# Speech Motor Programming in Stutterers: a pre-post therapy comparison

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## Abstract

*This study investigated the changes in speech reaction time (SRT) before and after therapy for words and sentences varying in their length and linguistic complexity. Eleven stutterers in the age ranges 18 to 34 years were compared on a choice reaction time paradigm. The results indicated shorter SRTs in post-therapy condition compared to pre-therapy condition. Significant interaction of test and complexity were observed. Within this perspective stuttering can be viewed as speech motor programming disorder, which is potentially benefited from the application of fluency enhancing therapy. Certain exceptions in the results can be due to variations in severity of stuttering and treatment influences in each participant.*

## Introduction

Van Riper (1982) defined stuttering as a disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound in a word. In the scope of this definition stuttering is considered as a motoric disturbance that results in a broad spectrum of dysfluencies. A major line of research over at least three decades has investigated the possibility of a motor control disorder as at least one component (Ingham, 1998; Peters, Hulstijn & Van Lieshout, 2000). Speech motor control perspective on stuttering has been largely responsible for promoting the view that stuttering is best understood as a neurophysiological disorder that directly affects the speech motor system.

The interaction between phonologic difficulty and stuttering has been argued since Brown's (1945) work on the influence of linguistic factors and occurrence of stuttering. These difficulties are thought to arise at the level of planning of speech or during initiation and execution phase of speech production. Stenberg, Monsell, Knoll and Wright (1978) proposed a model of speech production that can be divided into four stages – the programming stage, retrieval, unpacking and muscle command stage. According to this model, the total time needed to prepare a response, is an additive composition of each time interval resulting from the separate stages, since different stages are considered to be independent of each other. That is longer words will take more time to program, retrieve, unpack and execute compared to shorter words.

A commonly used technique to investigate motor programming in speech production is the use of Speech Reaction Time (SRT) paradigms (Kahneman, 1973; Sheriden, 1981; Van Lieshout, Hulstijn & Peters, 1996a) where SRT is defined as the time interval between stimulus presentation and speech onset. There is a consensus among researchers (Peters, Hulstijn & Strakweather, 1989; Van Lieshout, Hulstijn & Peters, 1996a; Aravind, 1997;

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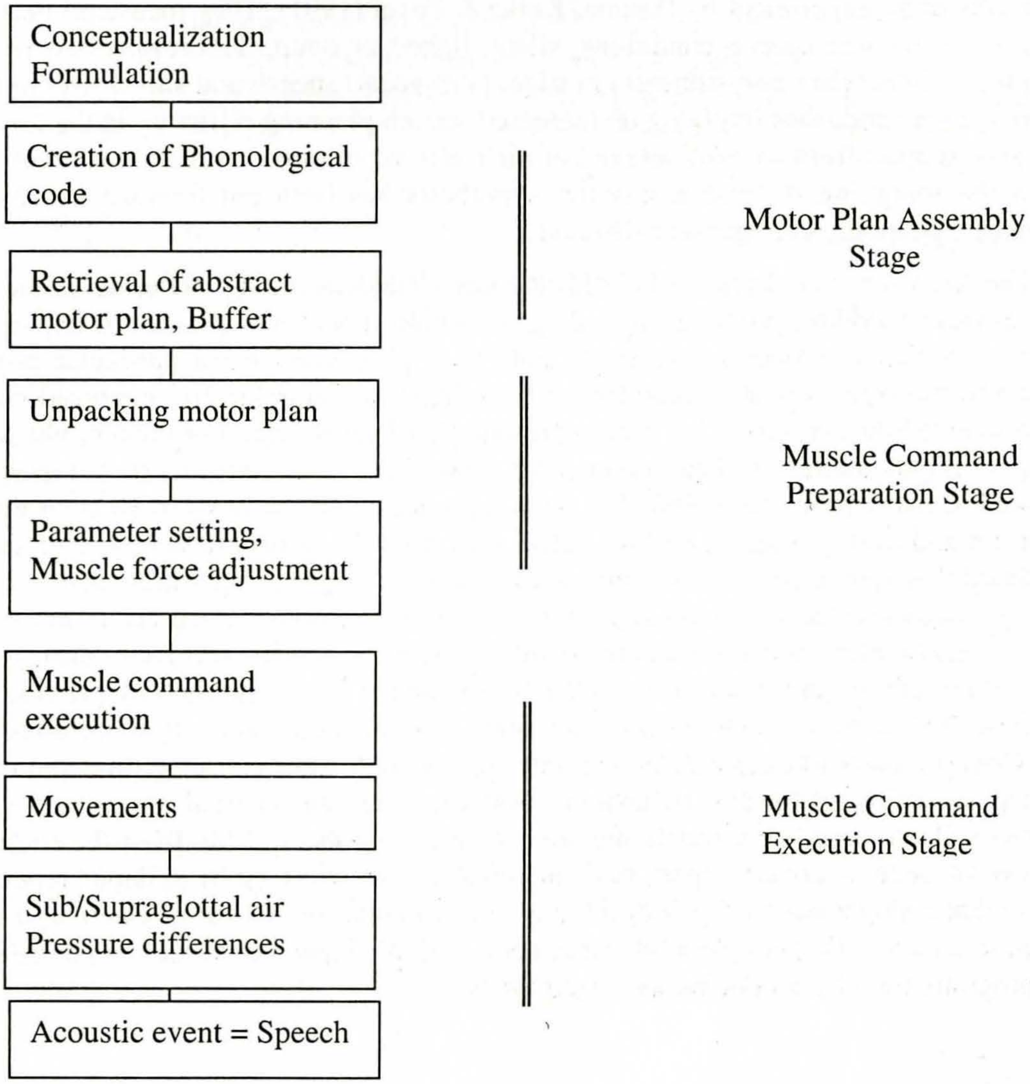
Vijay, 2001) on the use of SRT paradigms with varied task complexity to study response preparation in the temporal domain. The underlying assumption of this paradigm is that differences in the latency of reaction time (the dependent variable) consequent to manipulation of the eliciting stimuli (the independent variable) are a result of alteration in motor programming. An example that illustrates this assumption is that of increase in SRT in speech production by normal subjects when the size of the eliciting stimuli is increased by altering the number of syllables in it (Klapp & Wyatt, 1976). It is suggested that greater speech motor programming time is essential if utterances of increasing length have to be centrally organized.

