controls, had significantly longer SRTs. This finding is corroborated by earlier research conducted in the same direction by Peters et al. (1989) and van Lieshout et al. (1991).

One could attribute the differences between stutterers and non-stutterers on SRTs to increased planning or speech motor programming time in the former group. However, even when one assumes that processes preceeding actual execution of speech are impaired in stutterers, no definite statement can be made on the proportion of time devoted to each of the various premotor planning stages.

Furthermore, reaction time paradigms perse are no concrete indicators of response preparation by the very fact that at any instance in time, during a motor response, sensory analysis overlaps with response planning and response planning overlaps with response execution (Guitar, 1991).

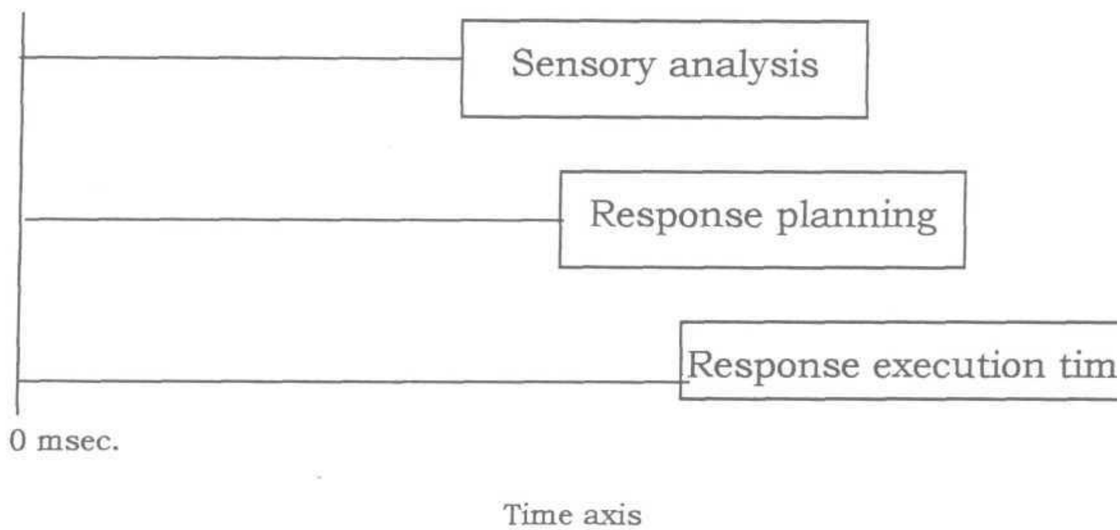

figure 9. Stages associated with production of a motor response (cf. Guitar, 1991).

Thus disambiguating the locus of disruption is difficult if not impossible in any speech motor control research. Postma etal, (1990a, 1990b) propose an impairment on similar lines.

According to them stutterers may have an impaired execution stage in addition to a planning defect. 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.

On closer inspection of the data some interesting and peculiar effects by manipulation of word length were observed. It was found that word length manipulation had more effect on stutterer's speech reaction time than the non-stutterer's, but only for complexity condition - ' B'. The other effects of word length were similar across groups.

The latter is explained by an equal amount of difficulty in both groups for increasing word lengths due to an increased programming time required to centrally organize utterences of increasing length (Klapp & Wyatt, 1976; Peters et al. 1989; van Lieshout et al.1991).

However, since we measured reaction times only in the acoustic domain, in the absence of simultaneous gathering of physiological data, it is not sufficient to answer questions regarding differential involvement of programming and execution stages in normal and stuttering groups. Nonetheless, whatever be the processes involved, they affect both the groups to the same extent.

Turning next to the peculiar significant interaction effect of word length on complexity ' B' condition, seen in stutterers alone, it can be attributed to an artifactual complexity effect. In this regard the findings were contrary to what might be expected for increased motoric complexity (i.e., greater SRTs with increasing complexity). The data consistently demonstrates a lower mean SRT for complexity ' B' condition across most response tasks. Although the same was observed in normals, unlike the stuttering group, it failed to reach significant levels.

