ARTICULATORY DYNAMICS OF STUTTERERS

Raghunatt

Reg. NO. M 9011

All India Institute of Speech and Hearing
MYSORE - 570 006
1992

DEDICATED To

AMMA & NANA

for their boundless love, understanding, tolerance, high ideals and capabilities which contributed significantly to my education and personal life.

CERTIFICATE

This is to certify that the Dissertation entitled: **"ARTICULATORY DYNAMICS OF STUTTERERS"** *is a bonafide work, done in part fulfilment for the Second Year M.Sc (Speech and Hearing) of the student with* **Reg.No.M 9011.**

DR.(MISS).S.NIKAM
DIRECTOR
All India Institute of
Speech and Hearing
MYSORE - 6

MYSORE
1992

CERTIFICATE

This is to certify that the Dissertation entitled **"ARTICULATORY DYNAMICS OF STUTTERERS"** *has heen prepared under my supervision and guidance.*

MYSORE
1992

Dr.S.R.SAVITHRI
GUIDE

DECLARATION

This dissertation entitled **"ARTICULATORY DYNAMICS OF STUTTERERS"** *is the result of my own study under the guidance of* **Dr.S.R.SAVITHRI,** *Lecturer, Department of Speech Sciences, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier at any other University for any other Diploma or Degree.*

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INTRODUCTION

"Stuttering has been called a riddle. It is a complicated, multidimensioned jig saw puzzle with many pieces still missing. It is also a personal, social and scientific problem with many unknowns" (Van Riper, 1982).

Wingate (1964) proposed a three part standard definition of stuttering. The first part denotes, the core features of stuttering which have universal applicability, the second and third parts identify the accessory and the associated features respectively. According to Wingate (1964) the term stuttering means:

1 (a) Disruption in the fluency of verbal expression, which is (b) characterized by involuntary, audible or silent repetition or prolongation 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 sterotyped speech utterances. These activities give the appearance of being speech related struggle.

3) Also, there are not infrequently (f) indication or reports of the presence of an emotional state ranging from a general

condition of excitment or tension to more specific emotions of a negative nature such as fear, embarassment, irritation or the like.

4) The immediate source of stuttering is some incoordination expressed in the peripheral speech mechanism. The ultimate cause is presently unknown and may be complex or compound.

Inspite of extensive research on stuttering the etiology of this disorder is still an engima. The etiology of stuttering is equivocal and several views pervail.

Orton (1927), Travis (1931) and Bryngelson (1935) developed cerebral dominance theory, according to which stuttering is attributed to inability to achieve the laterality which disturbs the synchronization of timing patterns from both hemispheres to their muscle groups. West (1943) views stuttering as a mild or latent form of epileptiform disorder called pyknolepsy which could be precipitated by various kinds of stress or a mild form of sub-clinical cerebral palsy.

Szondi (1932) and Seeman (1934, 1959) have called stuttering a neurogenic disorder. This was based on the neurological investigations which revealed signs of brain pathology, evidences of neuromuscular difficulties and disturbed functioning in the striopallidar system. Also, imbalance in the functioning of the sympathetic and parasympathetic systems has been reported. Eisenson (1958) suggested that stuttering is a persevarative response similar to the perseverative motor behaviour of some brain injured person. Rosenbeck (1985) has described stuttering secondary to nervous system damage and referred to it as neurogenic stuttering.

The middle of 20th century saw the advent of many psychogenic views on stuttering. Brill (1923), Coriat (1928, 1943), Fenichel (1945), Glauber (1955) have advanced psychoanalytic concepts to explain the development of stuttering. The act of stuttering has been regarded as a covert expression of hostile or aggressive impulses that the person fears to express openly. Johnson (1955) advanced diagnosogenic theory according to which stuttering develops due to the misdiagnosis made by the listeners. He stated that stuttering begins in parent's ears and not in the child's mouth. Shames and Sherrick (1963) have identified stuttering as an operant behaviour and state that it is a learnt behaviour which gets reinforced initially and persists.

While Brutten and Shoemaker (1967) considered stuttering as a disorder of conditioned disintegration and stated that "stuttering in its integral aspect is a failure or disruption of fluency resulting from emotional arousal that has become associated with speech and speech related stimuli through a process of classical conditioning". Bloodstein (1969) proposed anticipatory struggle hypothesis. According to this view, stuttering is the resultant of

1) a suggestion in the form of some outside stimulus of imminent difficulty in speech,
2) an anticipation of failure,
3) a feeling of need to avoid it,
4) abnormal motor planning for the voluntary articulation of the speech activity.
5) the mastering of certain preparatory sets for this purpose and
6) the production of tension and fragmentation which interferes with the normal process of speech.

However, the postulations of psychogenic theories of stuttering were not free of lacunae and hence lost attention. In 1951, Lee and Black came out with interesting findings on subjecting the stutterers and non-stutterers to different delays (in duration) in auditory feedback conditions. This was the evidence for the possibility of delayed auditory feedback mechanism in stutterers which leads to dysfluencies.

Wingate (1969, 1970, 1976, 1979 and 1984) has called stuttering as a prosodic disorder. This was based on the finding of significant relationship between stuttering and linguistic stress. Brown (1937) presented the rank order for incidence of stuttering of refined list of grammatical classes. This was the outcome of the studies by Brown (1938b), Hejna (1955), Wingate (1979), and prosody was identified as a major factor leading to stuttering. Since prosody has a physiological basis this research has yielded evidence of irregularities in vocal control and laryngeal functions among stutterers.

Freeman and Ushijima (1978) reported some distinct patterns of laryngeal abnormalities in stutterers. Studies based on voice onset time (Hillman and Gilbert, 1977), Voice and speech initiation time (Hayden, 1975), electromyography of laryngeal muscle, and endofibroscopic examination of larynx (Conture, et al 1977) also indicate laryngeal abnormalities in stutterers.

Peters and Boves (1987, 1988) demonstrated that in perceptually fluent speech, stutterers use unusual patterns of air pressure build up significantly more often than non-stutterers. They also reported that stutterers show a diminished capacity to coordinate respiratory movements, with laryngeal adjustments and articulatory movements during the onset of phonation.

Van Riper (1982) summarized several sources of evidence for emphasizing that timing disruptions in the programming of movement of speech muscles leads to stuttering. Several articulatory irregularities of stutterers have been reported in the literature. Longer phoneme durations (DiSimoni, 1974; Montgomery and Cooke, 1976; Healey and Adams, 1981; Prosek and Runyan, 1982; Healey and Ramig, 1986; Metz et al., 1990) and shorter phoneme durations (Reimann, 1976) have been reported. The results of some studies (Klich & May 1982; Holland and Starkweather, 1982; Pindzola, 1987; Healey and Ramig, 1986) have indicated no significant difference in phoneme duration between stutterers and non-stutterers. The velocities of articulators during stuttering has been found to be relatively low by Healey et al (1976). Inaccurate timing has been reported by Cooper & Allen (1977). Zimmermann (1980b), Klich and May (1982) concluded that stutterer's articulatory movements are spatially restricted with the velocity and direction of movement altered. Van Riper (1982) cited spectrographic and cineflurographic evidences to state inappropriate articulatory movements in stutterers. Janssen et al (1983) interpreted that stutterers may have difficulty in stabilizing the articulatory movements. Shapiro (1980) indicated excessive articulatory movements in stutterers and Guitar et al (1988) reported reverse muscle movements of articulators. Mohan Murthy (1988) reported that dysfluencies seen during stuttering indicated several laryngeal, aerodynamic and articulatory abnormalities.

Based on these evidences stuttering has been called an articulatory disorder. The articulatory behaviour in stutterers and non-stutterers have been studied using acoustic, cinefluoroscopic, cineradiographic and electromyographic analysis. Although there is a vast body of literature on the articulatory dynamics in stutterers, the studies deal with an isolated parameter and hence no conclusive inferences have been drawn.

In this context, the present study was planned. The aim of this study was to acoustically analyze the articulatory dynamics in four stutterers to obtain a wholistic and conclusive observation of articulatory dynamics in stutterers. Also, the diagnostic and therapeutic implications on the basis of acoustic analysis are suggested.

REVIEW OF LITERATURE

Stuttering is defined as a temporal disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound (Van Riper, 1982).

The results of several observations indicate that stuttering is associated with many articulatory abnormalities and hence can be called an articulatory disorder. The review of research on the articulatory dynamics of stutterers is organized as in Table-1: Vocal fold is also considered as an articulator as in several studies where voicing is considered as an articulatory feature and hence studies related to laryngeal dynamics have also been complied.

I. ARTICULATORY ERRORS

A. Temporal Errors:

1. Longer Phoneme Duration: Several investigators have reported longer phoneme durations in stutterers.

DiSimoni (1974) studied timing relationships in the speech of six stutterers with age ranging from 18 to 39 years. He found that the stutterers had significantly greater absolute vowel and consonant durations than the non-stutterers studied. In addition, the stutterers showed greater intraindividual variation in the duration of a given consonant.

I ARITICULATION ERRORS

A. Temporal errors

1. Longer phoneme duration:

-DiSimoni, 1974
Montgomery & Cooke, 1976
Healey Adams, 1981
Prosek & Runyan, 1982
Healey & Ramig, 1986
Kalveram & Jancke 1989
Revathi, 1989
Metz et al, 1990

2. Shorter phoneme deration:

Reimann, 1976

3. No significant differences:

Klich & May, 1982
Holland & Starkweather, 1982
Zebrowski et al,1985
Bealey & Ramig, 1986
Pindzola, 1987
Schaferskupper and Dames, 1987

4. Longer Duration between articulatory events:

Adams et al, 1975
Healey et al, 1976

5. Inaccurate Timing

B. SPATIAL ERRORS

1. Spatially restricted movements:

Zimmermann, 1980a
Klich & May 1982

2. Inappropriate articulatory placement:

Zimmermann, 1980a
Van Riper, 1982
Mohan Murthy 1988

3. Excessive articulatory movements:

Shapiro, 1980

4. Static positioning articulatory:

Zimmermann, 1980b
Pindzola, 1987

5. Forceful articulatlon

Webster, 1974

6. Loner velocities of articulators:

Adans et al , 1975
Bealey et al 1976
Zinnernann, 1980a

7. Reverse muscular movement:

Guitar et al,1988

8. Difficulty in stabilizing the articulatory Movements:

Janssen et al,1983

II. LARYNGEAL GESTURES

1. Inappropriate gesture

Adams & Reis, 1971
Conture et al, 1977
Freeman & Ushijima, 1978
Conture et al, 1980
Conture et al, 1982a
Mower 4 Fairbank,1991

III COORDINATION BETWEEN ARTICULATORY & PHONATORY EVENTS:

1. Longer VOT:

Agnello & Wingate, 1972
Wendell, 1973
Agnello et al,1974
Hillman 4 Gilbert, 1977
Basu, 1979
Zimmermann, 1980a
Healey & Gutkin, 1984
Borden & Aronson, 1987
Metz et al,1990

2. No significant difference in VOT:

Brenner et al, 1972
Metz et al, 1979
Watson 4 Alfonso, 1982
Borden et al, 1985
Zebrowski et al,1985
Revathi, 1989

IV COORDINATION OF ARICULATORY LARYNGEAL & RESPIRATORY EVENTS:

1. Miscoordination between these system:

Adams, 1974
Conture et al, 1985
Mohan Hurthy, 1988
Peters & Boves, 1988

T. COARICULATORY ERRORS

1. Abnormal formant transition

Stromsta, 1965
Adams 4 Reis, 1971
Agnello et al, 1974
Webster, 1974
Montgomery 4 Cooke, 1976
Manning 4 Coufal, 1976
Starkweather 4 Meyers, 1979
Zimmermann, 1980a
Van Riper, 1982
Wells, 1983
Howell, et al 1987
Mohan Murthy, 1988
Revathi, 1989

2. Extent of formant transition

Healey, 1981
Suchitra, 1985

TABLE-1: ARTICULATORY ABNORMALITIES IN STUTTERERS

Montgomery and Cooke (1976) studied the part word repetitions in the speech of adult stutterers. The spectrographic analysis revealed longer consonant duration in the initial segment of stutterred word. Healey and Adams (1981) conducted a study to explore the speech timing skills of normally fluent and stuttering children and adults, producing two sentences ten consecutive times, at basal and modified speech rates. Spectrographic displays of subject's utterances in both conditions were made in order to obtain consonant, vowel, pause and utterance duration measures. Results indicated that the two groups of children produced speech durational values similar to those of the two adult groups. However, for the second sentence, the stutterers exhibited breakdowns in coarticulatory sequences and articulatory imprecision (place of articulation). The adult stutterers were found to exhibit longer consonant and vowel durations compared to normal speaking adults.

Prosek and Runyan (1982) spectrographically measured the duration of stressed vowels extracted from short segments of connected speech. The stutterers spoke with more pauses and with longer average pause and vowel durations than did non-stutterers. Total duration of stressed vowels averaged to 170.6msec for stutterers and 144.1 msec for non-stutterers. Healey and Ramig (1986) measured the vowel, consonant and phrase duration of the fluent utterances using spectrogaphic analysis. The stutterers exhibited longer phoneme duration in the reading sample than in the utterance of short isolated non-sense phrase.

Kalveram and Jancke (1989) measured the vowel duration of eighteen stutterers and eighteen non-stutterers under DAF condition and reported longer vowel durations in stutterers. Revathi (1989) studied the acoustic temporal parameters in the speech of two normally non-fluent and two stuttering children. Spectrographic analysis was performed to measure vowel duration. The results indicated that stutterers had significantly longer vowel durations than normally nonfluent children.

