A Study of Co-articulation in Stuttering

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A Dissertation submitted in Part Fulfilment
for the Degree of Master of Science
(Speech & Hearing)

UNIVERSITY OF MYSORE

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MY PARENTS AND

MY BROTHER

<u>CERTIFICATE</u>

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DECLARATION

This dissertation entitled: A STUDY OF CO-ARTICULATION IN STUTTERING is the result of my own study undertaken under the guidance of Dr.Jayaram, M, Lecturer in Language and Language Disorders, All India Institute of Speech and Hearing, Mysore . This has not been submitted earlier to any other University for any other Diploma or Degree course.

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INTRODUCTION

Stuttering is a disorder of rhythm where fluency is affected. Repetitions of sounds and syllables and prolongations of sounds are the universally demonstratable characteristics of stuttering (Wingate, 1964). The behaviour of stutterers have been sought to be explained by many theories;(i) organic theories - where emphasis is on some physical and constitutional aspects? (ii) psychogenic theories - where personality and neurotic traits are given more importance; (iii) evaluational theories - where the diagnosis of the parents play a major role and (iv) learned behaviour theories where anticipation, conditioning and conflict are seen as key factc Though all these theories have considerably enhanced our understand ing of the problem of stuttering, most of the researchers are aware of the inconclusive findings of research into the nature of stutter ing.

The recent investigations into stuttering have been toward exploring the linguistic and phonetic side of the disorder. A major off shoot of this line of research is the focus on the coarti culatory aspect of stuttering. The idea that stutterers lack the coarticulatory transitions in their speech, first mooted by Stromst (1965), has not been well researched despite the fact that, at one time, research into coarticulatory aspect of stuttering showed rich promise for the future.

Coarticulation refers to the fact that individual phonemes in a speech sequence share both space and time with their neighbouring phonemes. In other words, certain characteristics of the preceeding as well as succeding phonemes in a sequence appear in the sound being produced. Coarticulation phenomena can be divided into two types: 'backward' coarticulation, in which articulatory characteristics of a phone can be observed in later phones in the string? and 'forward' coarticulation, in which an articulatory characteristics of a phone is observed during production of the proceeding phone(s). It has been reported that coarticulation is influenced by phonetic context, rate of speech, differential stress and morphemic boundaries (Lehiste, 1962? Lindblom, 1963? Ohman, 1966; Stevens and House, 1964).

The formant frequencies which depend on the size and shape of the vocal tract have long been identified with vowe1 values. Lloyd and more recently Potter and Peterson (1948) have demonstrated that vowel sounds are determined in part by the relative values of the formant frequencies rather than by the absolute magnitude of these formant frequencies. The speech organs are almost in a state of continuous movement as phonemic sequences are produced and these movements are reflected in the changing acoustical structure of the speech wave. Consonantal context, it has been shown among others by Stevens and House (1963) causes systematic shifts in the vowel formant frequencies depending upon the place and manner of articulation as well as voicing characteristics. This is one particular aspect of coarticulation (i.e., appropriate formant transitions) that has been reported to be lacking in the speech of stutterers (Agnello, 1966; stromsta, 1965). stromsta (1965) reported that stutterers often failed to show the typical raising or falling formant transitions of normal speech. Agmello (1966)found evidence of "numerous instances of coarticulatory failures" inthe stutterers' disfluent speech, but has not elucidated on them. However, two other studies (Hutchinson and Watkin, 1974; Montogomery and Cooke, 1976) have shown that only a small percentage of stutterers show evidence of this lack of formant transitions. Montogomery and Cooke (1976) reported that stutterers do not lack formant transitions but demonstrate formant transitions that are different from those found in fluent segments.t However, Montogomery and Cooke (1976) neither have elaborated on the type of coarticulatory transitional differences in the fluent and different utterances of stutterers nor have they compared them with the normals speech. Therefore, the occurrence of formant transitions and their nature in the stutterers speech needs to be investigated in more detail.

Statement of the problem:

The general purpose of this study was to investigate the presence, absence or deviation of coarticulatory transitions (first and second formant transitions) in the fluent and disfluent speech of stutterers and to compare this with the fluent utterances of non-stutterers. Specifically, the present study investigated,

1) the presence or absence of first and second formant transitions in the fluent and disfluent utterances in the stutterers speech consisting of VCV sequences.

2) Whether appropriate transitions appear in the vowels that are necessary to integrate them with the succeeding consonant? and

3) comparison of the coarticulatory transitions between (i) the fluent and disfluent utterances of stutterers and (ii) the fluent utterances of stutterers and non-stutterers.

LITERATURE SURVEY

The production of speech involves two fundamental aspects: The stationary properties of phoneme realization and the dynamic rules governing the fusion of strings of phonemes into connected speech (Ohman, 1966). The implication is that, the production of individual sounds is not of unique or of sole importance in connected speech;(and) that the individual phonemes share both space and time with their neighbouring sounds is equally important. Speech sounds overlap on one another in ongoing connected speech. Therefore, certain characteristics of the preceeding and the follow ing sounds in a sequence appear inthe sound being produced. This is the phenomenon of coarticulation.

The phenomenon of coarticulation has been known for a long time and has been the subject matter of extensive research in the past. Bloomfield (1933) stressed the point that the position of the arti- culators for a given sound was altered to be more compatible with those of the neighbouring sounds. Curtis (1954) demonstrated that overlapping articulatory movements in connected speech segments produced significant observable variations in the acoustic patterns. It was shown that when two sounds were articulated in a connected manner, the acoustic end product was not simply a combination or sum of the acoustic characteristics of the two individual sounds in question but rather a new acoustic pattern.

Two possible sources of influence can be identified with reference to the coarticulatory effects of phonetic contexts: influence of the sound(s) that preceed (backward coarticulation) and sounds that follow the sound being produced (forward coarticulation). In backward coarticulation, the erticulatory targets of a preceeding sound overlap with and influence those of the intended sound. It has been said to occur as a result of the mechanoinertial limitations of the muscles of the speech mechanism which cause articulator response to lag behind the arrival of neural commands and to persist after such commands cease (Henke, 1967; Lindblom, 1963; Stevens and House, 1963). In the forward or anticipatory coarticulation, the articulatory targets of the sound being produced are influenced by those of the upcoming sounds . Therefore, it is obvious that articulatory adjustments for the intended sound must occur in anticipation of the articulomotor characteristics of an upcoming, yet to be produced sound* Anticipatory coarticulation is frequently thought to be the result of 'look ahead' or 'scanning mechanism' that previews upcoming phonemes and modifies the targets of the phoneme being produced so that they are compatible with the upcoming phonemes (Henke, 1967).

The production of a given sound involves the simultaneous movement of a number of articulators with certain trajectories and multiple targets. The magnitude of observable coarticulation is contingent upon the degree of compatibility among the respective articulatcr trajectories, target values of each sound as well as the reciprocal adjustments made. Therefore, in addition to phonetic context, rate of speech, differential stress and morphemic boundaries appear to condition the coarticulation (Lehiste, 1962; Lindblom, 1963; Ohman, 1966; Stevens and House, 1963). In6ther words, the trajectory of a given articulator may be altered and varied according to the trajectory targets for preceding and upcoming speech sounds, and possibly to a lesser extent, according to speech rate and stress requirements. Consequently, the ideal target may not be achieved, but only approximated in ongoing speech resulting in target undershooting or overshooting.

Coarticulation occurs continuously in speech and assists in the smooth transition from sound to sound. For example, in the production of the word 'too', one can see that the lips would be slightly rounded and pushed forward simultaneously with the attainment of tongue closure for the initial sound. Such lip movement is in no way part of the normal articulatory target specification of /t/but is appropriate for the following vowel /u/. This is an example of anticipatory coarticultion where it is as if all motor commands for the components of target movements in a syllable are issued simultaneously at the onset of that syllable as long as they are non-contradictory (Kozhevnikov and Chistovich, 1965). The motor specification of target movements will include such factors

As which articulatory organs are to contract; which muscle or groups of muscles are to contract; the degree of force of contraction; the velocity of articulatory movements etc. Control of the ongoing speech is facilitated by proprioceptive, tactile and auditory feedback mechanisms. For the afferent information from these feedback channels to reach the planning unit involves a certain minimal delay. However, it is not necessary that the target movements be completed before afferent information is sent back to the planning unit. It seems plausible that the regulator and planning systems can extrapolate into the future and so predict the position that the articulatory organs will attain after a specific interval of time. We know that the muscle spindle is capable of providing 'predictive' information about the behaviour of a muscle (Bowman, 1971; MacNeilage, 1970, 1972? Smith and Lee, 1972) thus allowing compensation in advance by the regulator system. Consequently, it may not be necessary for each stage of the planning function (i.e. each target movement) to wait until the error signal of the previous stage equals zero.

The smooth triggering of successive target movements is an important requirement for fluent speech. To facilitate such smooth transition, it is necessary for the motor regulator to scan ahead to atleast the next target movement in time and make appropriate modifications to the current neurolinguistic program being processed at any given time. It is only by maintaining such constant surveillance that the motor regulator can ensure that the speech organs move in a parallel fashion and so enable coarticulation to occur freely.

Assuming that sequences of movements for an entire syllable are triggered off as a whole at the beginning of that syllable, the failure in such a sequence results in the fixation of target movements of the current neurolinguistic program being processed. It has been suggested in the literature that such a thing might be happening in the stutterers speech (Jayaram, 1979). Probably because there is fixation of the target movement of the first sound in a speech sequence and somehow the speech organs have not received the motor schema for the succeding sound(s) or syllable in time stutterers repeat or prolong them before going onto the next sound. This is consistent with the view that stuttering is morphemically bound in adult stutterers (Van Riper, 1971; Wingate, 1976). The logic is simple. If'smooth triggering of the successive target movements and modifications of the current neurolinguistic program being processed in the speech cycle is an imports requirement for normal fluent speech, then in a person having fluency disorder such a system might be faulty. This needs to be investigated at length.