Several explanations are possible for this "paradoxical complexity effect". However, first, one could argue that manipulation of complexity in terms of ontogenetically selecting sound stimuli was an insufficient means to test programming deficits at any level of the processes involved. Moreover, as Kornbrot (1989) suggests, there may exist the possibility of individual specific functional organization of production networks, governed by the motor task one needs to perform.

In other words, by extending Kornbrot's (1989) hypothesis it could be speculated that several features (like place, manner of articulaation) of an individual sound could be organized into a specific node at a higher organizational level. If so, the entire articulatory gesture would be performed as one cohesive co-ordinative structure (Saltzman, 1986)that obeys functional physiological flexibility (Folkins, 1985; Folkins and Canty, 1986)) and in such a case reaction time would be dictated only by the number of such nodes at the highest level of organization. Hence, complexity ' B' stimuli may have evoked the same degree of organizational complexity as condition 'A'. However, it is premature to conclude that similar factors may underscore complexity 'C condition, the same shall be dealt in the proceeding paragraphs.

A second alternative interpretation for this "paradoxical complexity effect" stems from the data analysis procedure adopted in the present study.

It was found that in complexity 'B' condition, greater amount of disfluencies were present. Articulatory fixations greater than two seconds were eliminated from data analysis, and only selected reaction time latencies were considered for block averaging. Hence, for the aforementioned task condition in question, the mean SRTs were considerably lower. Although this may have contributed, it seems highly unlikely that this specific data analysis procedure alone could have brought about the "paradoxical complexity effect" since the same was evidenced in SRTs of normal controls also.

However, the procedure may have contributed to the difference being significant in the stuttering group, due to an uneven distribution of disfluencies across word length.

The third alternative interpretation for the "paradoxical complexity effect" can be attributed to the compensatory strategies utilized by the two groups in question. In complexity 'C' condition, anticipating the production of complex clusters, the stutterers as a group may have taken a longer time to produce the same, thereby reducing the number of disfluencies, on the other hand complexity 'B' condition, not eliciting any such compensatory strategy, was produced with speech reaction times comparable to that of complexity 'A' thus increasing the number of disfluencies due to a difference in complexity and self repair strategies (Postma and Kolk, 1993).

In addition, words in complexity 'C' condition being slightly less familiar and more orthographically complex could have elicited longer SRTs. It is also well known that the reaction time in the (immediate) choice RT paradigm are strongly influenced by letter and word recognition processes (Peters and Hulstijn, 1987). This may have brought about implicit reading time differences (Carpenter and Just, 1983) and delays in the other sub-processes at the information processing level (van Lieshout et al. 1991), thereby contaminating the results.

Another intriguing feature was the results obtained in stutterers due to complexity manipulations, wherein significant differences between SRTs were evidenced for complexity 'A' and 'B' vs complexity 'C' conditions only at the bisyllabic word level. As previously highlighted, a possible explanation might be the "paradoxical complexity effect" influencing the significance of difference between SRT means in the complexity conditions, wherein the lowering of SRT mean in complexity 'B' condition resulted in a lesser difference between the same and complexity 'A'. In contrast, this effect would have exaggerated the mean difference between complexity ' B' and 'C', thereby resulting in the observed differences across complexity conditions.

Furthermore, as Peters et al. (1989) suggest, articulatory complexity in consonant clusters in general produce slower reaction times than simple non-cluster words. At another level, increased SRTs may be viewed as covert repair stategies utilized by the individual (Postma and Kolk, 1993), for errors in speech motor programming (of consonant clusters). Such errors could encompass coarticulatory transition - deficits and faulty anticipatory coarticulation (Stromsta, 1965).

On similar lines, Postma et al. (1990) add that, speech programming deficits could have stronger repercussions for conditions involving actual execution of speech. In this light, the strong increase in SRTs in complex cluster productions can be attributed to a "combined effect" of deficits in speech planning and increased phonetic complexity. Therefore, on the basis of these interpretations, the differential effects of complexity on SRTs in stutterers may be explained to an extent.