Metz et al (1990) compared the vowel durations of adults. Post-treated stutterers and non-stutterers spectrographic analysis revealed significantly longer vowel durations for stutterers. The average vowel duration for stutterers was 223.52msec and for non stutterers it was 174.42 msec.

2) Shorter phoneme durations:

In contrast to the earlier studies Reimann (1976) reported shorter vowel duration in stutterers. He studied the context dependance of vowel duration in German words. The stutterers investigated had shorter vowels than the control subjects. But they altered vowel duration in the same way the control subjects did depending on what consonant followed.

3) No significant differences:

Some studies have reported that there is no significant difference between the stutterers and the non-stutterers in phoneme durations. Klich and May (1982) studied the duration of the vowels /i/, /a/ and /u/ in seven adult stutterers. They found that the durations of /i/, /a/ and /u/ did not vary in different conditions.

Holland and Starkweather (1982) examined samples of spontaneous speech from young children who stuttered and from nonstuttering children matched very closely for age, classroom placement, school achievement, sex and socioeconomic status. The pairs of speech samples from matched subjects were searached for words that could be matched for syllable structures word length, stress pattern, position in the sentence, grammatical function in the sentence, and overall sentence length. Spectrograms of matched words were made and the duration of the stressed and unstressed vowels, overall word duration and the proportion of the total word duration taken up by the vowel were measured. The average word duration was 50msec longer for non-stutterers than for stutterers. Both the groups showed around 40msec of difference between stressed and unstressed vowel duration. There was no significant difference between the two groups in terms of vowel duration.

Zebrowski et al (1985) acoustically analyzed eleven young stutterers and eleven normally fluent peers in the age range of 3.1 years to 6.8 years. The measured acoustic variables consisted of vowel consonant transition duration (msec) and rate (Hz/msec), stop gap, frication and aspiration duration, voice onset time, consonant vowel transition duration and rate and vowel duration. Results indicated no significant differences between young stutterers and their normally fluent peers for any of the temporal measures.

Healey and Ramig (1986) compared adult stutterers and non-stutterers fluency during multiple productions of two dissimilar speech contexts. Spectrographic analysis, was performed on subjects five consecutive fluent productions of a simple isolated phrase and nine phrases extracted from an oral reading passage. Measures of fluent vowel, consonant and total phrase durations were claculated from the five repetitions of each phrase. Results indicated that duration measures for the stutterers remained relatively stable during multiple repetition of both the short phrase and the reading passage.

Pindzola (1987) compared the speech of adult stutterers and normals spectrographically. He reported that vowel duration was same in both normals and stutterers. Four adult stutterers and four age matched controls were made to read the German version of the text containing 140 syllables and tape recorded. The data were then analyzed and the results indicated that reading time (defined as the time needed to read the whole text) was about 1/3 longer than that of nonstutterers. But Articulation time (defined as reading time minus the pauses between the phrases) was the same in both groups (Schaferskupper and Dames, 1987).

4) Longer durations between articulatory events:

The period of inactivity between two consecutive articulatory gestures is represented in terms of duration between articulatory events.

Adams et al (1975) and Healey et al (1976) have reported longer durations between articulatory events in stutterers.

5) Inaccurate timing:

Inaccurate timing has also been reported by Cooper and Allen (1977). They investigated the speech timing control accuracy of stutterers and non-stutterers during both speech and non-speech activities. In general, they found that stutterers tended to be less accurate in their timing abilities than was the control group of non-stutterers during all the experimental tasks. The data also showed a wide range of timing abilities among all the subjects with some stutterers performance equal to those of certain non-stutterers.

B. SPATIAL ERRORS

1) Spatially restricted movements:

It has been reported that the stutterer's articulatory movements are spatially restricted with the velocity and the direction of movement altered.

Zimmermann (1980a) used high speed cineradiography to describe the kinematics and spatial and temporal organization of perceptually fluent speech gestures for six stutterers and seven normal speakers. Movements of the lower lip and jaw were analyzed in the CVCs /mam/, /pap/ and /bab/. The statistical analysis revealed that in perceptually fluent utterances, the organization of events necessary for speech production differs between groups of stutterers and normal speakers.

Klich and May (1982) studied the formant frequencies and rate of formant transitions of vowels /i/, /x/ and /u/ in seven adult stutterers. Based on the results they interpreted that vowel production in stutterers are temporally and spatially restricted.

2) Inappropriate articulatory placements:

Zimmermann (1980a), Van Riper (1982) and Mohan Murthy (1988) have reported that the articulatory movements in stutterers are inappropriate.

Zimmermann (1980a) cineradiographically studied the perceptually fluent utterances of six stutterers and seven normal speakers. Movements of the lower lip and jaw were analyzed in the CVCs /mam/, /pap/ and /bab/. The results revealed asymmetry between lip and jaw movements leading to inappropriate articulation.

Van Riper (1982) defined stuttering as a temporal 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. He cited several evidences based on spectrographic and cinefluorographic analysis to support this basic thesis and suggested that during repetitions highly inappropriate articulatory postures may be used. This inappropriate articulatory postures have been reported in both voiced and unvoiced sounds.

Mohan Murthy (1988) studied acoustic, aerodynamic and laryngeal correlates of stuttering in one adult stutterer. Spectrographic anaysis indicated articulatory fixations after which occurred inspiratory frication.

3) Excessive articulatory movements:

Shapiro (1980) reports of excessive articulatory movements in stutterers. She measured the EMG during stutterers dysfluent as well as fluent utterances. The muscles included were orbicularis oris, superior longitudinal and intrinsic laryngeal muscles. Analysis of EMG data suggested the following:

a) Excessive muscular activity during production of dysfluent as well as fluent utterance,

b) Inappropriate bursts of activity before and during periods of acoustic silence, once again, for dysfluent as well as for fluent utterances and

c) Lack of coordination of muscles during blocks which commonly function reciprocally.

These findings, strongly suggest that stutterers while speaking, experience many moments of disruption of normal coordination. Depending on a number of factors, including its nature, intensity, duration and timing of disruption, its effect may or may not result in audible or perceptible stuttering. In some cases a disruption occuring at the onset of a word may simply result in a slight delay in the initiation of the word, a pause too brief to be identified as a dysfluency. In other cases, the only result may be a shift in fundamental frequency, a voicing break, fry phonation or an abnormally long voice onset time.

4) Static Positioning of Articulators:

Zimmerman (1980b) and Pindzola (1987) have found that in stutterers articulators stay in static position during the production of a phoneme. Zimmermann (1980b) used high speed cinefluorographic technique to record articulatory movements during fluent and dysfluent speech from four stutterers and control utterances, from one normal speaker. The results indicated the following:

1) The inter-articulator positions occuring in both perceptually fluent and dysfluent utterances of stutterers were unlike those in fluent utterance of a normal speaker.

2) The aberrant inter-articulator positions preceded repetitive movements, and static posturing.

3) Consistent interarticulatory repositioning which precedes termination of an oscillatory movement or static position often resulting in

a) The lowering of the jaw or lip and/or

b) tongue shapes which resemble shapes found in normal speaker's fluent production or the resting tongue shapes of stutterers.

Pindzola (1987) reported that the stutterers spend longer time in static articulatory positions. In other words, the duration of steady state formant was found to be longer in stutterers.

5) Forceful articulatory patterns:

Webster (1974) suggested that stutterers use articulatory patterns that are too forceful and coarticulatory movements that are too rapid.

6) Lower velocities of articulators:

Adams, et al (1975), Healey et al (1976) and Zimmermann (1980a) have reported lower velocities of articulators in stutterers. Zimmermann (1980a) used high speed cineradiography to describe the kinematics and spatial and temporal organization of perceptually fluent utterances of six stutterers and seven normal speakers. The results indicated lower peak velocities of articulators in stutterers.

7) Reverse muscle movements:

Guitar et al (1988) found that stutterers reversed the onset of muscle activity. They examined lip muscle activity during the speech production of stutterers and fluent speakers to provide information about the nature of stuttering blocks. The action of Depressor Anguli Oris (DAO) and Depressor Labii Inferioris (DLI) were recorded using hooked wire EMG in three stutterers and three nonstutterers during the producton of the word "peek", "puck" and "pack". EMG records indicated that non-stutterers activated DAO prior to DLI for the production of the initial /p/. Stutterers frequently reversed this sequence of onset, particularly when they stuttered. The onset reversals of DAO and DLI in stutterers supports the view of stuttering as a disorder of timing. In other words, the reversed onsets are disruptions of the succession of DAO and DLI. The release of the sound may be delayed until the DAO activity is predominant over DLI activity and hence it depicts an error that leads to a delay in the production of the sound.

8) Difficulty in stablizing the articulatory movements:

Janssen et al (1983) designed a study to investigate the difference between stutterers and normal speakers in phonatory and articulatory timing during the initiation of fluent utterances of monosyllabic words. EMG recordings of four articulatory muscles and recordings of glottal vibrations were made during repetitive utterances of a series of monosyllabic words by fifteen stutterers and seventeen non-stutterers. These data were analyzed in terms of average interval between voice onset and onset of EMG activity and between onset of EMG activity in each articulators and in terms of the intrasubject variability of these durational measures. Results showed that there were no significant differences between stutterers and non-stutterers in average interval times and that stuterers in general were significantly more variable in their speech onset timing. From these results, it was interpreted that stutterers may have difficulty in stabilizing the articulatory movements and actions of the process of speaking resulting in fluctuations in the speed of production of sounds and sound sequences.

II LARYNGEAL GESTURES

Several investigators have reported inappropriate laryngeal gestures during the production of dysfluent utterances by stutterers. Adams and Reis (1971) investigated the difference in the frequency of dysfluencies of voiced and unvoiced phonemes. Two-test paragraphs were formulated each consisting of a 3:1 ratio of continuant to stops as words initiating sounds. One paragraph consisted of all voiced sounds while the second paragraph contained both voiced and unvoiced phoneme, thus requiring four timings as many on-off voicing adjustments. Results indicated that significantly fewer moments of dysfluency were noted on the first paragraph, containing voiced sounds and required no on-off glottal adjustments than for the second paragraph requiring multiple laryngeal maneuver.

Conture et al (1977) made fibroscopic and electromyographic investigations of larynx during stuttering. They found highly variable laryngeal behaviour and reported that the larynx is often inappropriately and nonpredictably opened or inappropriately closed and it oscillates between adductory and abductory postures. Freeman and Ushijima (1978) have studied EMG of intrinsic laryngeal muscles of four stutterers. Three significant findings emerged from this study:

a) Stuttered speech was accompanied by higher levels of muscle activity than was speech which contained little or no perceived stuttering.

b) Disruption in the reciprocity in laryngeal adductor and abductor muscles was observed and it was speculated that this leads to temporary breakdown in the ongoing process of speech production.

c) Evidence of abnormal muscle activity during perceptually fluent utterance was observed.

Conture, et al (1980) studied laryngeal heights during stuttering using videofluoroscopy technique. The observations indicated that many repetitons are characterized by a descending or lowering of the larynx compared to its height during fluent productions of vowel. Laryngeal behaviour during prolongation was much less variable and the vocal folds were tightly abducted.

Conture et al (1982) based on EMG study stated that laryngeal behaviour was more variable during sound/syllable repetition than sound prolongation. Their study also indicated that laryngeal behaviour not only differs between stuttering and fluent production but also between different types of stuttering as well.

Mowrer and Fairbank (1991) investigated a single case, 35 years old and with a history of neurogenic and psychogenic disorders. He displayed an unusual speech dysfluency consisting of within vowel interruption that often occurred in the word final position of a phrase or clause. The vowel in a CVC or CCVC monosyllabic word was arrested by a glottal stop followed by a reduplication of the previous vowel which seems to release the final consonant. The authors concluded that excessive laryngeal tension occurs during production of stressed vowels. This tension results in various degrees of intra-vowel laryngealization, the greatest of which was realized as a glottal closure.

III COORDINATION BETWEEN ARTICULATORY AND PHONATORY EVENTS

Mis-coordination between articulatory and phonatory events in stutterers have been reported by several investigators. Voice onset time is a very useful measurement and it indicates the coordination of articulatory and phonatory system. Most of the studies under this section are based on voice onset time.

1) Longer voice onset time:

Longer voice onset time has been reported in both perceptually dysfluent and fluent utterances of stutterers. Agnello and Wingate (1972) compared the VOTs in matched groups of twelve adult stutterers and twelve normals. They measured voice onset times for CV utterances using pressure sensor device and voice recorder. The stutterer's VOT was found to be longer than that of normals.

Wendell (1973) used spectrographic analysis to measure VOTs of CV utterances. He took matched groups of twelve child stutterers and twelve normals and found stutterers voice onset time to be longer.

Agnello et al (1974) employed spectrographic analysis on three adult stutterers and non-stutterers to measure voice onset time and voice termination times. He stated that stutterers employed significantly longer transition times for both voice onset time and voice termination time than non-stutterers.

Hillman and Gilbert (1977) studied the voice onset time for voiceless stop consonants in the fluent recording of ten stutterers and ten non-stutterers. The subjects were asked to read "The Rainbow Passage". Intervocalic voiceless stop consonant segments were selected and displayed on wide band spectrograms. Results of voice onset measurements obtained indicated that

a) The stutterers displayed longer voice onset time values than nonstutterers,
b) The voice onset time values increased in duration as place of articulation moved back in the oral cavity with the mean values of 38 msecs, 46 msecs and 54 msecs for /p/, /t/ and /k/ respectively.