Though there are a number of investigations on phoneme realization, research into fusion of phonemic strings has attracted attar tion only in the recent past. Consequently, serial ordering processes in speech production and the rules governing them has remained one of the least understood aspect of speech production. In one or the earliest studies on coarticulation, Kozhevnikov and Chistovich (1965) found that lip rounding for the vowel /u/ began simultaneously with the articulatory contact for the first consonant in a string of two consonants. This finding was independent of wor or syllable boundaries with in the sequence. These finding were, in general, supported later by Daniloff and Moll (1968) who found that the coarticulation of lip protrusion extend over as many as fo consonants in a sequence preceding the rounded vowel /u/. However, Kozhevnikov and Chistovich (1965) found that the lip protrusion gesture began simultaneously with the closure phase of the first consonant in the sequence whereas Daniloff and MOll (1968) found this to begin before the first consonant contact near the point in time at which articulatory movement toward the contact was initiate Kozhevnikov and Chistovich's articulatory syllable model of articu-lation was only partially supported by Amerman, Daniloff and Moll (1970) who foun3<6hat both jaw lowering and lip retraction for /x/ can coarticulate over a consonant sequence extending over two and perhaps 3 consonants preceding /x/ Similarly, lip, jaw, lingual and velar coarticulation have been studied extensively. The reader is referred to Kent and Minifie (1977) for a comprehensive review.

The concept of coarticulation of sounds has implications in stuttering. Traditionally, stuttering has been thought to occur 'on' certain sounds, those sounds which appear to express clearly the obvious breakdown in fluency (Brown, 1938; Bryngelson, 1955; Hah 1942; Hejna, 1955, Jayaram, 1979, 1983; Johnson and Brown, 1935;

Taylor, 1966a, 1966b). One consistent finding of this research has been that consonant are stuttered more frequently than vowels. However, the finding of substantially more stuttering on consonants than on vowels has probably reflected an artefact of phoneme occu-rrence; and the report of a rank order of difficulty among either consonants or vowels is questionable for the frequency of various positional occurrences of different sounds have not been considered (wingate, 1976). The observed higher frequency of stuttering on consonants compared to vowels has not been considered significant for other reasons as well:

1. The research has not demonstrated any general factor of phonetic difficulty, that is, there are no particular sounds more frequently associated with stuttering even among a majo-rity of stutterers.

2. Though there is a strong suggestion that individual stuttering tend to occur relatively more often in association with certain sounds, such occurrence is recognized to be quite variable.

3. A more universally based contradiction to the notion of diffe-rent sounds is that the possibility of any sound being asso-ciated with stuttering is completely qualified by where it occurs. A syllable initial sound is more likely to be asso-ciated with stuttering than the same sound in the syllable final position.

4. A careful consideration of actual instances of stuttering (repetitions - p<u>pp</u> pen or prolongation - <u>paaaa</u> pen) 'on' difficult sounds would clearly indicate that the stutterer is not really experiencing and difficulty with this particular sound, the deviance is that he is making it excessively.

These notions were the bases for the 'phonetic transition defect' theory of the nexus of the act of stuttering (Wingate, 1969). The stutterer has difficulty in moving on to the next sound despite his clear intention to do so. Therefore, the breakdown in fluency is an inability on the part of the speaker to continue in the phonetic sequence? the difficulty seems to involve the following sound.

In the vast majority of instances of stuttering occurence, the following sound invariably happens to be a vowel sound. It has also been unequivocally shown that the locus of stuttering is a function of position of occurrence of syllable or sound; stuttering occurs predominantly in regard to the initial syllable of words (Brown, 1933, 1945; Hejna, 1955; Jayaram, 1979; Quarrington, Conway and Siegel, 1962). Again, the relationship between stuttering and word-initial position turns out to be an artefact for most English words are stressed on the first syllable (Trnka, 1966; Voelker, 1942 Therefore, the predominant occurrence of stuttering in word initial syllable simply means that stuttering is associated primarily with verbal stress. This coupled with the fact that the following sound of a stuttered sound happens to be vowel implies that stuttering is a difficulty in transition to a stressed syllable because the vowel the nucleus of the stressed syllable. The stutterer has difficulty in actualising or realizing the vowel in a stressed syllable, that is, in achieving the configurations of the vowel which fully distinguishes it. Therefore, the stutterer is stuck on the preceeding phoneme or because of the difficulty in developing the intended vowel may actually employ a neutral vowel which simply signifies defective integration in the system.

Combining these formulations, suttering can be termed a defect in prosodic transition to stressed syllables (wingate, 1976, 1977). Prosodic refers to various suprasegmental features such as juncture intonation and stress changes which cut across the typical phonetic segments. 'Transition' refers to movement between sounds rather than stuttering 'on' a sound. Stressed syllables are inevitably associated with stuttering because the realization of the syllable nucleus (that is, the vowel which denotes the linguistic stress) is affected. Further, problem in stuttering occurs in transitions toward, not away from, the stressed syllable.

Van Riper (1971) defined stuttering behaviour as a word improperly patterned in time and the speakers reactions there to. Van Riper holds that stuttering reflects a breakdown primarily at the level of the syllable. According to him the stability of the motor patterns that maintain the integrity of syllables is lacking in stutterers for two reasons: (1) Stutterers rely more on auditory feedback for speech control instead of monitoring via tactile-kinesthetic-proprioceptive feedback, and (2) stutterers are thought to be deficient in their ability to time or integrate long motor sequences. A stressed syllable is likely to be the factor which typically 'times' a speech sequence upto a phrase in length. Stutterers are intermittently unable to achieve such 'timing' resulting in the production of sequences with inappropriate co–articulation.

Essentially, stuttering is then the reflection of deficiencies like instability of motor patterns for syllables, the inability to integrate a large number of discrete events in correct temporal order and possibly deficiencies in speech related respiration, phonation and articulation. One evidence for the presence of co-articulatory abnormalities on core behaviour of stuttering is the usage of schwa vowel instead of the target vowel in syllabic repetitions and sound prolongations (like /s - s - s - sandwich/) In such repetitions, the stutterer is searching for the /s/ with the necessary coarticulatory features for integrating this phoneme with the following vowel and as long as he doe not find them, he will continue to repeat. In other stuttering moments precise timin of transitional events between sounds is often lost due to breaks in airflow, excessive tension and inappropriate postures. The central concept of Van Riper's theory, then, is the presence of abnormalities of coarticulatory timings with the syllable as the important locus of stuttering.

Applying the concept of coarticulation to stuttering, it could be deduced that the stutterer probably repeats or prolongs the phoneme proceeding the stressed vowel in a syllable because he has not achieved the phoneme with the appropriate transitory characteristics that are necessary to integrate the phoneme in question to the succeeding stressed vowel. The stutterers inability to achieve the stressed vowel is probably reflected in his or her employing a neutral vowel which signifies that the phonatory aspect of the intended vowel has only been initiated but that it is not being developed or coordinated with proper oral shaping (wingate, 1976).

The articulatory postures used by the Stutterers on both voiced and voiceless sounds are often wholly inappropriate and may even be antagonistic. Normally, the production of an isolated consonant or vowel gives a different sonogram than the same sound produced within a syllable or word. In the latter, transitional formant patterns occur which are determined by the sounds that precede and follow the phoneme in question. It is said that these transitional patterns are lacking in the stutterers speech.

A number of studies have focussed on coarticulatory characteristics of stutterers speech. One of the first investigations to report that stutterers speech has abnormal transitional movements was Stromsta (1965) who reported that stutterers often failed to show the typical raising or falling formant transitions of normal speech seen on spectrograms. Further, juncture formants were not present or were different. Stromsta (1965) also reported that those children whose spectrograms of disfluencies showed anomalies in coarticulation failed to 'outgrow' their stuttering whereas those children whose spectrograms showed normal juncture formants had become fluent in the 10 year span since the original recording were made.

Agnello and his associates conducted a series of investigations on the coarticulatory differences in stuttering which included comparisons of spectrograms of stuttered and fluent speech. A number of acoustic irregulatories were observed in stuttered which were not perceptible to listeners. Even in their fluent speech, stutterers demonstrated a failure to assimilate adjacent phonetic segments, particularly in the normal transition of second formant (Agnello, 1966; Agnello and Buxtom, 1966). Specifically, they found that stuttered speech was markedly abnorma characterized by limited variance in formant structure, compressed frequency at the lower end of the speech spectrum, shorter phonation durations, lack of coordination between voicing and specific articulatory movement and numerous instances of coarticulatory failures. Repetitive stutterings occured because the appropriate transition pattern toward the next sound was not achieved. These have been interpreted as 'hanging on' attempts to approximate the next required articulatory target (Agnello, 1975; Agnello and Goehl 1965; Agnello, Wingate and Moulin, 1970).

Tatham (1973) has demonstrated a number of coarticulatory influences during stuttering by analyzing the temporal relationships between EMS trace from the upper lip (orbicularis Oris) and the acoustic signal. Comparing fluent versus stuttered productions of 'may be', significantly longer durations of EMS activity were observed between onset of the lip closure for /m/ and /1) complete closure for /m/ and (2) release of /b/ when 'may be' was stuttered. In a more definitive test, observations of EMG activity were compared in later segments, all nonstuttered, as a function of whether the initial /m/ was stuttered or not. Durations of EMG activity during labial construction for /b/ (in 'may be') were significantly greater for stuttered than for fluent utterances, The reduction to normal variability from /m/ to /b/ for stuttered utterances suggests a 'settling down' effect in EMS activity as the stutterers emerged from stuttering on /m/ into fluency on /b/. Knox (cited by Guitar, 1975) found that stutterers demonstrated inappropriate phonetic transitions and a slower than normal rate of articulation in the fluent syllables prior to stuttering.