The next perplexing question deserving some attention is that why in the foregoing complexity conditions significant differences were obtained only at the bisyllabic level? It could be argued that in this condition, the mean SRTs across complexity were almost evenly separated in the time domain probably resulting from greater errors in phonological encoding, prosodic parametrization of the articulatory plan (Wingate, 1988) etc., which may have specifically affected syllable rhymes (Wijnen and Boers, 1994) in the bisyllabic condition.

Although the above interpretation is compatible with the notion of a speech planning deficit in stutterers, the nature of the processes underlying such experimental observations are still largely a matter of speculation.

At this point, another important question arises as to whether stuttering is a disorder of motor programming? If so, complexity should have a greater effect at tri and multi syllabic than bisyllabic word level. Although based on a cursory view of the findings one might be tempted to speculate that maximum complexity effects were observed only for words with fewer syllables, a closer look at our data reveals a "ceiling effect" at the tri and multisyllabic word levels. Across complexity, the same "effect" was observed for the normal group, except for the multisyllabic, complexity 'B' vs 'C' condition.

Obviously, this would suggest that cluster production coupled with an increased word size, adversely affects production time in normals. In other words, the enlarged difference in SRTs, between complexity 'B' and 'C' is a product of word size and phonetic complexity. In this surmise, similar underlying elements of motor control process, could operate conversely to invoke the observed significant differences between complexity 'A' vs 'B' and 'A' vs 'C' at bisyllabic level. Thus, we have seen the within group variations that are far from clearing our viscous thoughts generated by a multitude of proposed, speculated and emperically evidenced research findings in the area of speech motor control and stuttering.

Between group comparison:

What is more interesting is the between group comparison made in an ambitious attempt to explain SRT differences between the two groups and to elaborate slightly and account for the underlying factors in the aetiology and pathophysiology of stuttering.

From the findings, it is evident that stutterers as a group had significantly longer SRTs than normal controls for almost all tasks and conditions. However, there was an absence of significant difference between stutterers and normals in monosyllabic (across all complexities), bisyllabic (only in complexity 'B' condition) and multisyllabic (only in complexity 'C' condition) word levels.

This indicated that more complex (word size and phonetic complexity) tasks resulted in significant group differences while the more simpler tasks did not (the exception being multisyllabic words at complexity 'C', the explanation for this has been dealt with later).

Moreover an absence of a significant difference at monosyllabic level, can be understood when stuttering is envisioned as a disruption in timing and coordination of intricate and ballistic network of movement subroutines constituting a relatively unstable coordinative system.

In this regard dynamic parameters of speech motor control such as displacement velocity ratios, peak velocity profiles, motor equivalence co-variability, interarticulator relative-timing and sequencing of patterns (Alfonso, 1991), will have lesser repercussions for motoric tasks that are less complex than otherwise.

Furthermore the differences between stutterers and normals, in SRTs become larger with longer and more motorically complex utterances. The above findings are corroborated by evidences in literature (Klapp et al. 1973; Peters et al. 1989; Postma et al. 1990; van Lieshout et al. 1991). Although this appears to be general trend, it is quite interesting to note that the multisyllabic words at complexity 'C' failed to produce significant between group differences, this may be attributed to the previously cited "ceiling effect" seen being motorically complex productions.

The collective implication of these and other cited findings in literature could be taken to suggest that stutterers have difficulties in speech motor planning. Although this possibility exists, there are other innumerable and formidable obstacles prior to establishing the true potency of the proposed speech planning deficit in stutterers.

Despite there being a vast body of research and emperical findings that are suggestive of a speech motor programming deficit in stutterers, one still needs to meticulously analyse additional factors that may influence SRTs in stutterers. There are several such potential factors that could have influenced SRTs in this study.