Basu (1979) compared the voice onset times of stutterers for voiced and voiceless stop sounds of Kannada language in spontaneous reading, in syllables and in isolation with that of non-stutterers. The results of the study revealed that the stutterers showed a longer voice onset time for voicedand voiceless stops both in reading and in isolation when compared to that of non-stutterers. There was a consistent increase in voice onset time with respect to the position of articulatory constriction in case of nonstutterers. No consistent variation in voice onset time with respect to the position of articulatory constriction was observed for stutterers. However, there was a difference in voice onset time for various stop sounds.

Zimmermann (1980a) described the spatial, kinematic and temporal measures of perceptually fluent utterances of six stutterers and seven non-stutterers. The high speed cineradiography technique was used. Apart from spatial irregularities voice onset time of stutterers was found to be longer.

Healey and Gutkin (1984) determined the fluent voice onset time and fundamental frequency contour measures from target syllables located at the beginning of a carrier phrase. Oscillographic and spectrographic analysis of subjects voice onset time and fundamental frequency at vowel onset, vowel fundamental frequency, speed and range of fundamental frequency changes were obtained. Results showed that VOTs for voiced stops and the range of fundamental frequency change for voiceless stops were associated with significant between group differences. Voice onset time in stutterers for voiced and voiceless stop was 28.88 msecs and 115.65msecs respectively. For non-stutterers voice onset time was 18.10 msecs and 95.17msecs respectively.

Borden and Aronson (1987) studied the coordination of laryngeal and supralaryngeal behaviour in six stutterers and non-stutterers. Simultaneous recordings of lip/jaw displacement, fast EGG and acoustic waveform was made. The analysis revealed tremors the lip/jaw displacement and fast EGG. The authors have inferred that the nature of speech timing and laryngeal behaviour in stutterers was different from that of controls.

Metz et al (1990) compared the speech naturalness of twenty post treatment stutterers and non-stutterers along acoustic and psychophysical dimensions. The speech of the non-stutterers was judged more natural than the speech of treated stutterers. The mean VOT for non-stutterers and treated stutterers was 44.66 msecs and 71.18msecs respectively. The vowel duration was 174.42 msecs for non-stutterers and 23.52 msecs for stutterers. These two measures highly correlated with speech naturalness.

2) No significant difference in voice onset time:

Some studies have indicated no significant difference between stutterers and non-stutterers for VOT value. Brenner et al (1972) attempted to determine what aspect of previous rehearsal aids in the reduction of stuttering. Five conditions were created: 1) no rehearsal, 2) silent rehearsal with no lip movement, 3) silent rehearsal with lip movement, 4) whispered rehearsal, 5) aloud rehearsal. Twelve stutterers read test sentences after three rehearsal under the different conditions described. Results indicated that the most effective reducers of stuttering was the aloud rehearsal suggesting that a combination of phonatory and articulatory motor maneuver was the most important element of rehearsal.

Metz et al (1979) analyzed spectrographically eighteen different sound clusters in words produced by five young adult stutterers and five normals. Stutterer's voice onset time were longer on only six of the eighteen clusters. Statistical analysis revealed no significant group differences in most of the phonetic contexts constituting their data base.

Watson and Alfonso (1982) determined the laryngeal reaction time and voice onset time values in a group of eight adult stutterers and eight normal speaking adults. Voice onset times were obtained from a nonsense syllable phrase beginning with a voiced schwa. The phrases consisted of three contiguous schwa + C1-V-C2 segments where Cl was either (/p/, /t/, /k/), C2 was always 1 and V was either the high front vowel /i/, the high back vowel /u/ or the low front vowel /x/. Spectrographic analysis was performed on the utterances produced. Analysis of variance indicated no significant group difference for any of the three places of articulation or the pooled voice onset time measures. There was no significant group differences for laryngeal reaction time values and a rank order comparison of laryngeal reaction time and voice onset time for the stuttering group revealed a non-significant correlation between these two measures of laryngeal timing (r = -0.275).

Borden et al (1985) performed electroglottographic and acoustical analysis of fluent and dysfluent utterances of stutterers. Voice onset time was measured during an adaptation task performed by stutterers and control subjects. There was no significant difference between the voice onset time of stutterers and controls. EGG for dysfluent utterance was characterized by a gradual instead of abrupt build up of the signal. This was the physiological basis of early onset of voicing.

Zebrowski et al (1985) had acoustically analyzed eleven young stutterers and eleven normally fluent peers in the age range of 3.1 years to 6.8 years. The measured acoustic variables consisted of vowel-consonant transition duration (in msec) and rate (Hz/msec), stop gap, friction and aspiration duration, voice onset time, consonant vowel transition duration and rate and vowel duration. Results indicated no significant difference between young stutterers and their normally fluent peers for any of the temporal measures. However, they speculated that, unlike normals, stutterers do not show any systematic relationship between the peak glottal opening and the articulatory release. This was based on the stop gap duration data. They interpreted that stutterers show less control and stabilization of laryngeal and supralaryngeal temporal coordination.

Revathi (1989) studied the acoustic temporal parameters in the speech of two normally non-fluent and two stuttering children. Spectrographic analysis revealed no significant difference between stutterers and normally non-fluent for voice onset time.

IV COORDINATION OF ARTICULATORY, LARYNGEAL AND RESPIRATORY EVENTS:

Adams (1974), Conture et al (1985), Mohan Murthy (1988) and Peters and Boves (1988) have reported miscoordination of articulatory, laryngeal and respiratory events during stuttering.

Adams (1974) has offered a physiologic and aerodynamic analysis of stuttering and fluency. He proposed that fluency is dependent on smooth coordination of activities of the respiratory, phonatory and articulatory system. Because evidence of disrupted motor timing can be found during stuttering at all levels of speaking system, the possibility exists that each level could serve as a form of difficulty that triggers miscoordination with other levels of the system.

Conture et al (1985) based on the fiberoscopic observation of larynx hypothesized that a complex interaction among the respiratory, laryngeal and articulatory systems contributes to the occurrence of the inappropriate abductory and or adductory laryngeal behaviour.

Mohan Murthy (1988) studied the acoustic aerodynamic and laryngeal correlates of stuttering. The measurements were made using spectrograph, electroaerometer and electroglottograph respectively. The observations made for nonfluent pretherapy utterances are presented below:

1) Inhalatory frications of varying duration (50 to 260 msec).
2) Speed quotient of vocal fold cycles, was less than one in the majority of cycles studied. This indicated inappropriately longer closing phases pointing to excessive adduction.

3) Atypical CV and VC transition of vocal fold cycles were observed.

4) Random variation of SQ from cycle to cycle was observed for vocal fold cycles during (1) inhalatory frication (ii) fricatives and consonants produced an exhalatory airstream.

5) Peculiar stair step patterns in opening phases of vocal fold cycles during inhalatory frication.

6) Abnormal EGG patterns during the opening phase of vocal fold cycles during exhalatory fricative production.

7) Some paradoxical observations where laryngeal tracing and voice bars on spectrogram did not correlate were observed which perhaps relate to the issue of nonlinear mechanisms in speech production.

8) Inappropriate timing of voicing.

9) A clear pattern of longer or shorter post therapy segmental durations is not evident.

10) A pattern of faster pre-therapy transition becoming slower following therapy was not evident.

11) Abnormal articulatory constrictions for fricatives were indicated by the spectrogram.

He further interpreted that dysfluencies seen during stuttering indicated several laryngeal, aerodynamic and articulatory abnormalities.

Peters and Boves (1988) examined the interaction of respiration, phonation and articulation. Pressure build up patterns preceding the onset of phonation were studied in 573 fluent utterances of ten stutterers and 552 utterances of seven control subjects. Stutterers evidenced deviant patterns of subglottal pressure build up much more often than did control speakers. Electroglottographic records were examined and stutterers evidenced abrupt voice onsets significantly more often than did controls. Acoustic measures of abruptness of voice onset, first syllable duration and average syllable duration were also obtained. The results indicated that there was a close relation between problem in the coordination of respiratory, phonatory and articulatory processes and dysfluencies in speech production.

V COARTICULATORY ERRORS

1) Abnormal formant transition:

Presence of abnormal formant transitions has been indicated in several studies.

Stromsta (1965) demonstrated that the spectrograms of stuttered speech revealed a lack of usual falling or rising transitions seen in the spectrograms of normal speakers. The juncture formants were either absent or different. He also added that these children whose dysfluencies showed anomalies in coarticulation failed to outgrow their stuttering. Those children whose spectrograms showed normal juncture formants had become fluent in the ten years span since the original recordings were made.

Adams and Reis (1971) investigated the difference in the frequency of dysfluencies of voiced and unvoiced phonemes in stutterers. They stated that increased stuttering is more likely to occur during voiceless to voiced phonation transition than voiced to voiceless transitions. They hypothesized that if the larynx was an important site in the breakdown of fluency, then conditions requiring increased laryngeal adjustment would create an increase in the frequency of stuttering. Data of this study also suggested that the termination or initiation of phonation is directly related to the frequency of stuttering.

Agnello et al (1974) analyzed spectrograms of the stutterers speech and concluded that stuttering dysfluencies did not show the normal downward shift of the second formant associated with normal articulatory positioning.

Webster (1974) compared stutterers and non-stutterers and suggested that stutterers use rapid coarticulatory movements.

Montgomery and Cooke (1976) analyzed perceptually and acoustically a carefully selected set of part word repetitions from the speech of adult stutterers. Spectrographic analysis revealed that abnormal or formant transitions characterized the initial segment of the stuttered word and the remainder of the word was identical to its fluently produced counterpart. The results were interpreted to mean that for the type of dysfluency selected, the articulatory breakdown was confined to the initial consonant and it was likely that abnormal formant transition from initial consonant to vowel, when present were due to deviant formation of consonant rather than to faulty transition dynamics.

Manning and Coufal (1976) investigated the dysfluencies during voiced-voiced,voiced-voiceless and voiceless-voiceless phoneme to phoneme phonatory transitions. The speech of eleven adult stutterers and a matched group of nonstutterers was analyzed according to the occurrence of disfluency during the above categories of phonatory transitions. Both stutterers and non-stutterers demonstrated a lower percentage of dysfluencies during voiced-voiced transitions than during voiced-voiceless, voiceless-voiced and voiceless-voiceless phonatory transitions.

Starkweather and Meyers (1979) compared the acoustic aspects of stutterers and non-stutterers. According to them stutterer's fluency was characterized by longer transitional subsegments within an intervocalic interval. Zimmermann (1980a) studied the perceptually fluent utterances of six stutterers and seven normal speakers using cineradiography. The results suggested that stutterers had longer transition time of the downward movement for each utterance. He also added that there are longer transition times for both lip and jaw.

Van Riper (1982) based on spectrographic and cinefluorographic analysis of stutterers speech reported that the transitional formant patterns are lacking in the stutterer's prolongation until just before the release takes place. He also added that perceived schwa in syllabic repetitions may be due to failure in coarticulation.

Wells (1983) studied the stuttered and non-stuttered phonemes of twenty adult males and analyzed for distinctive feature patterns using the Chomsky - Halle system. The features (+ consonantal), (-voiced), (+ continuant) and (-strident) occurred significantly more often in stuttering than in non-stuttering instances. Results suggest that in adults stuttering is most likely to occur when the primary sites of tension and discoordination are lingual and laryngeal and when -voice to + voice transition has to be made.

Howell et al (1987) analyzed 30 dysfluent episodes from eight stutterers. All of these dysfluencies occurred on words consisting of an initial voiceless stop consonant followed by a vowel. The spectrographic analysis revealed that the speech lacked normal formant transition between the initial consonant and the following vowel. The dysfluent vowels were shorter and lower in amplitude than the corresponding fluent vowels and there was no significant difference between the formant frequencies of the fluent and disfluent vowels.

Mohan Murthy (1988) studied the dysfluent utterance of one stutterers. The spectrographic analysis indicated faster pretherapy transition. Revathi (1989) studied the acoustic temporal parameters in the speech of two normally non-fluent and two stuttering children. Spectrographic analysis revealed that transition duration of F2 and speed of transition of F1 showed a significant difference between stutterers and normally non-fluent.

2) Extent of formant transition:

Healey (1981) conducted a spectrographic study and found that the adult stutterers were slower in completing the transitions from frication onset to peak amplitude during the production of the /s/ phoneme.

Suchitra (1985) studied coarticulation in fluent utterances of stutterers and compared it with the normal speakers. 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, the extent of such transitions was different in the two groups. The coarticulatory "differences" found in the fluent utterances of stutterers indicated that the articulatory configuration required for the production of a phoneme in question was not fully achieved.

The review of literature suggest that stutterers exhibit several articulatory abnormalities. Several of these studies have been conducted to analyze one of the parameters of articulatory dynamics. In the present experiment it is intended to acoustically study in detail, the articulatory dynamics in four adult stutterers.

METHODOLOGY

SUBJECTS: Four adult male stutterers as diagnosed by a speech pathologist were selected for this study. The age range of the four stutterers was 20-30 years. The subject details are in Table-2.

MATERIAL: Two tasks were used.

1) Spontaneous speech: The experimenter engaged the subject in a general conversation enquiring about his education, occupation, hobbies etc.

2) Reading Tasks: Standardized passages were used for getting reading samples. This included the rainbow passage (Fairbanks, 1967) and standardized passage in Kannada.