However, the coarticulatory 'deficiencies' has not been consistently observed with stutterers. Freeman and Ushijima (1975) found, that in the stuttered and fluent productions of the word 'causes', there was activity in the tongue directed at elevating the tip to the alveolar ridge for the "devoiced /z/" during the initial repetition /ka / (k____k ziz). Hutchinson and Watkin (1974) reported that only 12% of the stutterings they studied were characterized by abnormal phonetic transitions characteristic of coarticulation. Montogomery and Cooke (1976) in a spectrographic and perceptual study of part word repetitions found that consonant duration of stuttered CV's were approximately 40 MSecs longer than non-stuttered samples from identical contexts. Surprisingly, however, the durations of vowel segments were practically identical in stuttered and fluent segments. Unlike Agnello's (1966) report, Montogomery and Cooke (1976) found that 69% of the stuttered segment had formant transitions, however, in many cases different from those in fluent segments. Significantly, there was no evidence that the stuttered segments contained an inordinate percentage of schwa vowel occurrences, a prediction made by Van Riper (1971) and others. All these findings contradict the notion that coarticulatory movements do not occur during stuttering.

A number of studies, though they did not address the concept of coarticulatory aspect of stuttering as such, nevertheless, imply that coarticulation could be impaired in stutterers speech. Shapiro (1980) in an EMG study, found physiological differences in terms of excessive muscle activity, inappropriate bursts of activity and simultaneous contraction of agonists and antagonists in the dysfluent and fluent utterances of stutterers. These findings imply that when there is abrupt, excessive contraction of antegonist the appropriate articulatory configurations required for integrating the sound in question to the succeeding sounds may not be achieved and hence, stutterers speech (both fluent and dysfluent) may be characterized by absence of required coarticulation. Similarly, some findings of Zimmerman(1980a, 1980b) like the differences between the stutterers and the normals in the interarticular positions achieved, lowering of lip or jaw, longer durations between articular movement onset etc. imply the absence of required coarticulation in the stutterers speech. (Wells (1983) found that CV combinations were frequently stuttered than VC combinations. This coupled with Van Riper (1971) and wingate's (1976) notions imply that CV sequences were stuttered more than VC sequences because the consonantal configurations were not appropriate to be integrated with succeeding vowels.

All these research findings implicate coarticulatory "deficiencies" in the speech of stutterers, but the nature of such 'deficiencies' have not been delineated for the most part. Further, the findings have not been unequivocal. Stromsta (1965) and Agnello (1966) maintain that stutterers' speech with characterized by absenc of second formant transitions while another group of researchers (Hutchinzon and watkin, 1974; Freeman and Ushijima, 1975; Montgomery and Cooke, 1976) report that formant transitions are present in the stutterers' speech but that they are different from those found in normal speech. None of these a control group of normal speakers studies have employed/in their investigation. Therefore a more comprehensive study of the second formant transitions in the speech of both in order stutterers and normals is warranted in order to define the nature of coarticulatory transitions and their deviations,

if any, in the stutterers' speech.

Coarticulation has been studied in many ways; Analyzing primarily the acoustic wave (Ohman, 1966; Stevens and House, 1963; Stevens, House and Paul, 1966); employing electromyography to study the muscle activity along with an analysis of acoustic wave (Harris, Lysaught and schvey, 1965; MacNeilage, 1963; Ohman, 1967) employing the cinefluorographic technique to observe the articulatory movement (Amerman, Daniloff and Moll, 1970; Daniloff and Moll, 1969; Londblom, 1968); employing electropalatographic and photographic techniques (Kozhevnikov and Chistovich, 1965); and through perceptual studies (Ali, et al, 1971; Grimm, 1966; Kuehn and Moll, 1972; Lehiste and Shockey, 1972; Lindblom and Studdert-Kennedy, 1967; Montogomery and Cooke, 1976). The techniques of acoustic analysis, electromyography and perceptual analysis have been employed in the studies on coarticulatory aspects of stutterers speech.

METHODOLOGY

The present study employed the technique of analysing the acoustic wave to study the coarticulatory patterns in the speech of stutterers.

The aim of the present investigation was to study the transitory characteristics in the speech of stutterers and normals. Specifically, this study aimed to investigate whether the terminal formant frequency transitional values in the stutterers fluent and disfluent segments are influenced by the nature of the trans-consonantal vowels in VCV sequences. The study primarily aimed at measuring the formant frequencies (first and second formants) and formant frequency transitions in fluent and disfluent utterances of stutterers and to compare this with fluent utterances of normal speakers.

Subjects:

TWO adult male stutterers and two normal adult male speakers served as subjects in this experiment. The age range of the subject in the stuttering group was from 20-23 years and in the normal group from 22-24 years. The stutterers were all receiving or had received speech therapy for stuttering sometime in the course of their problem. The two sutterers were clinically judged to have mild degree of stuttering.

The stuttering group was matched with a group of two normal speakers whose educational, social and linguistic backgrounds were comparable with those of the stuttering group. All subjects in the two groups were native speakers of Kannada and could adequately read Kannada.

Materials:

The speech stimuli consisted of VCV sequences (See Appendix). The technique of analysis employed inthe present study (analysing the acoustic wave) necessitated the use of VCV rather than any other type of speech sequence. The phonemes selected consisted of mid low (a), front high (i) and back high (u) vowels. Among the consonants selected were both voiced and voiceless, slightly aspirated bilabials (p, b)retroflexes (t, d) and the Velars (k, g). Thus, nine speech sounds were selected. All vowels are phonemically short and covered all places of articulation.

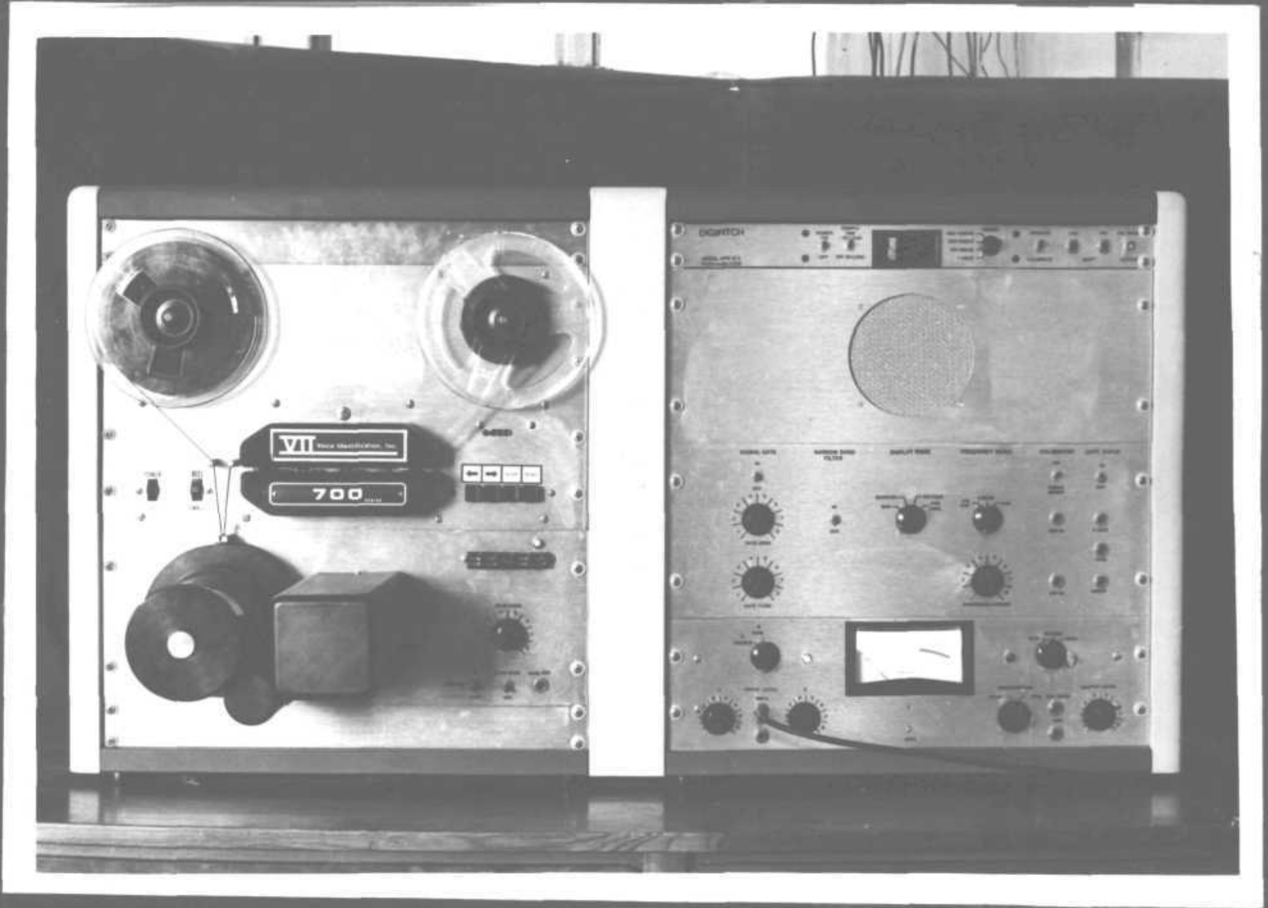
Using these nine speech sounds and the homorganic clusters of the consonants, 54 (3x6x3) nonsense disyllables were constructed. In such VCV sequences, vowels appeared in both initial and final positions with each consonant appearing in the medial position (eg. apa, api, apu; ipa, ipi, ipu; upa, upi; upu; ata, ati, atu etc)

Testing Procedure:

Subjects were tested individually ipa sound treated room. and the testing procedure and test environment for both groups of subject was indentical. The sequences in the list were presented in a random and counterbalanced order and the same order was followed with both the subjects in each group. To avoid the possibilities of direct adaptation effect, care was taken to ensure that no two syllable sequences with the same initial vowel or consonant occurred back to back. Each VCV sequence was neately written on a 6"x3" card and was presented to the subjects to be orally read by them. Subjects were instructed to reach each card, in their natural reading. Style and not stressing (or to give equal stress on all syllables) any syllable in any of the sequences. All readings of the subjects were recorded on the internal tape recorder of the spectrograph (spectrograph INC.700 series). The microphone was kept at a constant distance of 8 cms from the subject's mouth. The interval between the presentation of any two cards was 4 secs. Subsequently, two spectrograms were prepared for each sample, set at wide-band (300Hz) and narrow band (45Hz) filter and passed through the scale magnifier set to display 50 to 8000Hz. Thus, 432 spectrograms were obtained and later analysed. All tracings were made with the same spectrograph control settings and thus each spectrogram may be compared with any of the others.