First, the visual exclusion criteria for tonic articulatory fixations is by no means fool proof. We could have been completely blind to a physiologically aberrant mechanism underlying the speech musculature (eg: muscular hyperactivity - Starkweather, 1995) which could have stiffened the entire system and delayed the smooth execution of rapid movements.

Secondly in choice reaction time paradigms, as suggested earlier, word recognition differences in reading times and input processing (carpenter and Just, 1983) may have influenced the reaction time to a stimuli. Therefore to eliminate the possible disturbing influences of implicit reading time differences, our study incoorporated a picture - sentence reading task in comparison with a standard sentence. The results obtained form the above comparison were quite enlightening in that the picture-sentence reading task elicited a greater reaction time than the sentence reading task. These two conditions differed significantly within and across the groups.

Despite (two out of three) picture-sentences having more words than the standard-sentence as they both were approximated for their syllabic length, any difference in reaction time between the two would have to be attributed to a greater extent to the way in which these two sentences differed. As suggested by van Lieshout et al. (1991), in a picture-sentence task, due to a different mode of access to the semaantic and phonological codes, more extensive linguistic processing may be required (Kroll and Smith, 1989) resulting in increased speech reaction time for the same. Hence by utilizing pictures as stimuli one can circumvent possible effects of implicit reading differences.

Returning back to the discussion on factors influencing SRTs literature findings suggest that stutterers, when they perceived a more difficult task, may have slowed down by reducing the amount of movement (displacement) and/or increased the duration of production to permit them to gain better control of the motor output (Zimmerman, 1980a). In other words the increase in SRT in stutterers might reflect their inherent compensatory strategies adopted to speak more fluently.

Apart from the above, the role of anxiety (arousal) must also be considered in a high time stress speaking condition (Starkweather, 1995). However till date studies are a few in this area. Still the potential for an autonomic system involvement playing a causal role for oscillatory movements and static positioning of articulators cannot be ignored (Zimmerman, 1980c).

Finally, complexity of motor execution per se may, in turn, add to the speech planning deficits, as reflected by an extra longer duration for more complex utterance structures (Haber and Haber, 1982; Postma et al. 1990). However, this portrays a pervasive difficulty in stutterers to produce utterances that are well coordinated in terms of spatially and temporally ordered elements.

Thus, stuttering when viewed from a speech motor control perspective broadens our understanding of the underlying dysfunction (s) that would, on most accounts, explain the phenomena of stuttering.

SUMMARY
&
CONCLUSIONS

CHAPTER V

SUMMARY AND CONCLUSIONS

The present study was undertaken to verify the credibility of theories that attribute the locus of stuttering etiology to be a central speech planning dysfunction. The aim of this study was to investigate whether a long speech reaction in stutterers was a result of programining disorder or whether it was caused by a disturbance of motor initiation. It should be clear that premotor planning or programming for speech is assumed to consume more time if utterances of increasing length have to be centrally organized. A choice reaction time paradigm was utilized to determine the effects of three independent variables, viz: - word length, word-motoric complexity and linguistic complexity, on the dependent variable - speech reaction time. Word length was manipulated by alternations in the number of syllables in a word, whereas word-motoric complexity was manipulated by selecting stimuli that varied interms of ontogenetic acquisition of speech sounds, and lastly the linguistic complexity was varied by utilizing two different sentence tasks, viz: standard sentence and picture-sentence. By varying the response complexity in this manner it was intended to manipulate the response preparation in a way that if stuttering depends on motor-programming, then response complexity would adversely affect response preparation time (SRT) and this effect of "complexity" would be greater for stutterers than for normal controls. The material consisted of 36 meaningful Kannada words (9 monosyllabic, 9 bisyllabic, 9 trisyllabic and 9 multisyllabic) at three complexity levels. While complexity 'A' consisted of words with phonemes |b|, |t|, |k|, |m|, |i|, | a |, | g |, complexity ' B' consisted of words with phonemes | t |, | dz |, | s |, |r|, |1| and complexity 'C' consisted of words with non-gemminate phoneme clusters |sk|, |sl|, |bl|, |kr|, |bhr|, |gr|, [k | , | r|, |pr|. Three standard sentences with 3 words and three picture-sentences were also used. These words and sentences/picture-sentences each written on a card formed the test material. A manual slot machine was prepared so that individual cards could be slid through the slit.