PROCEDURE: The subject was seated comfortably in a quiet room of the Speech Science Laboratory, AIISH and he was instructed to speak/ read into the microphone (Cardiode, Unidirectional) which was kept at a distance of 10cms from his mouth. All the speech and reading samples were recorded on high fidelity magnetic 7 1/2" tapes using the internal taperecorder of the sound spectrograph VII 700. The speech and reading samples were listened to and the perceptually dysfluent and their counterpart fleunt utterances (if any) were selected. Wide band bar type of spectrograms were obtained for all these utterances.

	Subject I	Subject II	Subject III	Subject IV
Age of onset	From birth	From six years of age	From birth	From four years of age
Family history of stuttering	No	No	No	No
History of Delayed Speech & language	No	No	No	No
Family history of delayed speech & language	No	No	No	No
Stuttering features	Repetitions Prolongations Interjections Silent Paeuses (in-appropriate).	Interjections Repetitions Prolongations	Repetition Inter-jection Silent & audible pauses	Repetition Prolonga-tion inter jections, audible pause (in-appropriate)
Variations in stuter-ing	Severity in-creases when speaking to strangers. Words star-ting with stop conso-nants	Severity in-creaseswhen speaking to elders-words starting with stop consonants	Severity is constant in all situat-tions, words starting with stop consonants	Severity increases when spea-king to strangers and elders in words starting with stop consonants
Secondaries	Eye blinking Facial grimaces & sweating	Gross head movements & hand movements	Blinking of eye & facial grimaces	Gross head & hand movements & eye blinking
Languages known	Kannada, English	Kannada	Malayalam, English	Malayalam, English, Urdu.

TABLE-2: Subject details

MEASUREMENT

Using the wide band bar type of spectrogram, the following measurements were made.

1) PHONEME DURATION: Vowel duration was measured as the time between the point of onset and cessation of glottal vibration and of resonance areas. The duration of voiced or voiceless consonants was measured as the time between the offset of resonance for the preceding vowel and the onset of resonance for the following vowel (medial position). In the initial position, it was measured as the time between the onset of voice bars or burst to the onset of resonance for the following vowel. The fricative duration was measured as the time between the onset and offset of frication.

2) VOICE ONSET TIME: Voice onset time was measured as the time between the articulatory release as evidenced by the burst and the onset of glottal activity for the following vowel as indicated by the voice bars in the spectrogram.

3) ASPIRATION DURATION: Aspiration duration was measured as the duration between the onset and offset of low frequency energy.

4**) TRANSITION DURATION OF F2 OF THE FOLLOWING VOWEL:** Transition duration was measured as the time between the onset of transition of F2 to the steady state of F2 in the vowel.

5**) SPEED OF TRANSITION OF F2:** The frequencies at the onset and termination of the transition of F2 were measured. The difference between these divided by the transition duration for F2 was considered as the speed of transition of F2.

These measures of dysfluent and fluent utterances were compared and analysis of variance (ANOVA) was applied to find out the significant difference between the dysfluent and fluent utterance. Descriptive analysis of spectrogram was also performed to delineate the results.

RESULTS AND DISCUSSION

RESULTS

The results are presented based on descriptive and inferential statistical analysis and discussed. The descriptive analysis on different spectrograms revealed various articulatory errors as in Table-3.

1) Errors of aspiration
2) Errors of coarticulation
    (a) Lack of formant transition
    (b) Longer transition time
    (c) Shorter transition time
3) Addition or interjection
4) Errors in manner of articulation
5) Errors in place of articulation.
6) Errors in place and manner of articulation
7) Prolongation.
8) Errors of aspiration and coarticulation
9) Errors of coarticulation and and place of articulation.
10) Errors of coarticulation and prolongation.
11) Errors of coarticulation and manner of articulation.
12) Errors in coordination of articulatory and glottal gesture.

TABLE-3: Articulatory errors in stutterers.

1) Errors of aspiration:

Three subjects S2, S3 and S4 aspirated the initial phoneme of the dysfluent word and had aspirations in between the words. The initial phonemes aspirated were vowels, stop consonants and nasals. Spectrograms in Fig-1-15 depict aspiration as exhibited by the subjects in various conditions. It could be observed that while some of the utterances (for eg spectrograms in Figs.l&2) are produced with continuous flow of speech, some utterances are disrupted because of aspiration between or within the words. The mean duration of aspiration was 186.5msecs (In the spectrograms, Du refers to dysfluent utterance and Fu refers to fluent utterance).

Zebrowski et al (1985) reported aspirations in word initial bilabial stops in the utterances of eleven young stutterers. They speculated that aspiration indicated some complex interaction between supralaryngeal and laryngeal structures and movements during production of the stop consonant. Aspiration is defined as the glottal friction produced with or without glottal pulsing while glottis is narrowly or widely opened and supraglottal vocal tract is unobstructed (Dixit 1979).

Aspiration is depicted as low frequency energy on the spectrogram. Aspiration in stutterers associated with phonemes, vowels, stop and nasal - indicates that the glottal gesture is inappropriate. Instead of a vibrating vocal fold,

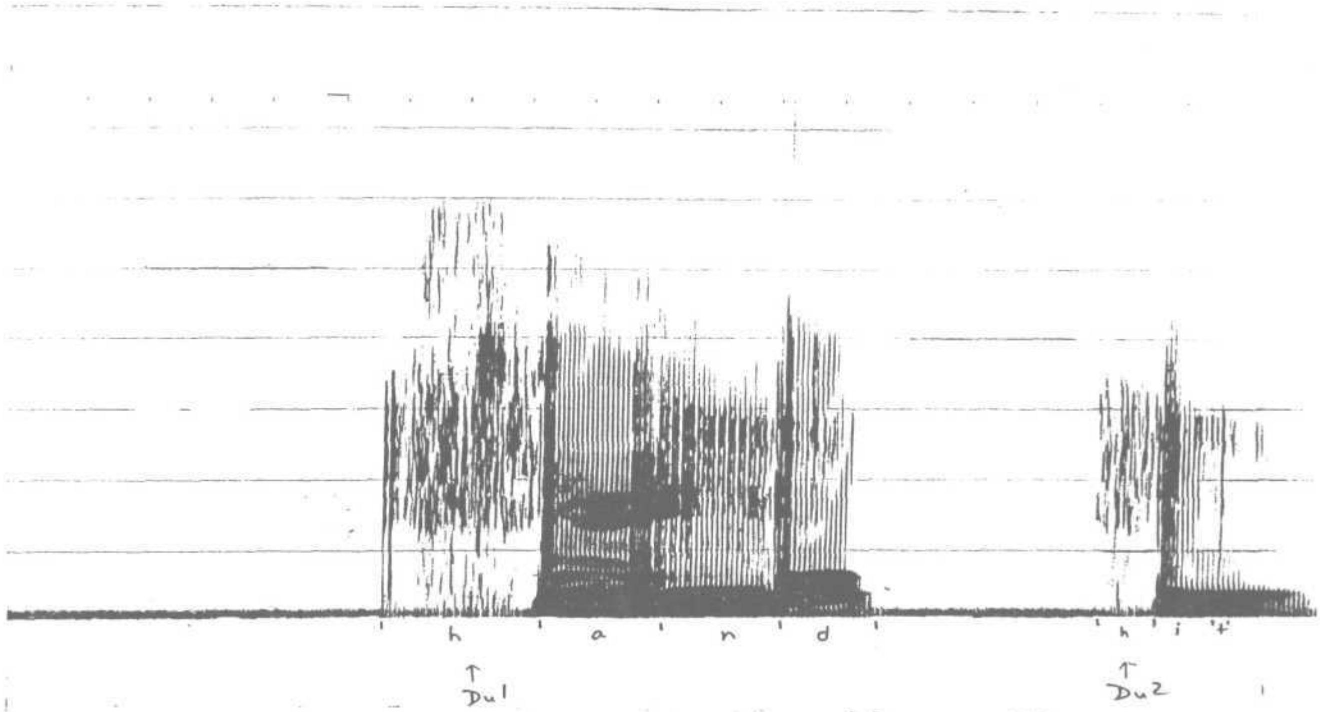


Fig-1: Spectrogram depicting aspiration in the words /and and it/(aspiration indicated by Du1 & Du2 and arrow)

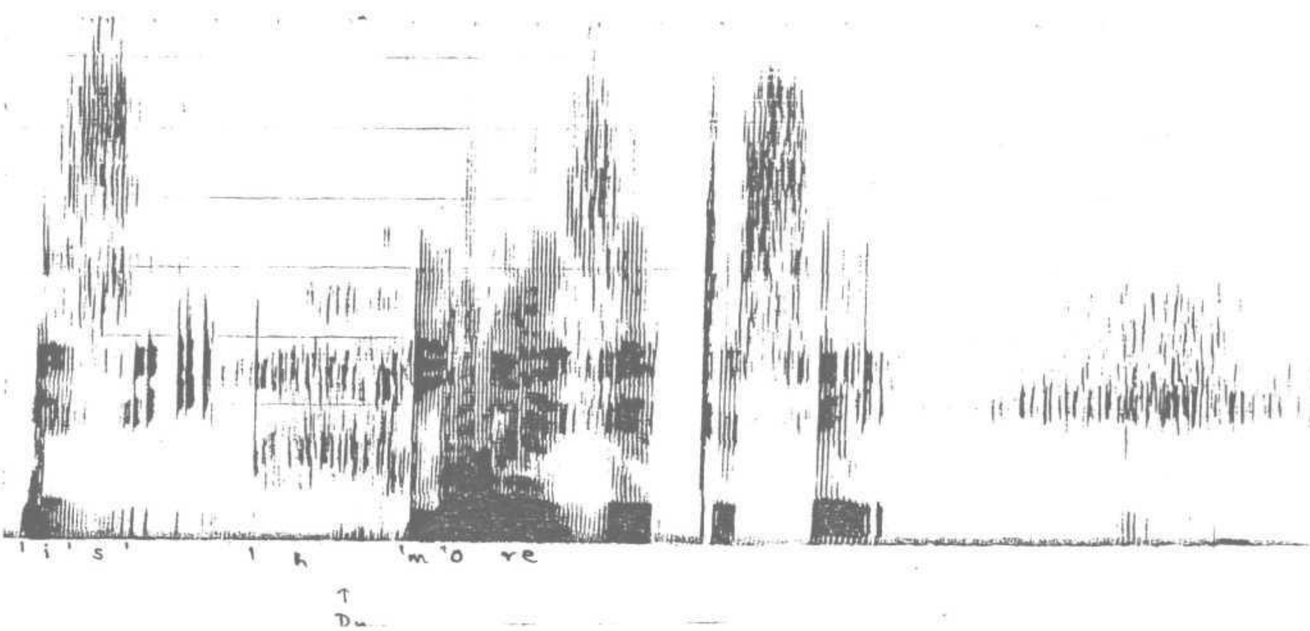


Fig-2: Spectrogram depicting aspiration in the phrase/is more easy/(aspiration indicated by Du and arrow)

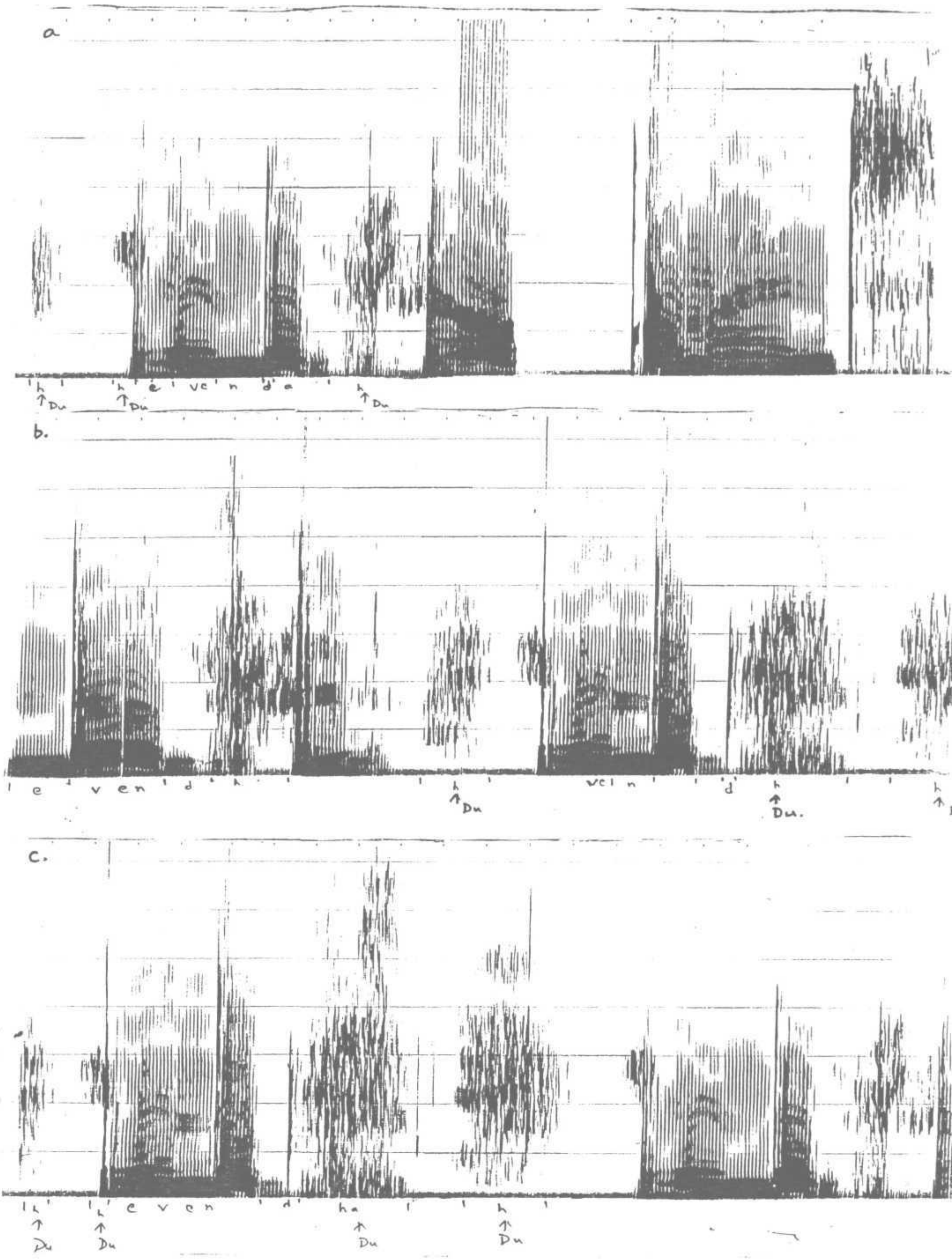


Fig-3a,b,c: Spectrogram depicting aspiration in the phrase /even the/(aspiration indicated by Du and arrow)