Measurement of Formant Transitions:

The technique of Ohman (1966) for the measurement of second formant transitions was followed in the present study. The frequency of the second formant was measured in the stationary part of the initial and final vowel as well as at the beginning and end of the closure of the stop consonants. Thin lines were drawn with a pencil so as to follow the centre of the second formant bars as seen in the spectrograms and vertical lines were drawn at the beginning and end of the stop closure. The second formant frequencies were measured at the point where the vertical lines intersected the formant line. Frequency measurements thus made were later rechecked by a speech pathologist - phonetician. Frequencies measured in this fashion were accurate within less than 50 cycles/sec.



PHOTOGRAPH OF SPECTROGRAPH INC -700 SERIES

RESULTS AND DISCUSSION

The essential interest of this study was the spectrograph patterns of the co-articulatory transitions in the stutterers' speech. Specifically the main interest was to analyse the second formant transition in the fluent and disfluent utterances of stutterers and to compare these with the fluent utterances of normals. In the present study, though each stutterer read 54 VCV sequences none gave a stuttering block on any of the sequences. Therefore, comparison of co-articulatory transitions in the fluent and disfluent utterances of stutterers could not be made. No effort was made to put any of these data to statistical test for several reasons;

1) Overall pattern features were evident to visual inspection and a simple quantification would be sufficient.

2) Statistical tests and inferences would have been superfluous since the major analysis, that of comparison between fluent and disfluent segments of stutterers, could not be undertaken. Therefore, the present study focussed on a descriptive analysis and resorted to reporting of trends instead of a statistical test of hypotheses.

Tables 1 and 2, give the average first formant transitions for the vowels preceeding and succeeding the consonant, respectively while Tables 3 and 4 give the average second formant transitions

Table-1: First formant transitions in H_2 of the initial vowel in the fluent utterances of normal speakers and stutterers.

	Normals			Stutterers		
	a	i	u	a	i	u
p	699-588 (-111)	310-273 (-37)	303-244 (-59)	683-604 (-79)	280-140 (-140)	240-240 (-)
t	715-520 (-195)	294-280 (-14)	244-240 (-4)	635-504 (-131)	332-298 (-34)	240-240 (-x)
k	683-556 (-127)	288-280 (-8)	259-244 (-15)	620-525 (-95)	357-298 (-59)	240-240 (-)
b	683-504 (-179)	285-266 (-19)	275-248 (-27)	620-461 (159)	342-289 (-53)	240-240 (-)
d	683-540 (-143)	350-289 (-61)	244-240 (-4)	640-493 (-111)	226-289 (-47)	240-240 (-)
g	651-461 (-190)	332-297 (-41)	240-240 (-)	588-446 (-142)	287-277 (-10)	240-240 (-)

Table-2* First formant transltions in H_2 of the final vowel in the fluent utterance* of normals and stutterers.

	Normals			Stutterers		
	a	i	u	a	i	u
p	525-667 (+142)	257-280 (+ 23)	240-235 (+15)	572-620 (+48)	287-287 (-)	240-240 (-)
t	443-715 (+222)	247-280 (+33)	240-260 (+20)	541-603 (+62)	289-289 (-)	240-240 (-)
k	461-651 (+190)	298-369 (+71)	240-245 (+5)	539-604 (+65)	314-314 (-)	240-240 (-)
b	539-669 (+128)	273-273 (+20)	240-280 (+40)	541-620 (+79)	308-308 (-)	240-240 (-)
d	414-666 (+252)	200-358 (+158)	240-264 (+4)	477-588 (+111)	280-280 (-)	240-240 (-)
g	446-683 (+237)	282-291 (+9)	237-260 (+23)	462-605 (+143)	280-888 (+8)	240-240 (-)

Table-3: Second formant transitions in H_2 of the initial vowel in the fluent speech of stutterers and normal speakers.

	Normals			Stutterers		
	a	i	u	a	i	u
p	1291-1117 (-174)	2233-1800 (-433)	733-658 (-75)	1141-1125 (-16)	2020-1660 (-360)	562-502 (-60)
t	1366-1525 (+159)	2166-2116 (-50)	916-720 (-196)	1391-1538 (+147)	1983-1983 (-)	738-615 (-93)
k	1308-1500 (+192)	2200-227S (+75)	704-608 (+96)	1041-1091 (+50)	2075-2100 (+25)	691-566 (-125)
b	1225-1141 (-84)	2192-2092 (-100)	750-675 (-75)	1234-1233 (-1)	1875-1891 (+16)	625-591 (-34)
d	1425-1650 (+225)	2266-2041 (-225)	1025-766 (-259)	1366-1541 (+175)	2133-2091 (-42)	741-616 (-125)
g	1250-1341 (+91)	2275-2308 (+33)	808-750 (-58)	1358-1433 (+75)	2125-2150 (+25)	791-641 (-150)

Table-4: Second formant transitions in H_2 of the final vowel in the fluent speech of stutterers and normal speakers.

	Normals			Stutterers		
	a	1	u	a	i	u
p	1133-1208 (+75)	2183-1958 (-225)	675-741 (+66)	1158-1300 (+142)	2116-2058 (-58)	741-875 (+134)
t	1542-1291 (-251)	2183-2258 (+75)	908-679 (-229)	1450-1375 (-75)	2050-2200 (+150)	975-908 (-167)
k	1433-1325 (-108)	2300-2325 (+25)	833-641 (-192)	1375-1325 (-50)	1800-1908 (+108)	883-780 (-103)
b	1101-1233 (+132)	2150-2033 (-117)	614-712 (+98)	1091-1258 (+167)	2066-2058 (-8)	683-825 (+142)
d.	1458-1258 (-200)	2208-2250 (+42)	895-650 (+245)	1400-1350 (-50)	2133-2208 (+75)	966-768 (-198)
g	1291-1283 (-8)	2266-2275 (+9)	803-650 (-153)	1466-1450 (-16)	2366-2533 (+167)	883-765 (-118)

found in the fluent utterances of normals and stutterers. A note regarding the interpretation of the data given in the tables is appropriate here. The numbers /699-588/ given in the first column first row of table-1 should be interpreted in the following way: (1) there was downward transitory movement of the first formant. '699' denotes the frequency of the formant measured in the most stationary part of the vowel while '588' denotes the terminal frequency of formant transition measured in the neighbourhood of stop gap. The number '111' denotes the difference between the steady state and transition values and refers to the extent of transition. The sign (±) proceeding '111' denotes rising (+) or falling (-)formant.

Figures 1 and 2 show the spectrograms of fluent utterances of normals and stutterers. The procedure of drawing lines to measure the steady state and transition values of formants has been indicate in these spectrograms. The following observations can be made from Tables 1-4 and figures 1-2.

(1) Rising or falling transitions of first and second formants were the same in the fluent utterances of normals and stutterers. This was true for both the initial and final vowels of VCV sequences,

(2) However, there were some exceptions to this general rule (See figures 1-2). For eg., (i). When the second formant of the initial vowel was falling in the speech of normals, it was steady