Further the speech motor research using SRT paradigm can be discussed in the context of the model by Van Lieshout (1995).

The model consists of three main stages as follows:

1. The motor plan assembly stage in which an abstract motor plan is assembled.
2. The muscle command preparation stage in which muscle commands are turned to the context of the verbal motor task and
3. The muscle command execution stage in which muscle commands are initiated and executed. Figure 1 illustrates the speech motor production model by Van Lieshout (1995).

**Figure 1:** Speech motor production model by Van Lieshout (1995).



It follows from the above argument that if people have speech motor programming deficits they require more time to assemble motor plans. This effect would be greatest for longer words, since, they have more units to program. It explains stuttering events which occur more frequently with certain linguistic features such as with increasing size of a word or sentence, at the beginning or initial position of the word (Soderberg, 1966; Jayaram, 1984). This in conjunction with Hulstijn's (1987) view that speech utterances are supposed to be programmed before their initiation which lead to the hypothesis that programming or planning processes may be involved in or is responsible for the origin of stuttering.

Introducing simultaneous recordings of various speech physiological processes and employing systematic manipulations of speech tasks within the reaction time paradigm, Peters, Hulstijn & Starkweather (1989) investigated whether there are differences between stutterers and nonstutterers in the planning processes. They conducted the experiment in two conditions of time pressure (high and low) and two conditions of preparation (delayed and immediate responding) in a reaction time paradigm. The results suggested that the reaction-time of stutterers and nonstutterers are both increased by longer utterances and that the effect is proportionally greater for the stutterers, particularly in the prelaryngeal subintervals. The results are interpreted as suggesting that stutterers may have difficulty in the motor programming of speech behaviour.

Another argument for locating the cause of stuttering in the speech planning is given by the results of an experiment by Postma, Kolka & Povel (1991). They measured maximum speaking rates in three speech conditions: silent, lipped or overt. The results revealed that stutteres were slower than non-stutterers in silent (sub-vocal) speech and still slower in lipped and overt speech conditions implying on 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.