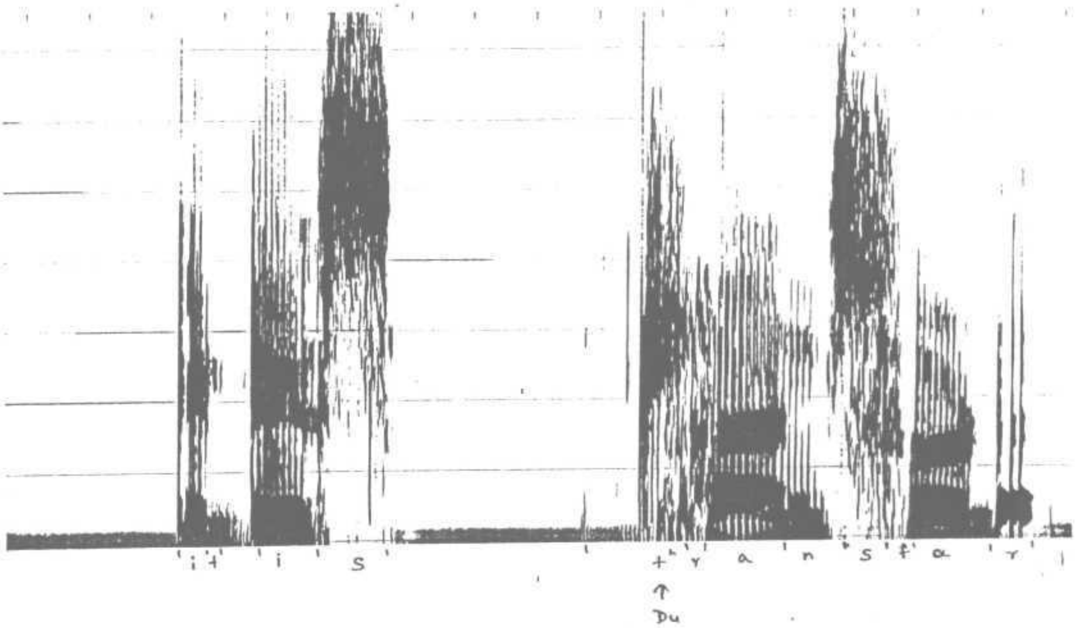


Fig-4: Spectrogram depicting aspiration in the phrase /it is transferred/ (aspiration indicated by Du and arrow)

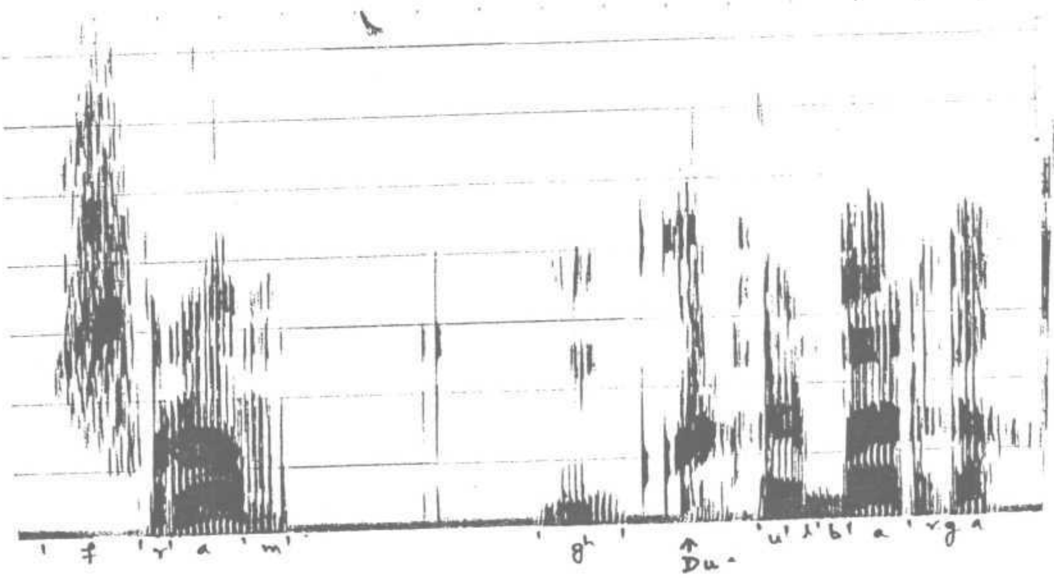


Fig-5: Spectrogram depicting aspiration in the phrase /from Gulbarga/ (aspiration indicated by Du and arrow)

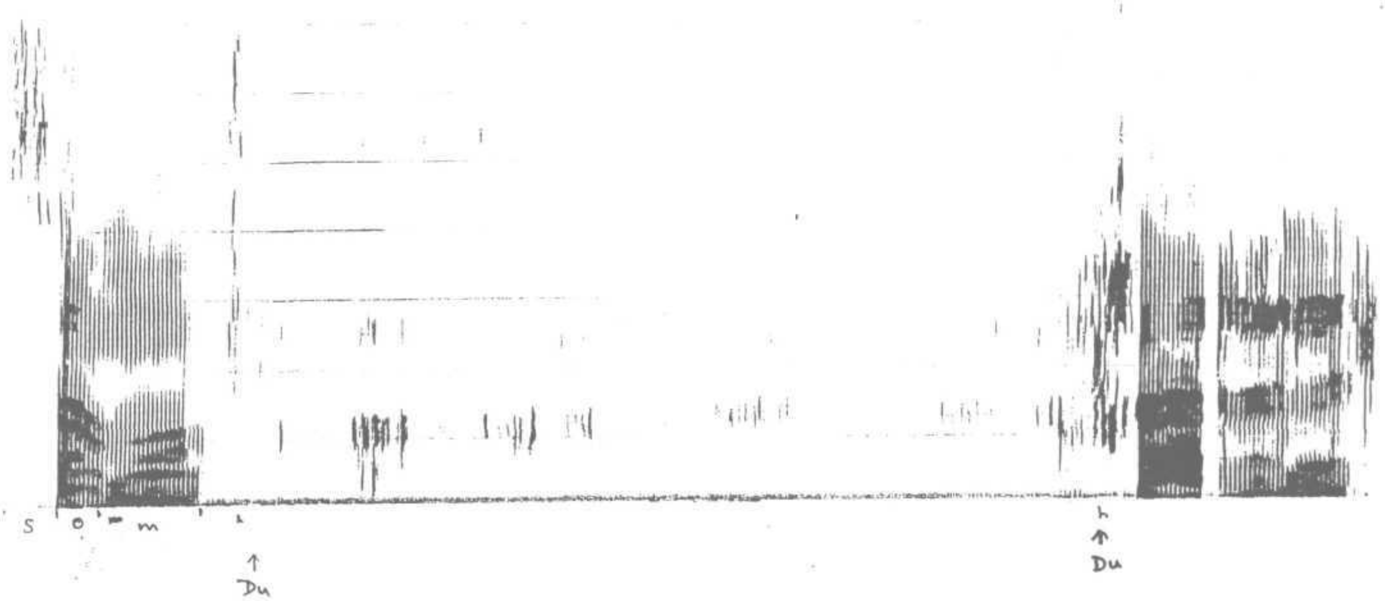


Fig-6: Spectrogram depicting aspiration in the phrase /some of our/ (aspiration indicated by Du and arrow)

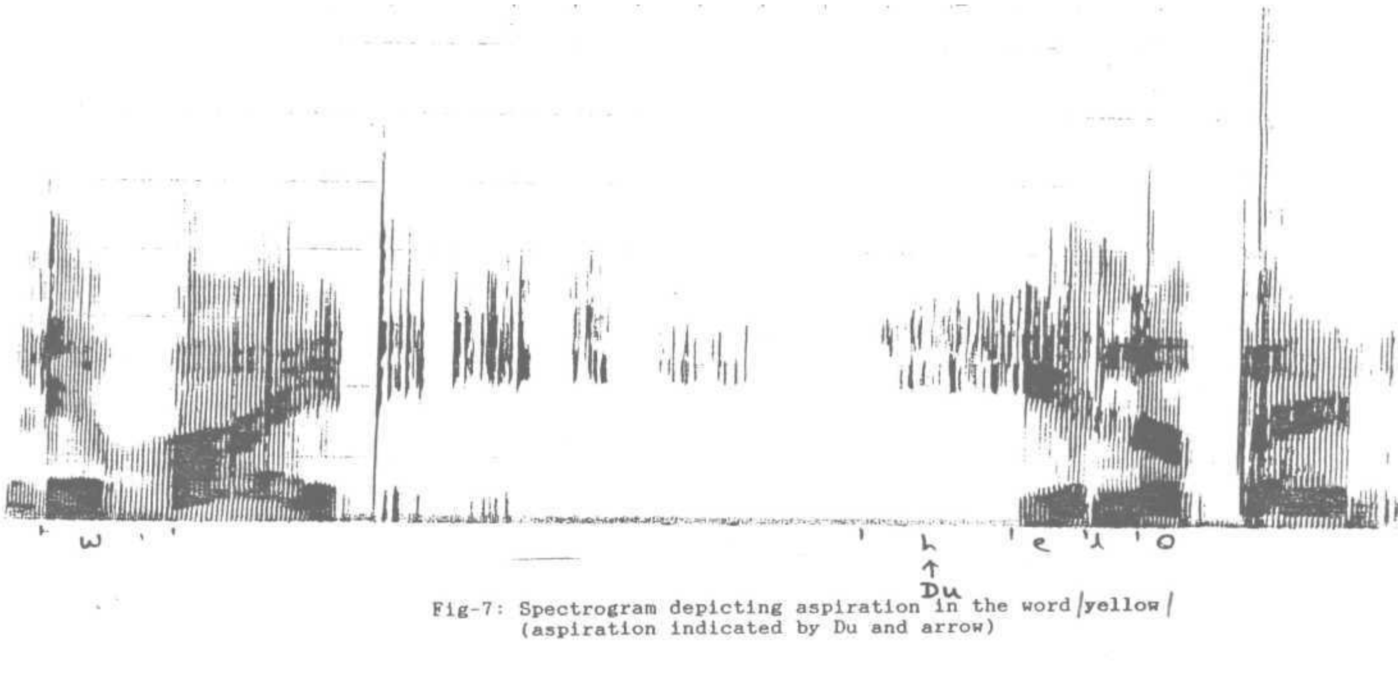


Fig-7: Spectrogram depicting aspiration in the word /yellow/ (aspiration indicated by Du and arrow)