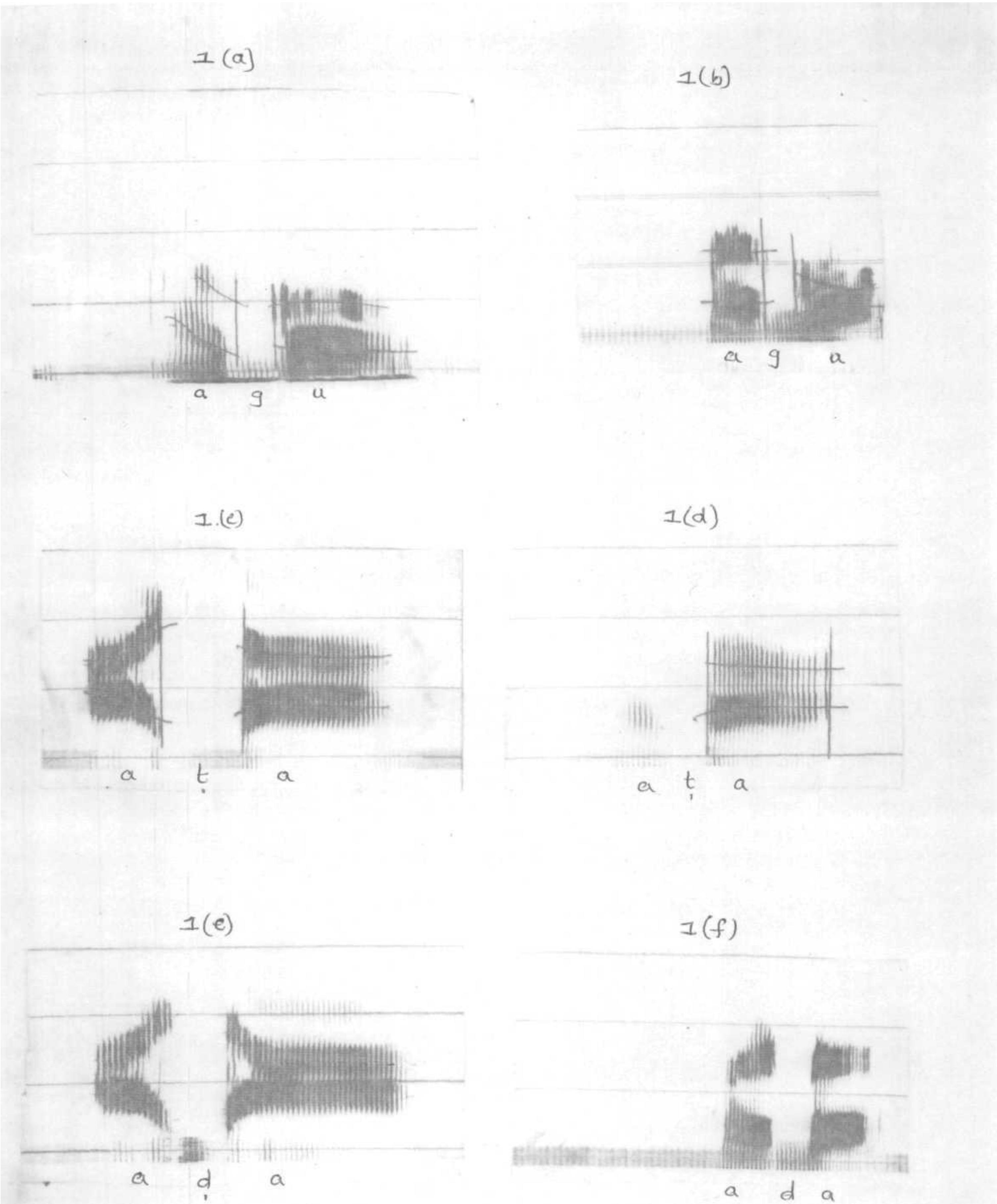
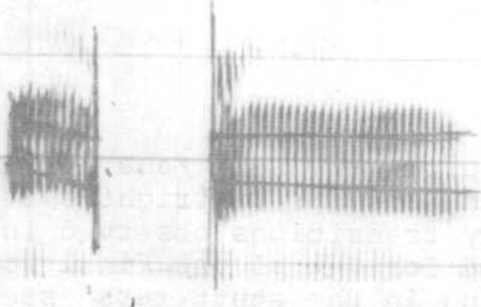


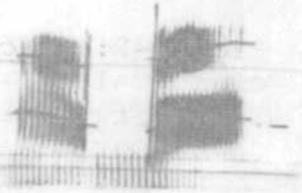
Figure-1: Spectrograms of fluent productions of /agu, aṭa, aḍa/ of normals (left side) and stutterers (right side). The difference in coarticulatory transitions observed in these spectrograms are (i) falling second formant of the initial vowel in normals while it is steady in stutterers (Fig.1a and 1b) (ii) falling second formant of the final vowel in normals while the same is rising in stutterers (fig. 1c and 1d).

2(a)



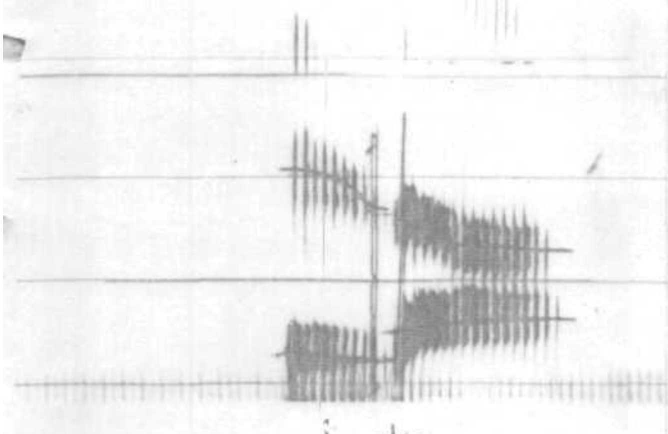
a b a

2(b)



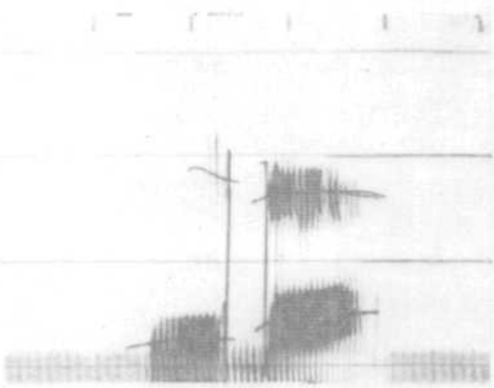
a b a

2(c)



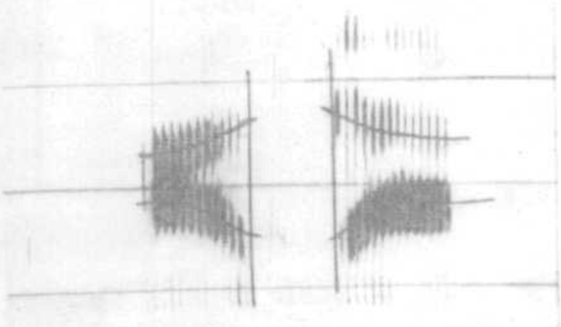
i ḍ a

2(d)



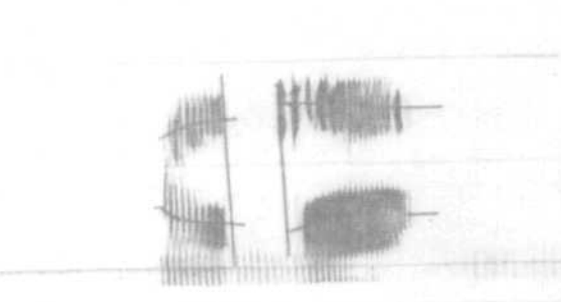
i ḍ a

2(e)



a g a

2(f)



a g a

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in the fluent utterances of stutterers (Figures la-1b); (ii) when the second formant of the final vowel was steady in the speech of normal speakers, the same was rising in the fluent utterances of stutterers (Figures 2a-2b).

(3) The extent of transition of the first formant (the difference between steady state and terminal values) for both initial and final vowels in the fluent utterances of stutterers is different from those of normals. The extent of transition was less for vowels /a/ and /u/ and more for vowel /i/ in the initial position but less in the final position.

(4) The first formant transition for vowel /u/ in the initial position shows a falling trend in the speech of normal speakers whereas such a trend was not observed in the case of fluent utterance of stutterers (Table-1); similarly, first formant transitions for the final vowels /i, u/ indicated a rising trend in the speech of normal speakers, but such a trend was absent in the fluent utterances of stutterers (Table-2).

(5) The extent of second of formant transition for initial vowels /a, i/ was less in the fluent utterances of stutterers compared to normal speakers. However, for vowel /u/, it was less for consonants,/p,t, and b, d/ but more for consonants /k, g/ (Table-3).

(6) Extent of second formant transitions for all vowels in the final positions was more in the fluent speech of stutterers when the

formant frequencies were rising. For eg. vowels /a, u/ adjacent to consonants /p, b/; vowel /i/ with consonants /t, k and d, g/. On the other hand it was less when the formant frequencies were falling. For eg. vowels /a, u/ with consonants /t, k, d, g/; vowel /i/ with consonants /p, b/.

Tables 1 to 4 give enough evidence to indicate that the fluent utterances of stutterers were different from fluent utterances of normals in regard to the formant transitions. This is in conformity with the results of Agnello (1966) and Agnello and Buxton(1956). Specifically, though the direction of transition (i.e. rising or falling) was the same. for the most part, in the fluent utterances of both groups of subjects, the extent of such transition was different between the two groups. The extent of transition was less for vowels /a, u/ while it was more for vowel /i/ which simply indicates that even in the fluent speech of stutterers, the appropriate configurations for the vowel preceding a stop consonant were not achieved. These observations indicated that sutterers speech articulators move towards proper articulatory configurations required for the phoneme in question but, they were not fully achieved. This, ofcourse, is only a prediction from the acoustic data coupled with what is known about normal articulatory dynamics. This has to be experimentally verified in the future.

In normal speech, the configurations required for proceeding and succeeding vowel are influenced by the consonant in between. For eg., the first formant of vowel /u/ showed a falling tendency when it was followed by a stop consonant. This was not observed in the fluent speech of stutterers where the first formant did not show any transition (steady formant). This simply indicates that the juncture formants were absent even in the fluent utterance; of stutterers. In other words, it indicated that stutterers failed to assimilate adjacent phonetic units even in their fluent speech. It is not known whether these acoustic irregularities, seen on spectrograms, would be perceived by the listeners and hence, needs to be verified.

In summary, the above observations indicate the following trends:*

1) The fluent utterances of stutterers are not the same as those of normal speakers in terms of formant transitions.

2) Stutterers do not achieve the articulatory configurations required for assimilating the adjacent phonetic units even in their fluent speech.

3) Stutterers do not show functure formants that are necessary for integrating vowels with succeeding stop consonants even in their fluent utterances, and

4) Stutterers do show a number of co-articulatory transitional 'deficiencies' even in their fluent utterances.

*'A11 these trends' are hypothetical in nature and should be vigorously tested in future.

Spectrograms shown in figures 3 and 4 point to another characteristic of formant transitions in the fluent speech of normals and stutterers. This refers to the missing second formant of the initial or final vowels, particularly of the initial vowel, in the fluent utterances of stutterers. Such a feature was not observed in the fluent utterances of normals. The significance of this feature is not known at this point of time, but lends credence to the view that the stutterer does something to change the second formant transitions even in their fluent speech.