The 'covert repair' hypothesis holds the key to understanding stuttering as the result of phonological encoding problem. Spreading activation model was utilized to explain how errors arise due to improper selection of units (e.g. phonemic) for a particular program. According to the spreading activation model there exists a hierarchically organized network of interconnected unit or nodes for each representational level (e.g. morphemic, phonemic). Each super ordinate node is linked to numerous subordinate nodes or units (e.g. a morpheme node linked to many phoneme units). The units are selected on the basis of whether they are active or not and also depending on how active they are with respect to neighboring units. It is speculated that sometimes a wrong unit outmatches the target in activation or the selected target unit's activation level decays rapidly (for unknown reasons). Such errors in selection make the phonetic plan vulnerable to phonemic and phonetic distortions. These distortions or errors in programming are detected by internal monitoring loops and thereby provide many opportunities for self-repair of the program prior to overt articulation (thus referred to as covert). Covert repairs like error detection, interruption and repair consume time and may be manifested as overt stuttering Behaviour. For example, an internal error such as an interrupted syllable could be covertly repaired by restarting the syllable from the beginning; the effects of such a covert repair may manifest as an overt (sub) syllabic repetitions. Assuming that a single covert repair cycle may not guarantee successful production, it would follow quite logically that people who stutter need multiple repairs in succession to achieve a correct program, thereby producing increased SRTs.

Several studies (Aravind, 1997) have reported difficulty in phonological encoding in persons with stuttering. On the contrary, no systematic predictable relation between phonological difficulty and the occurrence of stuttering like dysfluencies at the early stage of stuttering has been reported. It is believed that acoustic, kinematic and EMG evidence indicates that at least some adults who stutter differ from adults who do not stutter in the organization of speech movements and their control, even if the resulting speech is fluent perceptually. However, there is a possibility that these differences are the result of learned coping strategies or the effect of therapeutic procedures adopted.

If stutterers have longer Speech Reaction Time (SRT) compared to nonstutterers and if fluency shaping therapy brings about fluency in them, then it follows that their SRT's should be similar to those of nonstutterers. In this context, the present study investigated the effect of therapy on speech motor control using speech reaction time paradigm for simple/complex words, short/long words and simple/complex sentences in stutterers.

## Method

**Subjects:**

Eleven stutterers participated in the study. All the subjects were proficient in reading, writing and speaking Kannada and had normal hearing and vision with no background of any neuromotor disorders. None of them had undergone any kind of formal speech therapy previously. No attempt was made to systematically control the degree of stuttering or the treatment variables. Stuttering severity was determined by speech-language pathologist using the Stuttering Severity Instrument scores on reading and conversational speech. Table 1 shows the details of subjects.

**Table 1**: Subject details

| Sl. No. | Age in Years/ Gender | SSI Score | | Provisional diagnosis |
|---|---|---|---|---|
| | | Pre-therapy | Post-therapy | |
| 1 | 22/M | 15 | 0 | Very Mild Stuttering |
| 2 | 23/M | 14 | 0 | Very Mild Stuttering |
| 3 | 20/M | 19 | 2 | Mild Stuttering |
| 4 | 18/M | 17 | 2 | Mild Stuttering |
| 5 | 19/M | 19 | 1 | Mild Stuttering |
| 6 | 23/M | 17 | 0 | Mild Stuttering |
| 7 | 20/M | 21 | 0 | Mild Stuttering |
| 8 | 18/M | 24 | 0 | Moderate Stuttering |
| 9 | 34/M | 23 | 4 | Moderate Stuttering |
| 10 | 21/F | 24 | 0 | Moderate Stuttering |
| 11 | 18/M | 32 | 13 | Severe Stuttering |

**Material:**

Material prepared by Aravind (1997) was used. It consisted of 36 Kannada words varying in word length (with three words each in monosyllabic, bisyllabic, trisyllabic and polysyllabic levels) and motoric complexity varying in steps such that

Complexity A had words with phonemes /b/, /t/, /k/, /m/, /g/;

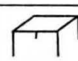
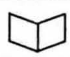
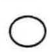
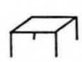
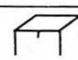
Complexity B had words with phonemes /dz/, /s/, /r/, /l/, and

Complexity C had words with clusters /sk/, /sl/, /bl/, /kr/, /bhr/, /gr/, /pr/.