Ten stutterers and ten normals in the age range of 18 - 40 years and 16 - 38 years respectively, participated in the task. They were tested individually. They were seated comfortably in the recording room of the Speech Science Department and were instructed to read the word/sentence as early as possible into the microphone. Each card was slid into the slot (which made a noise) and was visually presented to the subject. The noise of the card slide and the subjects response was audio-recorded which was fed to the DSP Sonograph 5500 through line input. The speech reaction time was measured as the time difference between the onset of the impulse and the onset of the speech on the waveform as displayed on the screen.

Thus, in this regard SRT measurements were made for all independent variables and an analysis of variance was used to determine the within group and between group differences with respect to word length and word complexity variables. A Fisher's PLSD post hoc test followed the within group analysis of variance to delineate the locus of significant difference between means. For studying the linguistic complexity variable, within and between group comparisons for standard and picture-sentences were carried out using a paired and unpaired t-test respectively.

The results of the study indicated :

(1) A significant difference in SRTs between normals and stutterers with longer SRTs in stutterers, the exception to the rule being an absence of significant difference between normals and stutterers in monosyllabic (across all complexity conditions), bisyllabic (only in complexity 13' condition) and multisyllabic (only in complexity 'C' condition) word levels.

(2) An increase in SRTs with an increase in word length and word complexity. This effect was greater for stutterers than for normal controls. However,

(a) Word length manipulation had a greater effect on stutterers SRTs in complexity 'B' condition only, and all other significant effects of word length were similar across groups and conditions.

(b) Complexity manipulations at bisyllabic level in stutterers were significant for ' A' vs ' C and ' B' vs ' C conditions. In normals, at bisyllabic level differences were significant at ' A' vs ' B' and ' A ' vs ' C and for multisyllabic level at 'B'vs'C condition.

(3) Significant differences were elicited between the SRT's of standard sentences vs picture-sentences and multisyllabic word level vs standard sentences for both within and across group conditions.

(4) Increase in percentage of stuttering events with increase in word length and word complexity in stutterers was observed.

In conclusion, manipulations of complexity (word length and motoric), to an extent depict the inability of stutterers to program and produce utterances that are well co-ordinated in terms of spatially and temporally ordered elements. However, other possibilities - differences in input preserving, interference between language formulation and production, and strategies of slowing down to enhance fluency, on difficult speech tasks, severity of stuttering and treatment influences - may have been responsible for the results obtained.

Despite contamination of results by the above, it can still be argued that there is a definite tendency for stutterer's SRTs and dysfluencies to be greater under conditions that increase the complexity of response preparation or production. The results of the study suggest that the sutterers may be endowed with inefficient motor programming capabilities, that are aggravated by increased production demands especially under time stress conditions.

Suggestions for Future Research:

(1) A larger sample may need to be considered for inductively drawing inferences from such speech motor control experiments in stuttering.

(2) It would also be of additive benefit to "sub-group" stutterers and then perform similar experimental protocols to test the speech motor control processes in these well defined populations.

(3) It would be interesting to study phonological and semantic priming effects on sRTs, in a hope that it may shed light on the underlying neuronal activation processes that may be aberrant in stutterers.

(4) SRT paradigms utilizing stimuli across languages in bilingual and multilingual stutterers, may be the window through which one can investigate language and phonetic influences on the occurances of stuttering events.

(5) Simultaneous measurement in physiological (electromyographic) aerodynamic and articulatory-kinematic domains, integrated into SRT paradigms would reveal the "proximal" factors underlying the pathophysiology of stuttering.

(6) Lastly, invaliable foresights can be obtained by investigating the effects of treatment variables with simultaneous physiological and SRT measurements.

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