The spectrograms in figures 5 to 10, point to a feature of speech production which has not been reported in the literature hitherto. The reference is to the second formant transition of vowel /a/, shown by one normal speaker, where the formant is both rising and falling at the same time. This was observed in the initial as well as final position of VCV sequences. Research directed towards duplicating this finding as well as ascertaining its significance is warranted.

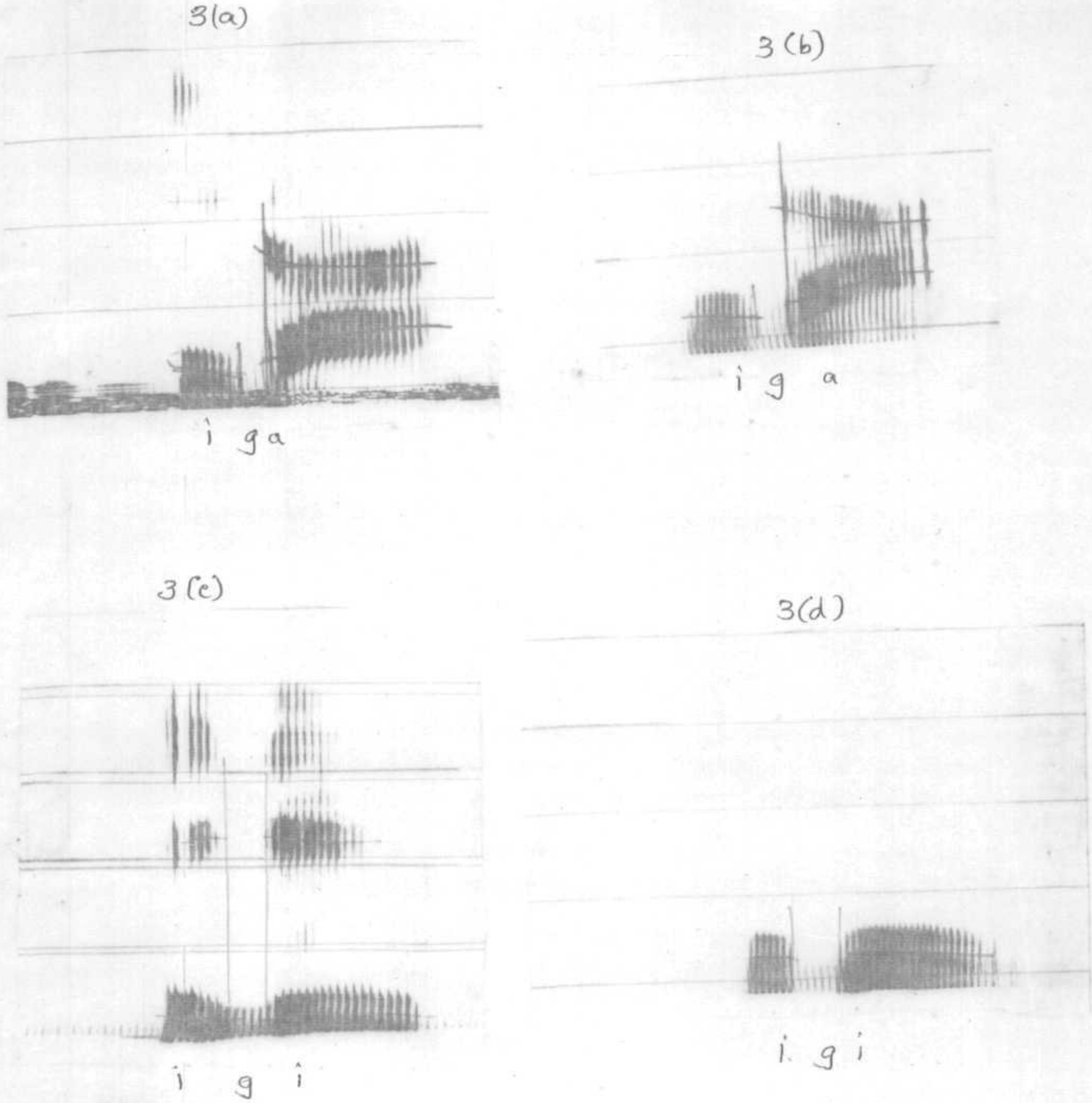

Figure-3: Spectrograms of fluent utterances of normal speakers (3a, 3c) and stutterers (3b, 3d). Note the missing second formant in the utterances of stutterers (initial vowel figure 3b final vowel 3d).

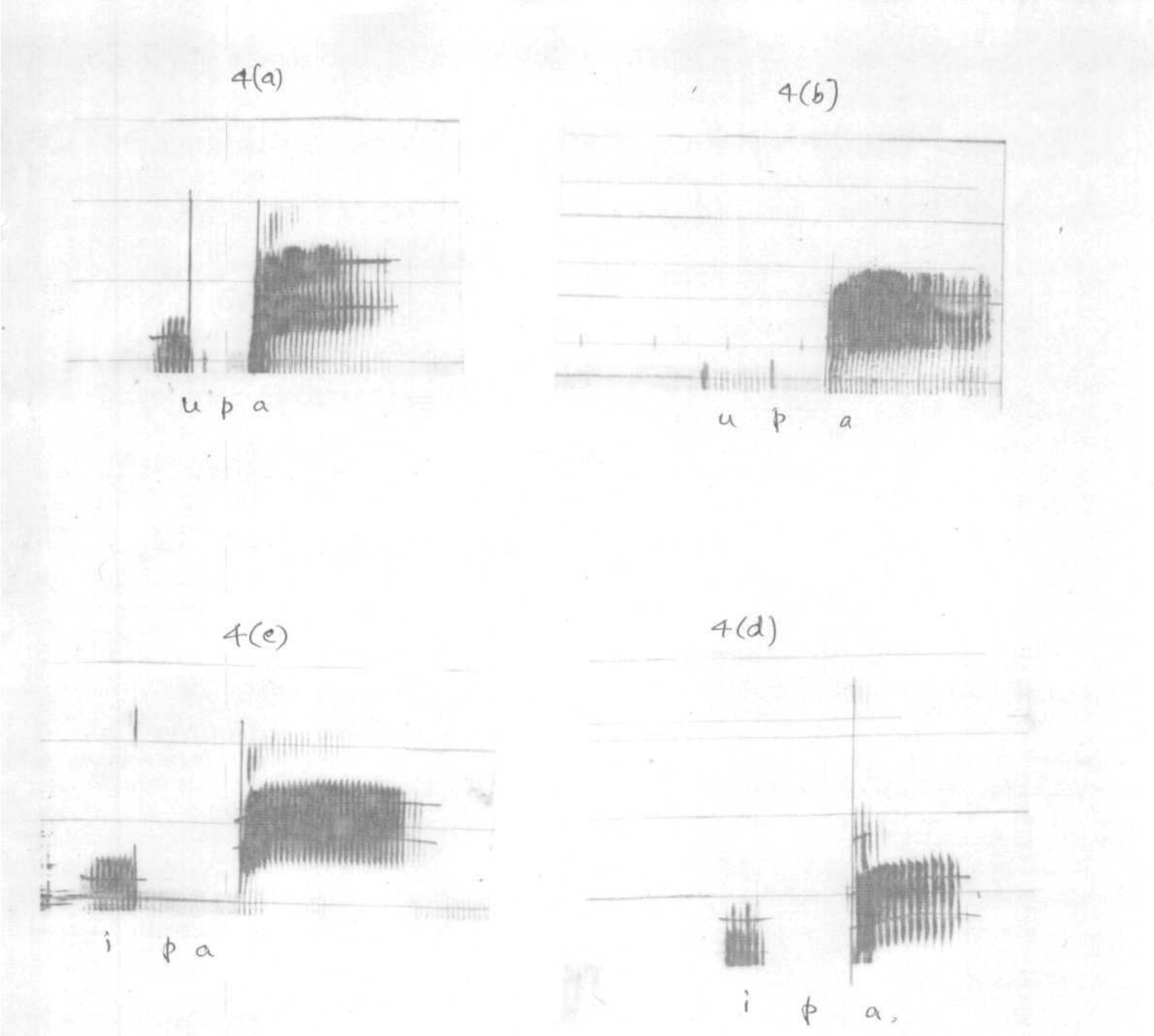

Figure-4: Spectrograms of fluent utterances of normal speakers (4a, 4c) and stutterers (4b, 4d). Note the missing second formant in the utterances of stutterers (initial vowel fig. 4b and4d).