Apart from the words, standard and picture-sentences were also used. Three written sentences (standard sentence) and three sentences (one with three words and the rest was with four words) represented by orthographic, numeric and pictorial items (sequenced to form a picture sentence) were used. All words and sentences were written one each on a power point slide. Power point slides were prepared with a 2 KHz warning tone of 200 ms followed by the word or sentence which formed the material. Table 2 shows the material used in the study.

**Table 2:** Materials used

| Word Complexity/ word length | A | | B | | C | |
|---|---|---|---|---|---|---|
| Mono Syllabic | ಬಾ | /ba:/ | ಚಾ | /ta:/ | ಸ್ಕೂಲ್ | /sku:l/ |
| | ತಾ | /ta:/ | ಜೂ | /zu:/ | ಸ್ಲೇಟು | /sleitu/ |
| | ಕೀ | /ki:/ | ಸೀ | /si:/ | ಬ್ಲೇಡು | /bleidu/ |
| Bi Syllabic | ಮನೆ | /mane/| | ಸೂಜಿ | /su:dzi/ | ಕ್ರಾಂತಿ | /kra:nti/ |
| | ಕಾಲು | /ka:lu/ | ಲಾರಿ | /la:ri/ | ಭ್ರಷ್ಟ | /bharata/ |
| | ಬೀಗ | /bi:ga/ | ಸರ | /sara/ | ಗ್ರಂಥ | /grantha/ |
| Tri Syllabic | ಇರುವೆ | /iruve/ | ಸರಸ | /sarasa/ | ಕ್ಷಮಿಸಿ | /kshamisi/ |
| | ಅಗಸ | /agasa/| | ರಂಗೋಲಿ | /rango:li/ | ಶ್ರವಣ | /ravana/ |
| | ಎರಡು | /eradu/ | ಚಪ್ಪಲಿ | /tappali/ | ಕ್ಷತ್ರಿಯ | /kshatri:ya/ |
| Poly Syllabic | ಬೀಗದ ಕೈ | /bi:gadakai/ | ಸೋಮವಾರ | /So::mava:ra/ | ಕ್ರಾಂತಿವೀರ | /kra:ntivi:ra/| |
| | ಗಾಳಿಪಟ | /ga:lipata/ | ರಾಮಾಯಣ | /ra:ma:jna/ | ಗ್ರಂಥಗಳು | /granthagalu/ |
| | ಕನ್ನಡಕ | /kannadaka/ | ಚಂದಮಾಮ | /tandama:ma/ | ಪ್ರಾಂತಗಳು | /pra:ntagalu/ |

| Standard Sentences | Picture – Word Stimuli |
|---|---|
| ಅವರು ಕ್ಶಮಿಸಿ ಎಂದರು | ಇದು + 1 + |
| /avaru kshamisi endaru/ | /idu/ + 1 + |
| ಕರ್ಣನ ಕವಚ ವಜ್ರದ್ದು |  + ಮೇಲೆ +  + ಇದೆ |
| /karnana kavat vajraddu/ |  + /me:le/ +  + /ide/ |
| ಸತೀಶ ಮಧ್ಯಾಹ್ನ ಹೋದನು |  +  + ಕೆಳಗೆ + ಇದೆ |
| /sati:sha Madhya:hna ho: danu/ |  +  + /kelege/ + /ide/ |

**Procedure**

Subjects were seated in front of a computer screen in Speech-Language Science laboratory and were tested individually. Words/sentences were visually presented one at a time on the computer screen.

The experiment utilized a choice reaction time paradigm with high time pressure and no feedback on individual reaction times. Subjects were instructed to read the word/sentence as fast as possible, soon after it appeared on the computer screen. To familiarize them with the procedure, few practice or trial runs were given. Also stutterers were instructed not to use fluency-enhancing techniques during the test and this would have interfered with the task demands.

A multiple pre-post test design was employed. Subjects were tested prior to and after successful completion of prolongation or modified airflow therapy. The therapy was non programmed. Moving from one step to another required 95% fluency. Each subject attended daily therapy of 45 minutes. In addition, each of them had to practice for 2 hours/day. The total number of sessions varied from 15 to 40.