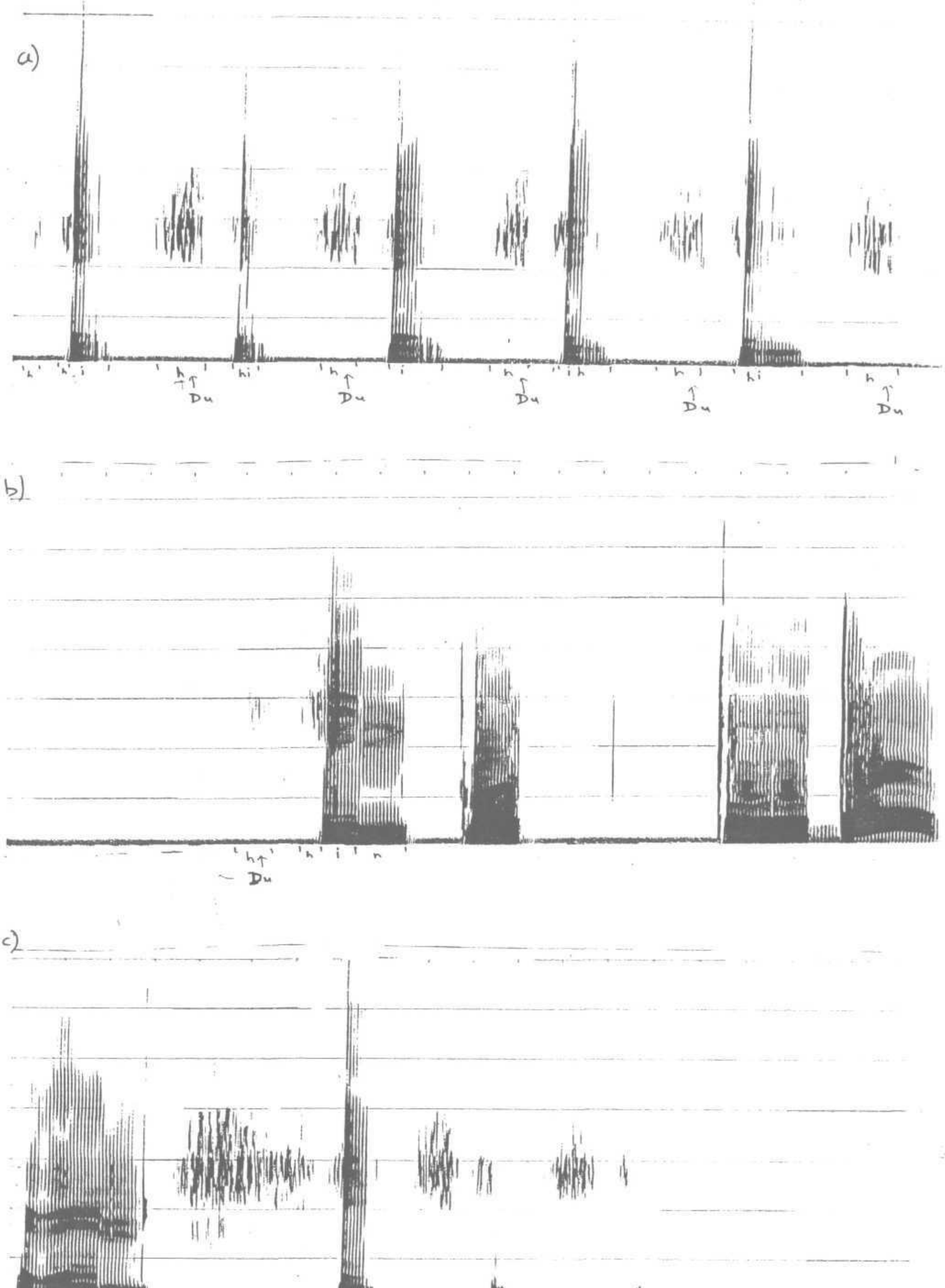


Fig-8: Spectrogram depicting aspiration in the word /input/
a, b, c (aspiration indicated by Du and arrow)

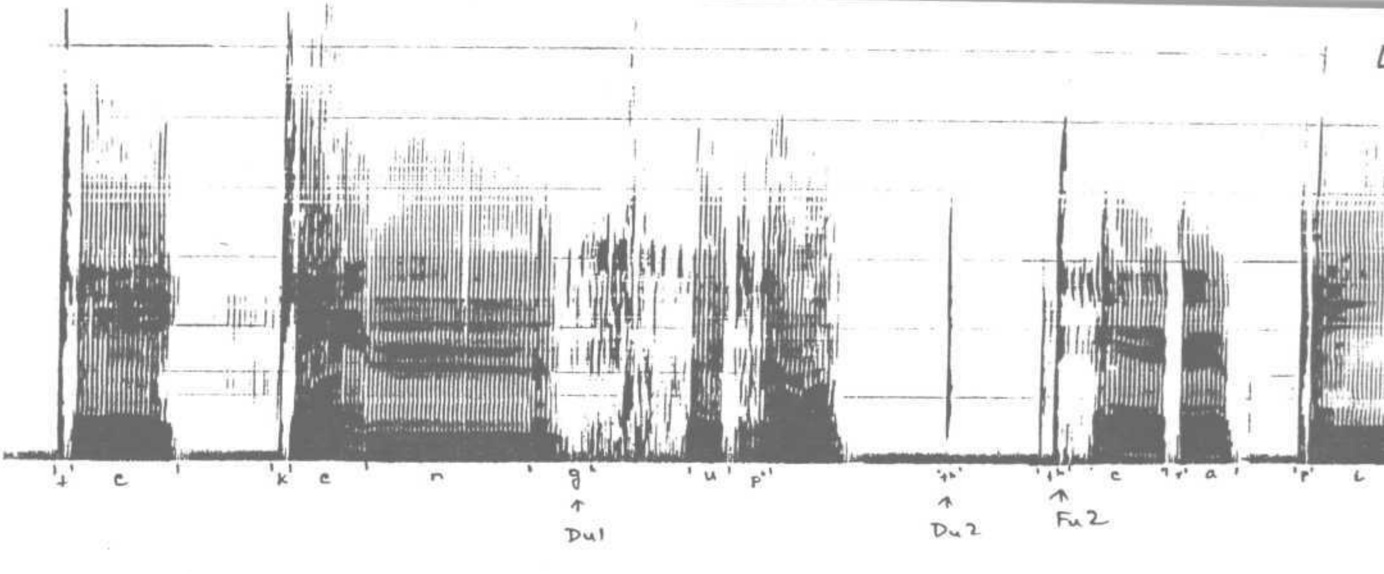


Fig-9: Spectrogram depicting aspiration in the phrase/taken group therapy/(aspiration indicated by Du1 and arrow)

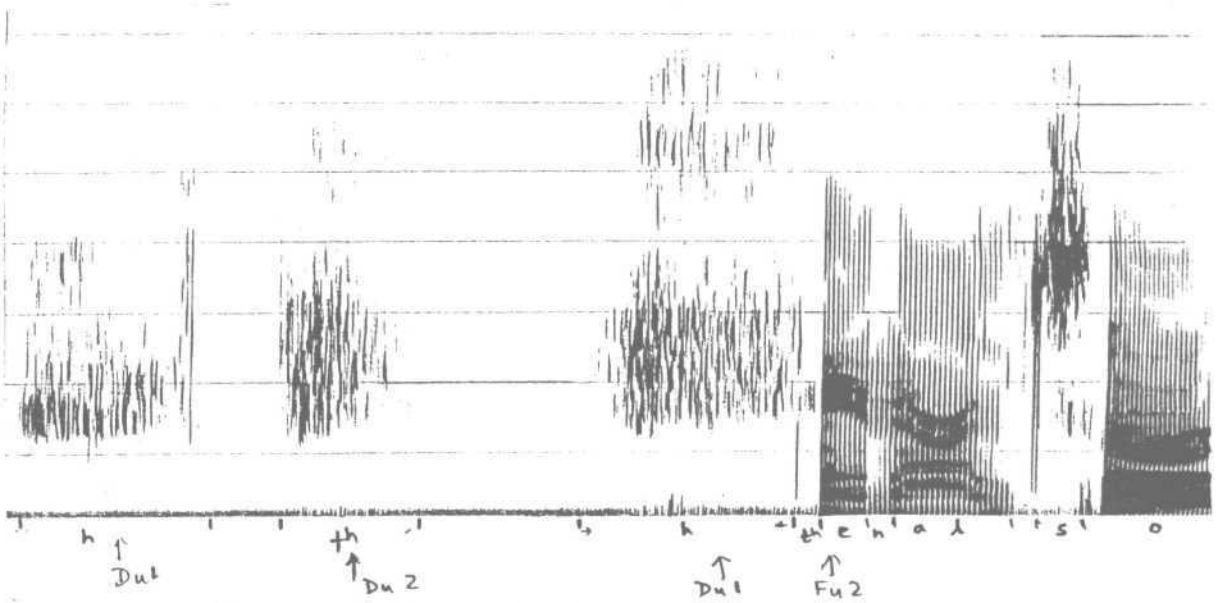


Fig-10: Spectrogram depicting aspiration in the phrase/then also/(aspiration indicated by Du1 and arrow)

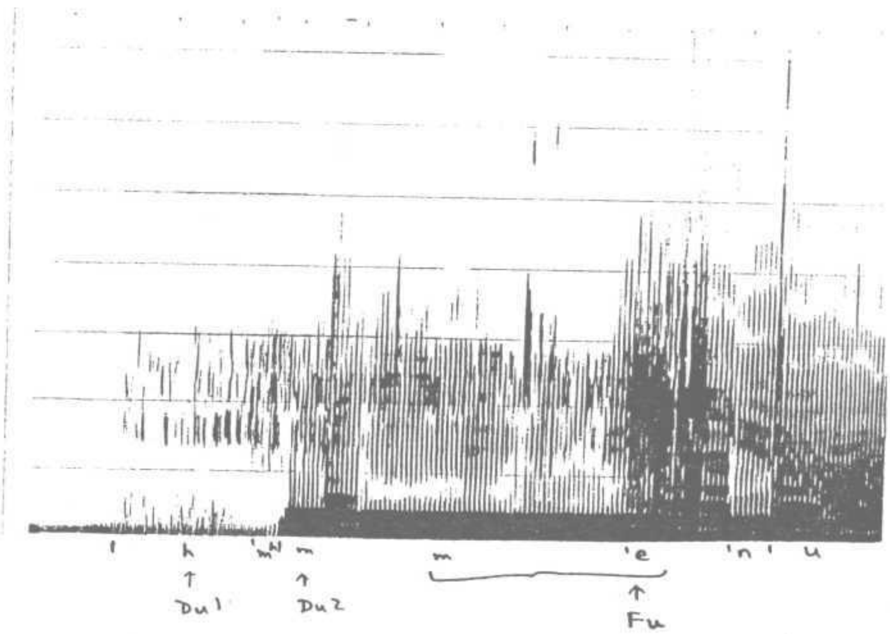


Fig-11: Spectrogram depicting aspiration in the word/menu/ (aspiration indicated by Du1 and arrow)

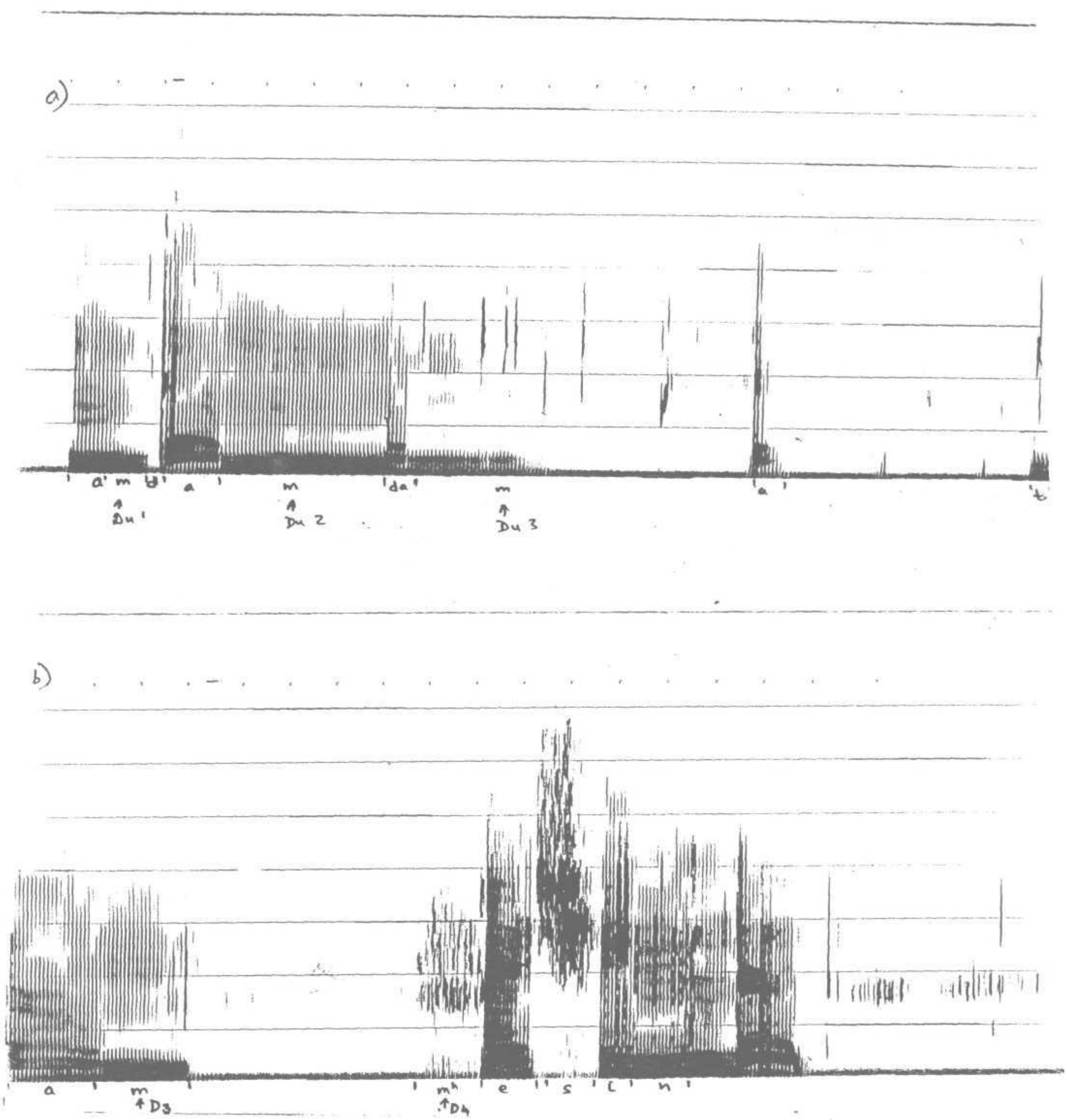


Fig-12: Spectrogram depicting aspiration in the phrase the a & b |machine| (aspiration indicated by Du4 and arrow)