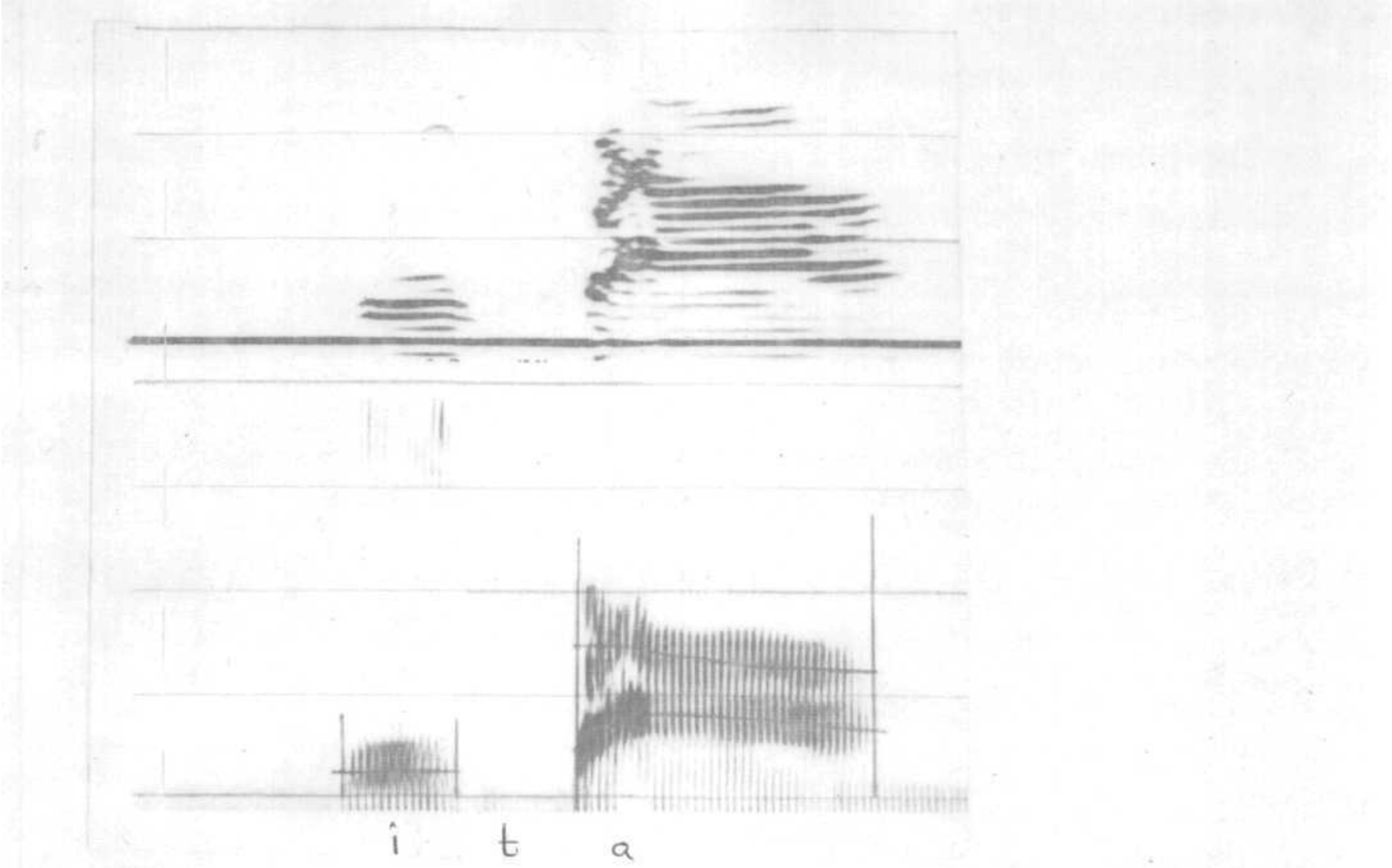

Figure-5: Wide band and narrow band spectrogram of /ita/ of normal speaker. Note the second formant rising and falling at the same instance of time.

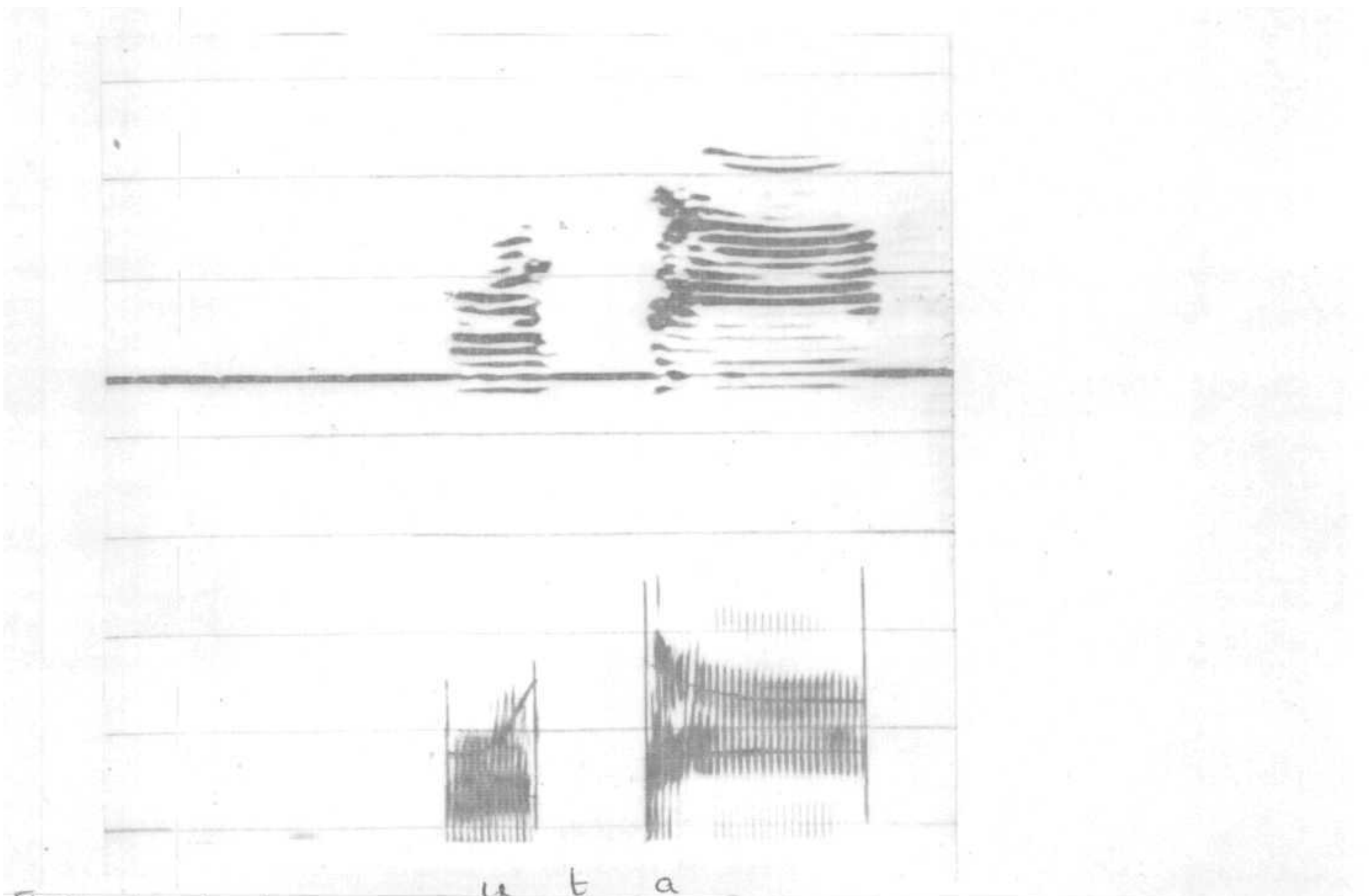

Fig:6: Wide band and narrow band Spectrogram of |uṭa| of normal Speaker. Note the Second formant rising and falling at the Same

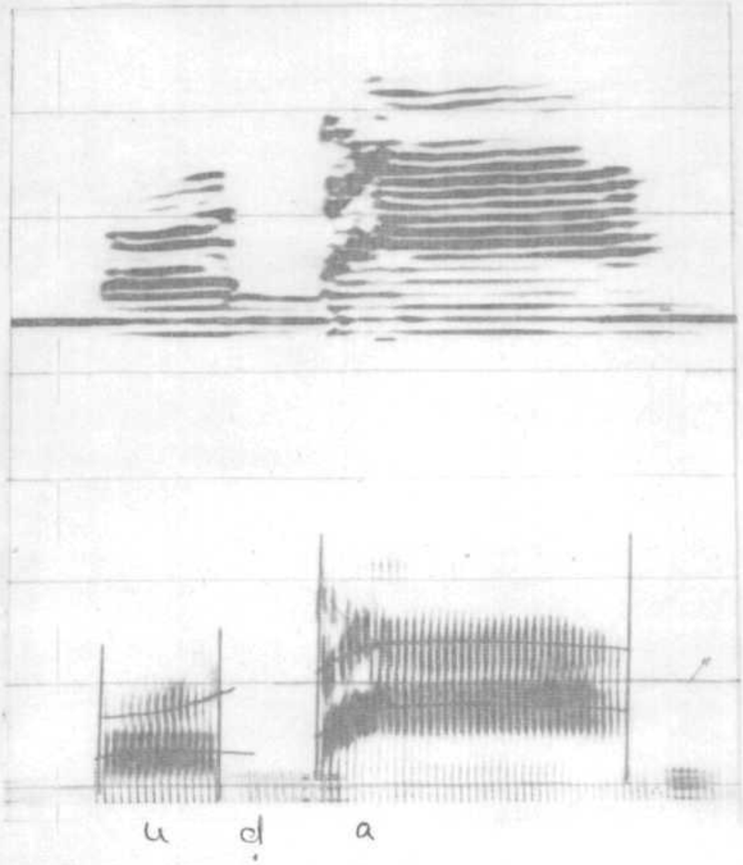

Figure-7: Wideband and narrow band spectrogram of /uḍa/ of normal speaker. Note the second formant rising and falling at the same instance of time.