The subject utterances and transient stimuli (2 KHz pure tone) were recorded using Sony deck CFSWY55 type recorder. The recorded utterances were line fed from cassette deck onto the computer memory with an analog to digital converter, digitized at 16 KHz sampling rate. All the fluent utterances were considered for analysis. In order to be accepted as fluent, an utterance had to satisfy two criteria:

1. There should be no visual signs of struggle in the subject's face or body just before or during the token. The experimenter took note of these visual signs of dysfluency during the recording sessions.
2. The utterances should not contain audible hesitations, prolongations and repetitions. These acoustic signs of dysfluency were judged by the experimenter from an audio recording of the subject's speech.

**Analysis**

Cool Edit Program was used for the measurement of speech reaction time (SRT). Using the waveform display, SRT was measured as the time duration between the onset of the tone and the onset of the word. Figure 2 illustrates the measurement of SRT.

**Statistical analysis:**

The data was tabulated and mean SRT prior to and after therapy was calculated. One factor analysis of variance using repeated measures design was used to find the significant difference between pre and post therapy SRT and interaction between word complexity, word length and test condition. This was followed by Tukey's Post hoc test to identify the locus of significant difference between the means. To study the linguistic complexity variables, comparison for standard sentences and picture sentences were carried out using paired t-test.

## Results

1. **Complexity levels:**

The results indicated shorter SRTs in post-therapy condition compared to pre-therapy condition. Also, standard deviations were higher in pre-therapy condition compared to that in the post-therapy conditions. SRTs increased with increase in word length (except for bisyllabic words in complexity 'A', polysyllabic words in complexity 'B' and for bisyllabic, trisyllabic, polysyllabic words in complexity 'C' in the pre-therapy condition and for bisyllabic words in complexity 'A' and for bisyllabic, trisyllabic and polysyllabic words complexity 'C' in post-therapy condition) and increase in word complexity (except for polysyllabic words in complexity B in both pre and post-therapy conditions and for bisyllabic words in complexity C in post-therapy condition). Table 3, 4 and 5 show the mean SRT and standard deviations for stutterers in both pre-and-post-therapy condition for four levels of word length and three levels of complexity.

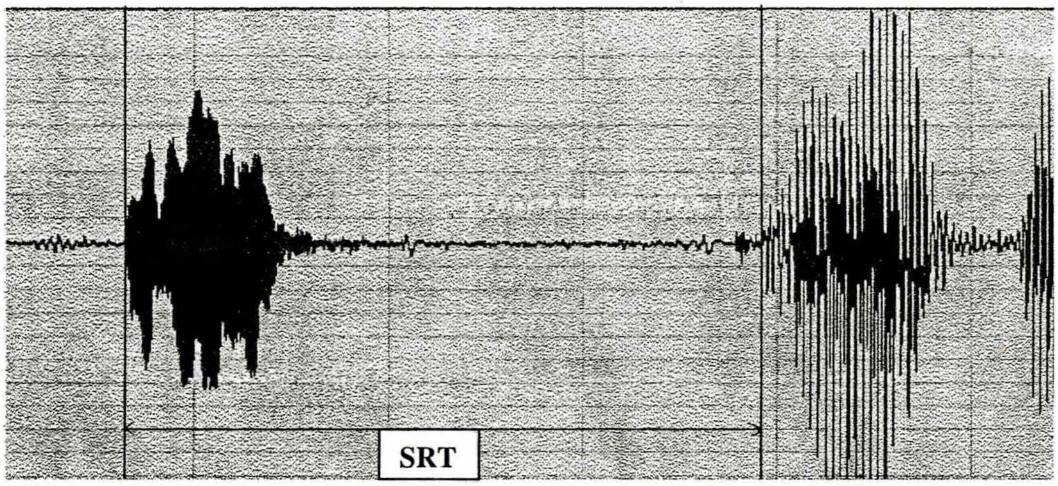



**Figure 2:** Illustration of the measurement of speech reaction time. (target 'kra:nti)

**Table 3:** Means and standard deviations (SD) of SRT's (in ms) in pre and post-therapy condition for four levels of word length at complexity 'A' condition.

| Word Length | Pre-therapy | | Post-therapy | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Monosyllabic | 576.9 | 110.3 | 577.1 | 124.2 |
| Bisyllabic | 564.3 | 114.9 | 528.8 | 112.7 |
| Trisyllabic | 630.8 | 151.1 | 596.0 | 227.2 |
| Polysyllabic | 776.9 | 308.4 | 630.3 | 179.0 |

**Table 4:** Means and standard deviations (SD) of SRT's (in ms) in pre-and post-therapy condition for four levels of word length at complexity 'B' condition.