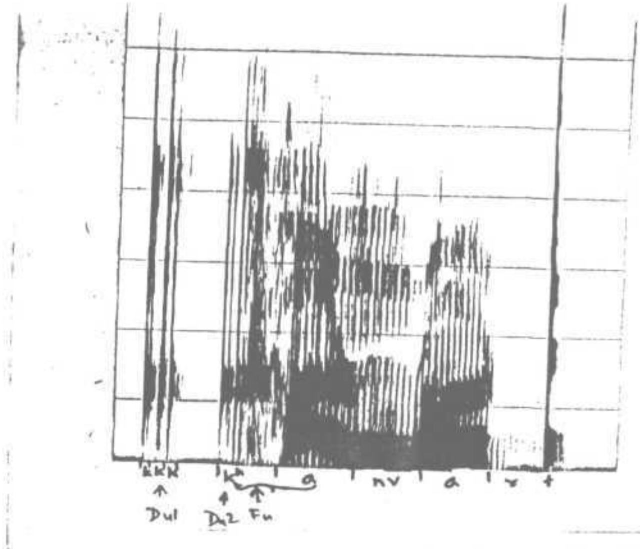


Fig-13: Spectrogram depicting aspiration in the word/convert/ (aspiration indicated by Du2 and arrow)

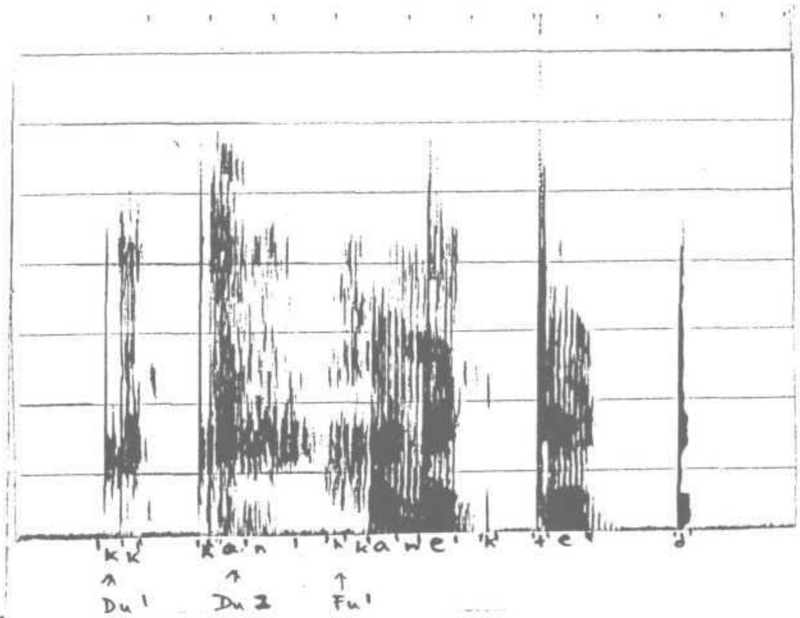


Fig-14: Spectrogram depicting aspiration in the word /connected/ (aspiration indicated by Du2 and arrow)

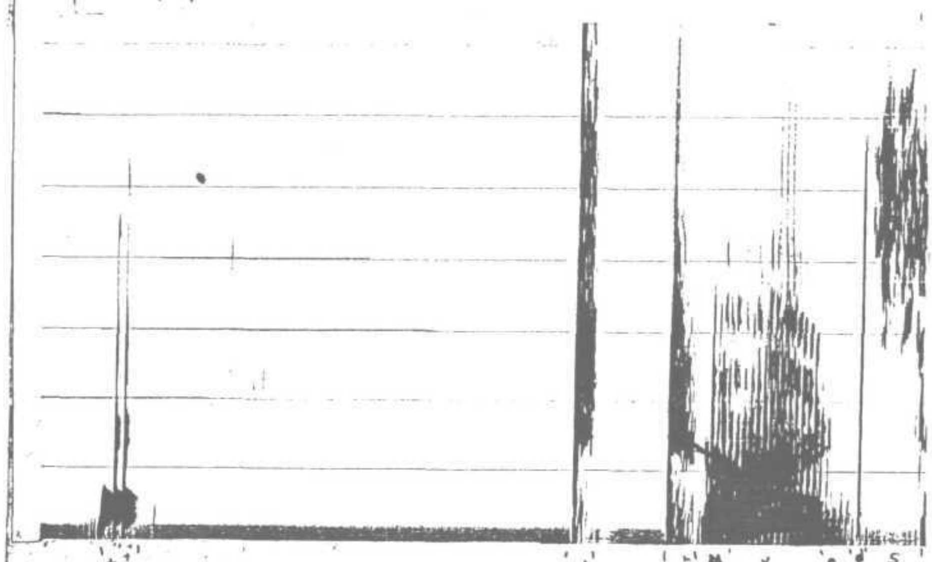


Fig-15: Spectrogram depicting aspiration in the word /towards/ (aspiration indicated by Du2 and arrow) the gesture is open vocal fold. Also, the aerodynamics involved is inappropriate. The duration of aspiration indicates that a high subglottic pressure is involved which was not necessary during the production of these phonemes. Aspiration between words or within words indicate that the glottis is inappropriately and non-predictably open which might be because of a high subglottic pressure causing air to pass through glottis resulting in aspiration.

2) Errors of coarticulation

CV formant transition errors were observed in both initial and medial segment of stuttered words produced by all the four subjects. The initial phonemes of these words were stops, fricatives and nasals. The fourth subject produced coarticulation error for affricate /j/ (Fig 32) and spectrogram for trill /r/ (Fig 28) also. Spectrograms in Figs-16-43 depict errors of coarticulation produced by all the four subjects. These errors of coarticulation could be classified into four types:

a) Lack of formant transitions.

b) Longer transition duration of F2.

c) shorter transition duration of F2.

d) Inappropriate transitions.

a) Lack of formant transition:

Spectrograms in Figs.16-30 depicts lack of formant transition as exhibited by the four subjects. Transitions are

Fig-16: Spectrogram depicting lack of formant transition in the word |convert|(lack of formant transition indicated by Du and arrow)

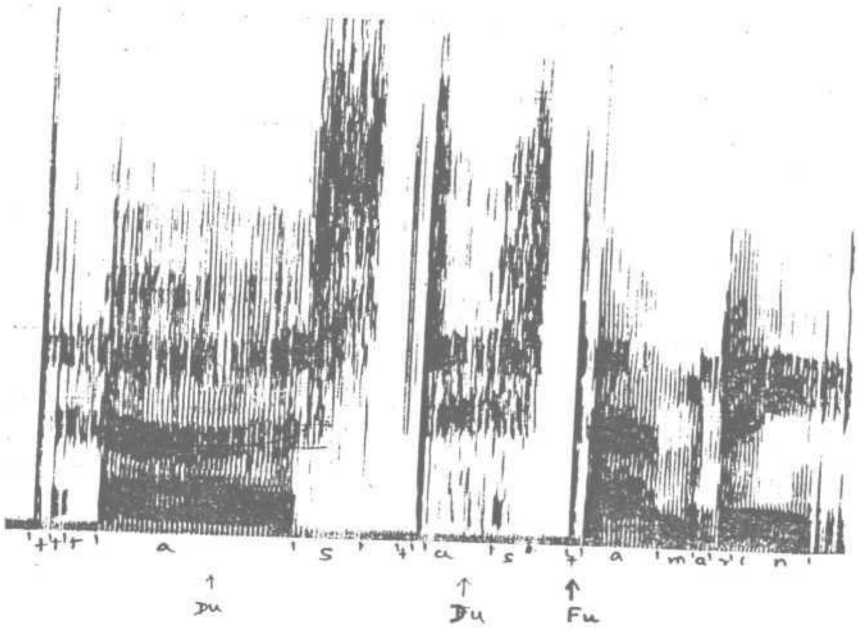


Fig-17: Spectrogram depicting lack of formant transition in the word |stammering|(lack of formant transition indicated by Du and arrow)

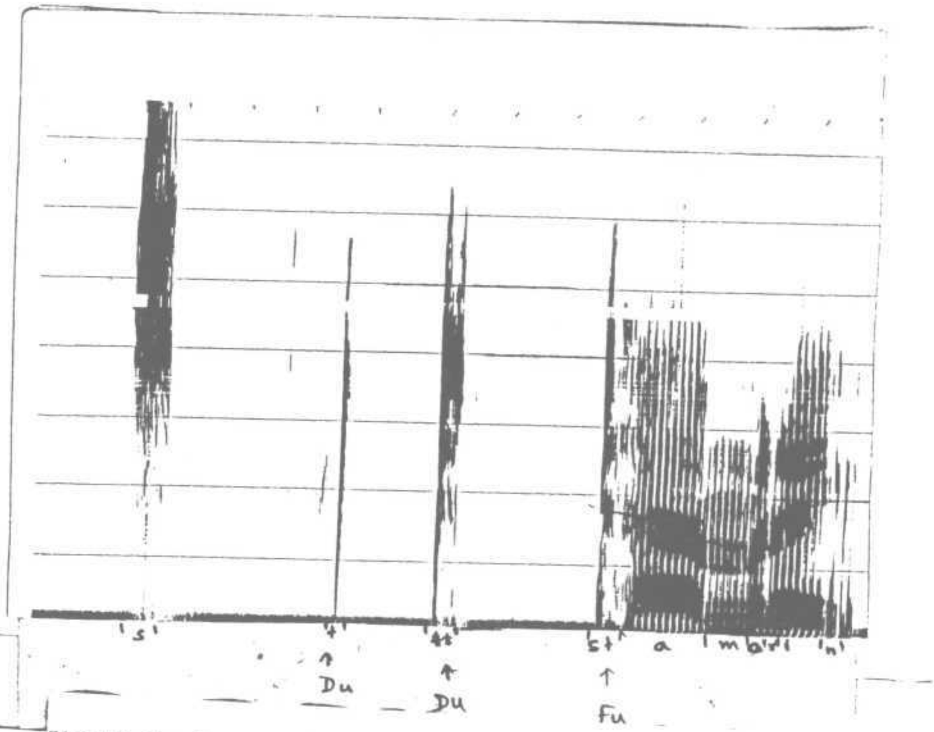


Fig-18: Spectrogram depicting lack of formant transition in the word /stammering/ (lack of formant transition indicated by Du and arrow)

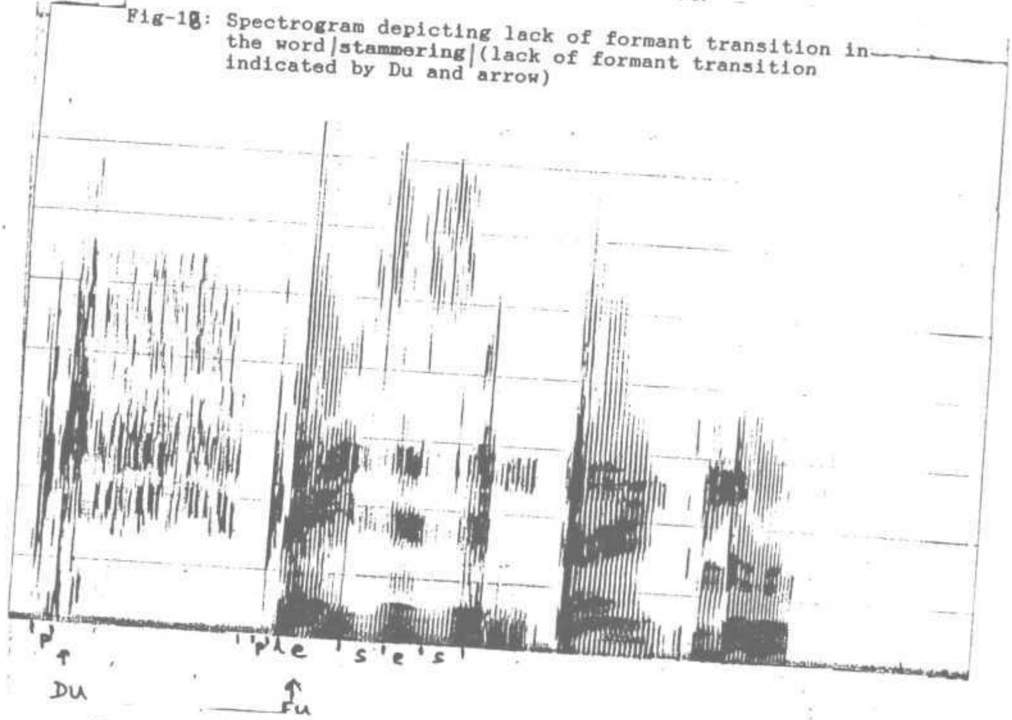


Fig-19: Spectrogram depicting lack of formant transition in the word /places/ (lack of formant transition indicated by Du and arrow)