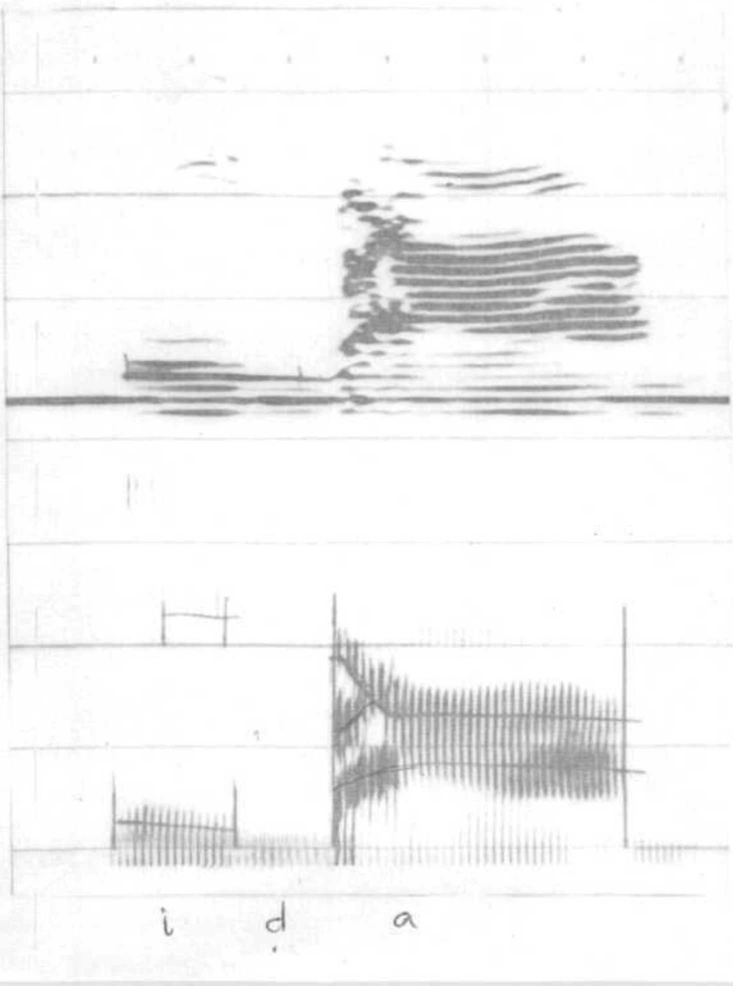

Figure-8: Wide band and narrow band spectrogram of /iḍa/ of normal speaker. Note the second formant rising and falling at the same instance of time.

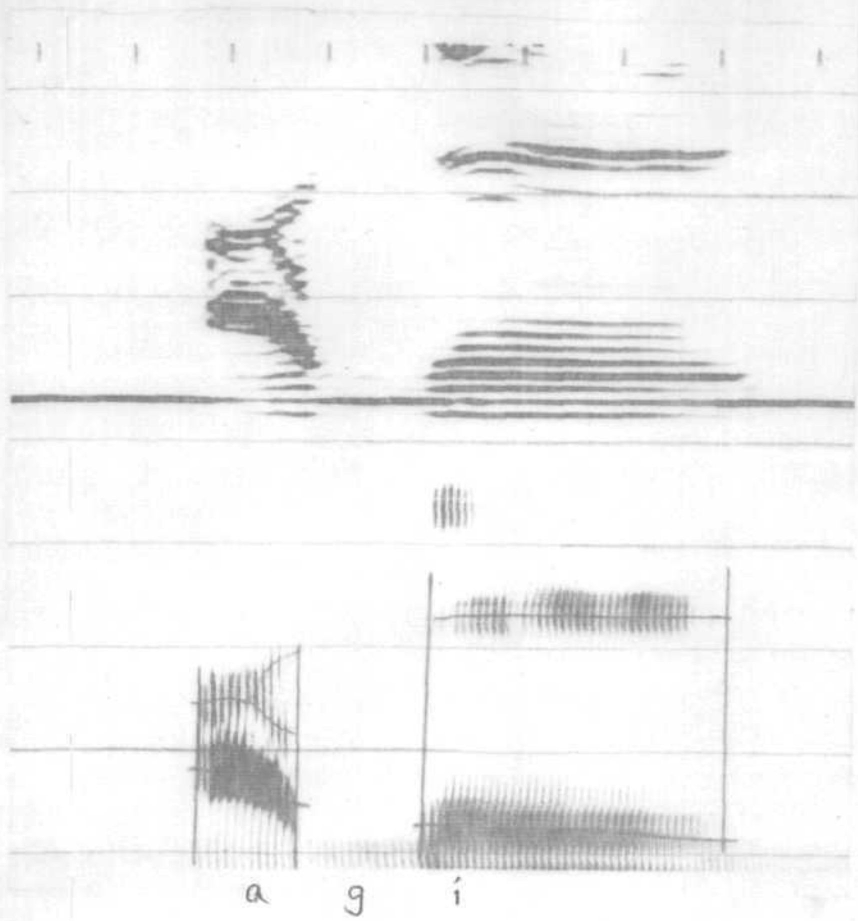

Figure-9: Wide band and narrow band spectrogram of /agi/ of normal speaker. Note the second formant rising and falling at the same instance of time.

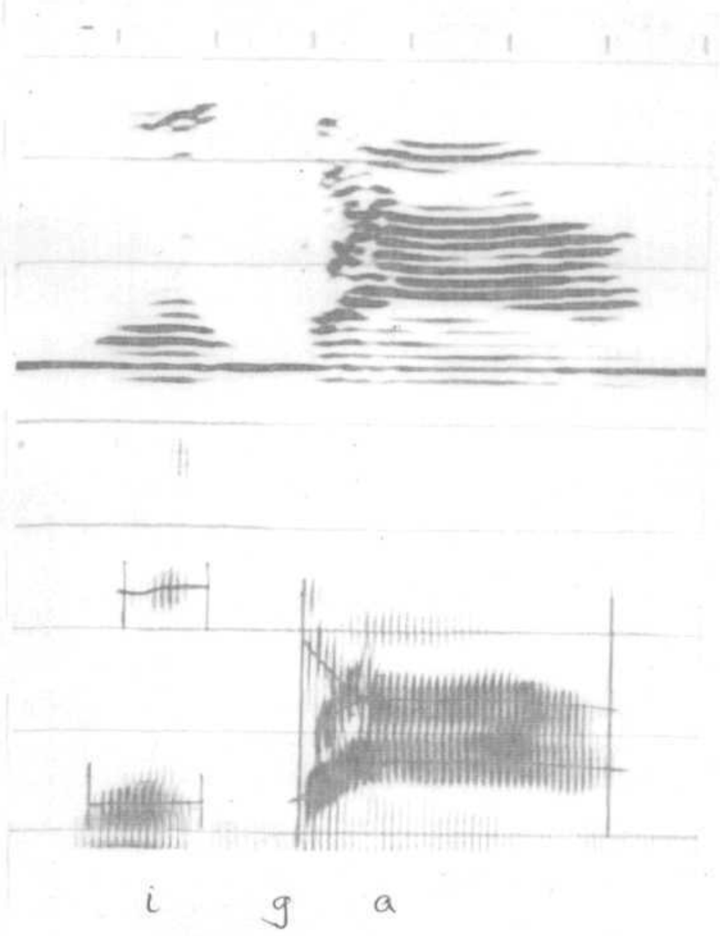

Figure-10: Wideband and narrow band spectrograms of /iga/ of normal speaker. Note the second formant rising and falling at the same instance of time.

SUMMARY AND RECOMMENDATIONS

Inspite of the theoretical simplicity and appeal of the notion that stuttering reflects a lack of coarticulation, it has received little recent empirical support. The purpose of the present study was to analyze the extent of first and second formant transitions in the fluent and disfluent speech of stutterers and to compare this with the fluent utterances of normal speakers. The technique of analyzing the acoustic wave was employed to test the problem selected. A list of 54 VCV nonsense disyllables consisting of short vowels /a, i, u/ and stop consonants /p, t, k, b, d, g/ was constructed. The subjects, 2 stutterers and 2 normal speakers, orally read this material in a random order, from the recordings of which both wide band and narrow band spectrograms were made. Altogether 432 spectrograms were prepared and analysed.

No effort was made to put the data to any statistical test (Results and Discussion) but on the other hand the data were descriptively analysed. As the stutterers did not emit even a single stuttering block on any of the VCV sequences, comparison between the fluent and disfluent utterances in regard to formant transitions could not be made in the present study. However, a comparison between fluent utterances of stutterers and normal speakers was made. Results indicated that, though the rising and falling trend of the formant frequency transition was the same in fluent speech of stutterers as it is in the normal speakers (contrary to the findings of Agnello, 1966), the extent of such transitions was different in the two groups of subjects.

In general, the data obtained in the present study indicated the following trends:

1) the fluent utterances of stutterers were not the same as fluent utterances of normal speakers,

2) even the fluent utterances of stutterers manifested a number of coarticulatory transitional differences when compared to the utterances of normals, and

3) the coarticulatory 'differences' found in the fluent utterances of stutterers indicated that the articulatory configurations required for the production of a phoneme in question were not fully achieved.

These observations, in general, led credence to the notion that the fluent speech of stutterers is not the same as the fluent speech of normals speakers (Wendahl and Cole, 1961? Williams, 1951) and is also consistent with the large body of literature on linguistic factors in stuttering.

Two other Observations were made from the spectrograms which were not very consistent.

(1) the second formant was missing in a number of VCV sequences in the fluent speech of stutterers. Such a feature was not observed in the speech of normals, and

(2) the second formant of vowel /a/ was both rising and falling at the same instance of transition in some utterances of a normal speaker. The significance of this is not known at present, but this is a unique feature that has not been observed or reported in the past.

All the observations mentioned above, except the last one, warrant vigorous experimentation on the coarticulatory aspects of stuttering in the future.

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APPENDIX

VCV Sequences

Vowels /a,i,u/ and consonants /p,ṭ,k,b,ḍ,g/.

/apa/	/aṭa/	/aka/	/aba/	/aḍa/	/aga/
/api/	/aṭi/	/aki/	/abi/	/aḍi/	/agi/
/apu/	/aṭu/	/aku/	/abu/	/aḍu/	/agu/
/ipa/	/iṭa/	/ika/	/iba/	/iḍa/	/iga/
/ipi/	/iṭi/	/iki/	/ibi/	/iḍi/	/igi/
/ipu/	/iṭu/'	/iku/	/ibu/	/iḍu/	/igu/
/upa/	/uṭa/	/uka/	/uba/	/uḍa/	/uga/
/upi/	/uṭi/	/uki/	/ubi/	/uḍi/	/ugi/
/upU/	/uṭu/	/uku/	/ubu/	/uḍu/	/ugu/