| Word Length | Pre-therapy | | Post-therapy | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Monosyllabic | 624.3 | 127.3 | 595.1 | 120.3 |
| Bisyllabic | 633.7 | 139.4 | 603.0 | 123.2 |
| Trisyllabic | 754.0 | 406.2 | 602.5 | 126.4 |
| Polysyllabic | 746.4 | 261.4 | 623.1 | 133.6 |

**Table 5:** Means and standard deviations (SD) of SRT's (in ms) in pre-and post-therapy condition for four levels of word length at complexity 'C' condition.

| Word Length | Pre-therapy | | Post-therapy | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Monosyllabic | 807.8 | 313.2 | 648.3 | 119.1 |
| Bisyllabic | 745.2 | 352.4 | 581.6 | 98.8 |
| Trisyllabic | 792.1 | 373.2 | 640.5 | 149.7 |
| Polysyllabic | 798.9 | 291.4 | 636.9 | 142.8 |

In complexity 'C' phonemic reversal errors were observed in 18.2% of subjects (for e.g. "sulku" instead of target "sku:lu").

- **Within group comparisons**
  - **Word length**: Results of (one factor) ANOVA repeated measures indicated a significant interaction between word length and complexity for complexity 'A' in pre-therapy condition, [F(1,35)=P<0.00]. A post hoc analysis indicated significant difference between the mean SRTs of bisyllabic vs. polysyllabic, monosyllabic vs. polysyllabic, trisyllabic vs. polysyllabic across complexity 'A' in pre-therapy condition. No interaction effect between word length and complexity was observed in post therapy condition.
  - **Word complexity**: Results of (one factor) ANOVA with repeated measures followed by post hoc analysis indicated that SRTs of simple words were significantly different from those of compound or complex words for monosyllabic and bisyllabic words in pre and post therapy conditions. In pre-therapy condition significant interaction effects were observed for SRT means for all complexities at monosyllabic word level [F(1,35)13.880,=P<0.00]. No significant interaction effects were obtained for any complexities at trisyllabic or polysyllabic word level in any of the conditions.
- **Between group comparisons**: Results of paired sample t-test revealed significant interaction between groups for all word levels in complexity 'C' and for polysyllabic words in complexity 'A' and 'B'. But, no significant interaction effects between the groups for monosyllabic, bisyllabic and trisyllabic words in complexity 'A' and complexity 'B' were noticed. Table 6 shows the P values.

**Table 6:** Results of paired sample t-test for between group comparisons across all tasks conditions.

| Tasks | A | B | C |
|---|---|---|---|
| Monosyllabic | t(32)=0.009<br>p=0.99.<br>p>0.05 | t(32)=1.505<br>p=0.142<br>p>0.05 | T(32)=3.299<br>p=0.002*<br>p<0.05 |
| Bisyllabic | t(32)=1.567<br>p=0.127<br>p>0.05 | t(32)=1.282<br>p=0.209<br>p>0.05 | t(32)=2.689<br>p=0.011*<br>p<0.05 |
| Trisyllabic | t(32)=0.929<br>p=0.360<br>p>0.05 | t(32)=2.048<br>p=0.050<br>p>0.05 | t(32)=2.201<br>p=0.035*<br>p<0.05 |
| Polysyllabic | t(32)=2.934<br>p=0.006*<br>p<0.05 | t(32)=2.461<br>p=0.019*<br>P<0.05 | t(32)=3.051<br>p=0.005*<br>p<0.05 |

Significant interaction effect of test x complexity was observed. There was interaction of length x complexity x test condition, length x test condition, and length x complexity were not significant. Table 7 shows the results of 3-way ANOVA.

**Table 7:** Results of 3-way ANOVA-between group comparison depicting F-test & P values.

| Between group | dF | F | p-value | Significant/not significant |
|---|---|---|---|---|
| Length | 3 | 6.990 | 0.000 | Significant |
| Test | 1 | 41.947 | 0.000 | Significant |
| Complexity | 2 | 13.514 | 0.000 | Not Significant |
| Length x test | 3 | 1.391 | 0.244 | Not Significant |
| Length x complexity | 6 | 11.597 | 0.145 | Not Significant |
| Test x complexity | 2 | 4.247 | 0.015 | Significant |
| Length x test x complexity | 6 | 0.735 | 0.621 | Not Significant |

Paired sample t-test indicated significant difference between the pre-and post-therapy conditions for standard sentence (t = 3.273 at 0.003) and picture sentence (t=2.573 at 0.015). Certain interesting observations in this task performance for picture stimulus were found. In this task semantic errors were noticed in 36.4% of subjects (for e.g. "chair" instead of target "table"). In picture sentence 2, 9% of times semantic error for picture word was present (produced "chair" instead of "table"). Also for picture sentence 3, 36.4% of times in pre-therapy condition and 45.5% of times in post-therapy condition similar error was noticed ("chair" instead of "table" and "pencil" instead of "pen").

**Individual subject data:**

Not all subjects showed decrease in SRT in post-therapy condition. Subject 5 consistently showed longer SRTs in post-therapy condition. It was noticed that 27.3%, 72.7%, 54.5% and 81.8% of subjects had shorter SRT in post-therapy condition compared to pre-therapy in complexity 'A' for mono, bi, tri, polysyllabic stimuli, respectively. 54.5%, 45.5%, 63.6% and 90.9% subjects had shorter SRT in post-therapy condition compared to pre-therapy condition in complexity 'B' for mono, bi, tri and polysyllabic utterances respectively. Also, 72.7%, 63.6%, 72.7% and 72.7% of subjects had shorter SRT's in complexity 'C' for mono, bi, tri and polysyllabic stimuli, respectively. The shorter SRT (in post-therapy condition) was more prominent for polysyllabic words and complexity 'C'.

## Discussion

The results indicated several points of interest. First of all, the results revealed significantly shorter speech reaction times in post-therapy condition (p=0.000) compared to pre-therapy condition. The results are in consonance with those of Hurford and Webster (1985). Hurford et. al. conducted a simple visual manual reaction time task and found significant differences between groups (stutteres vs. nonstutterers), trials (pre-therapy and pretest vs. post-therapy and post test) and trial x conditions interaction. The authors found that reaction time decreased significantly as a function of stutterer's participation in therapy. Various factors that could have been responsible for the variations in reaction were critically analyzed. A weakening of arousal is impaired in stutteres. 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. Thus it is more prudent to say that stutterers, as a group appear to take more time in some or all of the processing tasks related to speech motor behavior. As evident from the data, presence of semantic errors in 36.4% of stutterers and phonemic errors in 18.2% of stutterers at the perceptual level can be supportive of aberrant information processing to some extent. These behaviors may benefit from learning to produce speech more slowly, articulating more slowly as well as increasing length of voicing as evidenced from acoustic studies of treated stutterers. Longer intervals of voicing, as noticed in some of the subjects may be the result of facilitated speech production by providing more sensory information to be used in the planning process or it may be the effect of simplified laryngeal activity along with the effective coordination between various systems involved in speech production or the result of reduced muscle tension. In turn the effect can be hypothesized as reduced reaction time for better coordination between various stages of speech production.

Second, SRTs increased with increase in word length and word complexity. But there were some exceptions. Also, results revealed significant interaction between the test condition and complexity (p=0.015), where the pre- and post-therapy difference in SRT was found to be greater for more complex words via complexity 'C' than complexity 'B' and 'A'. This can be attributed to the requirements for more coordination of intricate and ballistic network of movement subroutines for complex utterances compared to simple utterances.

Peters et al. (1989) suggest that articulatory complexity in consonant clusters in general produces slower reaction times than non cluster words. At another level, increased SRTs may be viewed as covert repair strategies utilized by the individual (for errors in speech motor programming (of consonant clusters). Such errors could encompass coarticulatory transition defects the faulty anticipatory coarticulation which improved as a function of therapy.

In addition, as words in complexity 'C' condition were less familiar and orthographically more complex they could have elicited longer SRTs in the pre-therapy condition but this influence is ruled out as there is larger pre, post therapy difference for complexity 'C' and for greater word lengths viz. trisyllabic and polysyllabic words at complexity 'B' and for polysyllabic words at complexity 'A'. This would suggest that cluster production coupled with an increased word size, adversely affects production time in general as seen in both the test conditions (p=0.000). The closer inspection of data revealed that word length manipulation had more effect on stutterer's speech reaction time in pre therapy condition than post-therapy condition, but only for complexity condition "A". The other effects of word length were similar across groups as no test and length interaction was observed (p=0.244).

The latter is explained by an equal amount of difficulty in both groups for increasing word length due to an increased programming time required to centrally organize utterances of increasing length (Klapp & Wyatt, 1976; Peters, et al. 1989;). Between group comparison revealed that significant group differences for the two conditions existed for words that are more complex (word size and phonetic complexity). There was a significant pre-post therapy difference for all word levels at complexity 'C' and for polysyllabic words at complexity 'A' and 'B'. Although results are suggestive of differences for difficult and complex stimuli, overall absence of length vs. test, length vs. complexity and length vs. test vs. complexity interactions accounts for the differences in individual subjects performance.

Third, certain interesting observations in the task performance for picture stimulus were found. In picture sentence 2, 9% of times semantic error for picture word was present (produced "chair" instead of "table" and "pencil" instead of "pen"). Also for picture sentence 3, 36.4% of times in pre-therapy condition and 45.5% of times in post-therapy condition similar error was noticed ("chair" instead of "table" and "pencil" instead of "pen"). Though in the experiment SRT was calculated with respect to the obtained target rather than the expected one, such findings could be of interest to highlight the presence of faulty planning in stutterers or a mere compensatory strategy adopted to react faster to the stimuli which are interfered from the memory of previous utterance as noticed. An alternative explanation for such errors can be due to the role of anxiety in a high time stress speaking condition (Starkweather, 1995). The collective implication of these and other cited findings in literature could be taken to suggest that stutterers lack speech motor control which varies as a function of response complexity and is influenced by learning through fluency enhancing techniques.

Fourth, not all subjects showed considerable increase in SRT in post-therapy condition. Thus, one needs to analyze additional factors that may influence SRTs hypothesized to be responsible for reduction in reaction time latencies. However if arousal played role in the observed decrease in reaction time latencies in the post therapy condition, one might suspect a higher number of anticipation errors (trials in which the participant responded prior to the presentation of the stimulus).

It has been speculated that stuttering can result from a defect in sensory feedback reception associated with speech production. The basic notion is that the physical consequences that accompany repeated instances of stuttering may have an inhibitory effect on several different response modalities. This condition which could have established itself prior to therapy may be responsible for the longer pre-therapy reaction time latencies. Thus the extensive utilization of fluency producing skills reduces inhibition of response initiation and allows for quicker response times as observed in the post-therapy trial. Hurford et. al laid emphasis on the relaxed nature of the target behavior as a result of the speech muscles which are not tensed or inappropriately constricted. But the generalization of responses from manual task (Hurford et al. 1985) to speech task (present study) is questionable as the underlying mechanism may differ.

Within the perspective of reaction time studies in stutterers it is evidenced that stutterers, as a group, are slower in making manual, vocal and verbal responses to auditory and visual stimuli. One could attribute these group differences to increased planning or speech motor programming time in stutterers compared to normals. However, even when one assumes that processes preceding actual execution of speech are variable in the therapy that could have been responsible for the same. In choice reaction time paradigms word recognition differences in reading times and input processing may have influences on the reaction time to a stimulus. Therefore, to eliminate the possible disturbing influences of implicit reading time differences, this study incorporated a picture-sentence reading task in comparison with a standard sentence. The results highlighted significant differences across test condition for standard sentences (p=0.015) and picture sentences (p=0.003). The greater improvement in performance with picture sentences after therapy speculates for facilitation in linguistic processing. Van Lieshout et al (1989) suggested that more extensive linguistic processing might be required in a picture sentence task due to a different mode of access to the semantic and phonological codes. This results in increased speech reaction time. Thus, the facilitation could have greater effect for complex stimuli.

The results partially support the hypothesis that SRTs should decrease in the post-therapy condition compared to the pre-therapy condition. This also supports the notion that stuttering is a speech motor programming error.

To conclude, within this perspective stuttering can be viewed as a speech motor programming disorder, which is potentially benefited from the application of fluency enhancing therapy. Certain exceptions in the results can be due to variations in severity of stuttering, and treatment influences in each participant. Future research could examine more closely the relationship between the therapy and reduced reaction time latencies found in the post therapy stutterers. Closer examination of these variables may lead to a better understanding of the effectiveness of particular therapy program and the etiology of stuttering.

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