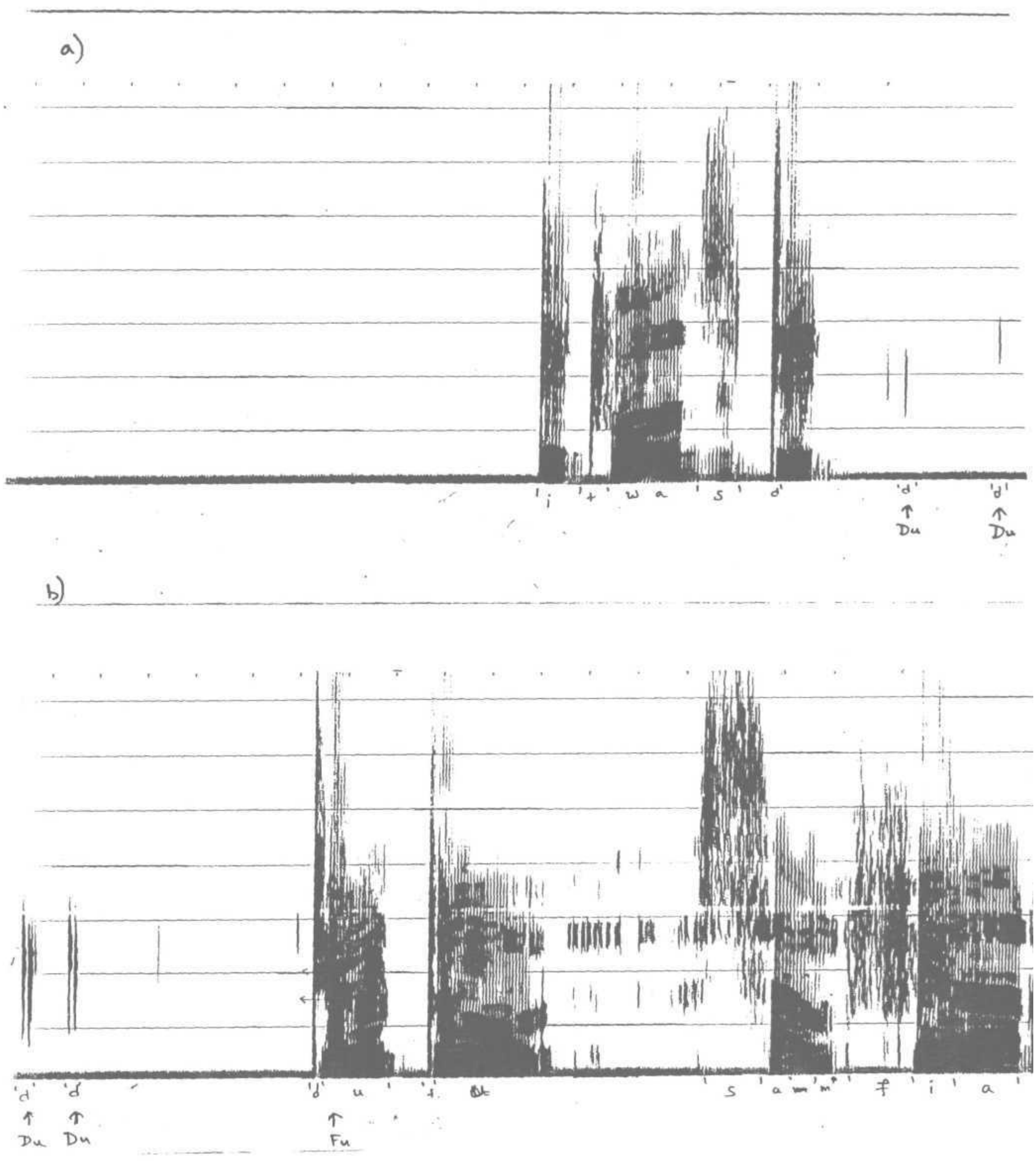


Fig-20a, b.: Spectrogram depicting lack of formant transition in the phrase/it was due to/(lack of formant transition indicated by Du and arrow)

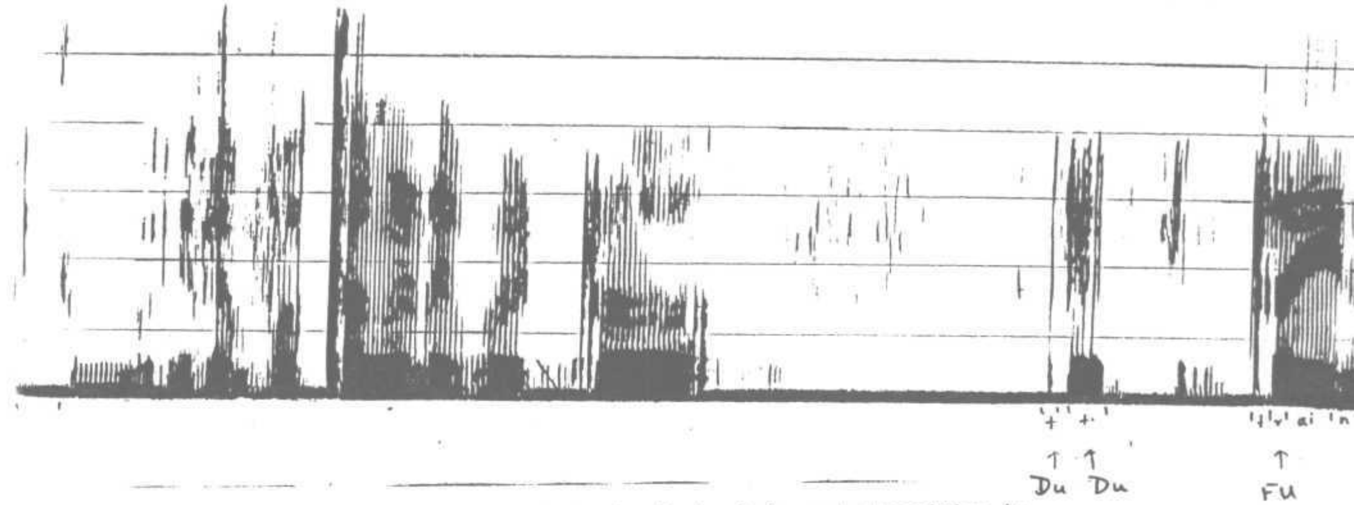


Fig-21: Spectrogram depicting lack of formant transition in the word |training| (lack of formant transition indicated by Du and arrow)

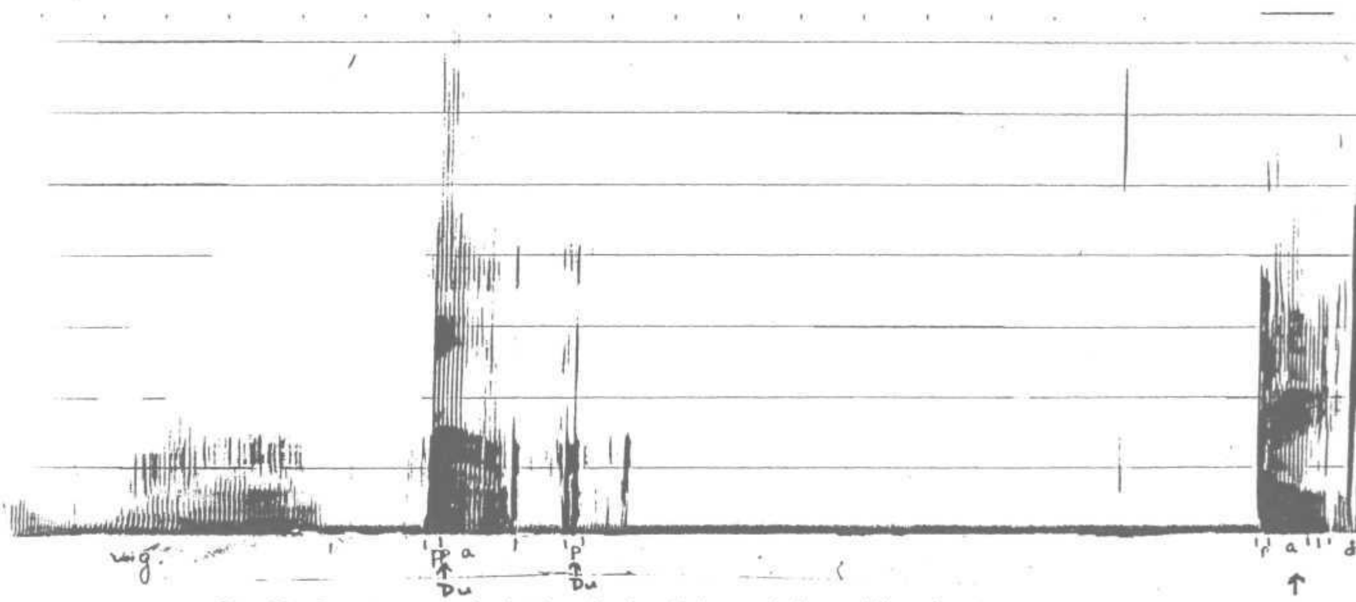


Fig-22: Spectrogram depicting lack of formant transition in the word |palti| (lack of formant transition indicated by Du and arrow)

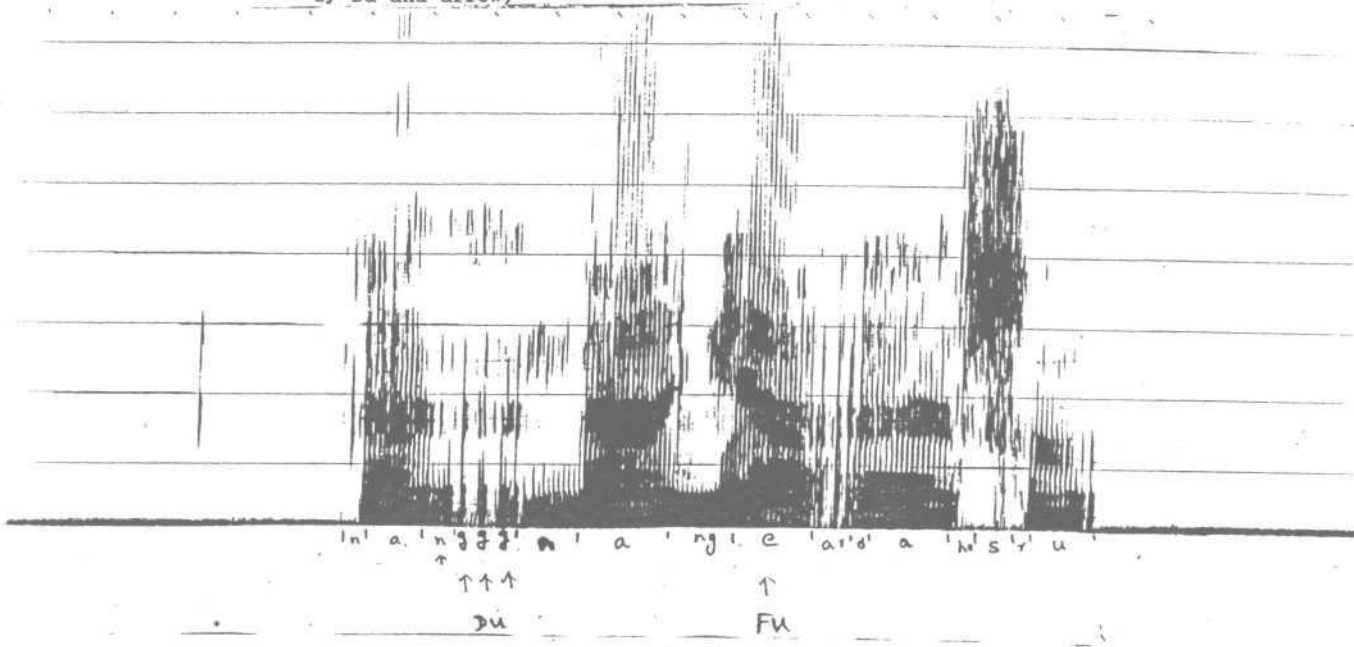


Fig-23: Spectrogram depicting lack of formant transition in the phrase| nanage arda hesru| (lack of formant transition indicated by Du and arrow)

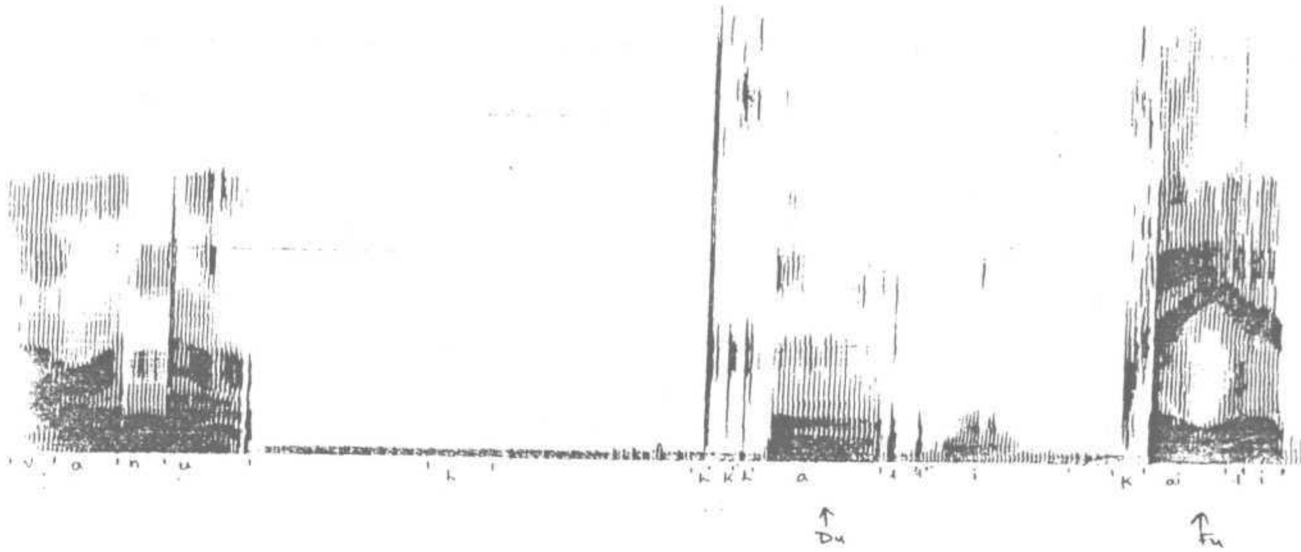


Fig-24: Spectrogram depicting lack of formant transition in the phrase /avanu kaiyatti/ (lack of formant transition indicated by Du and arrow)

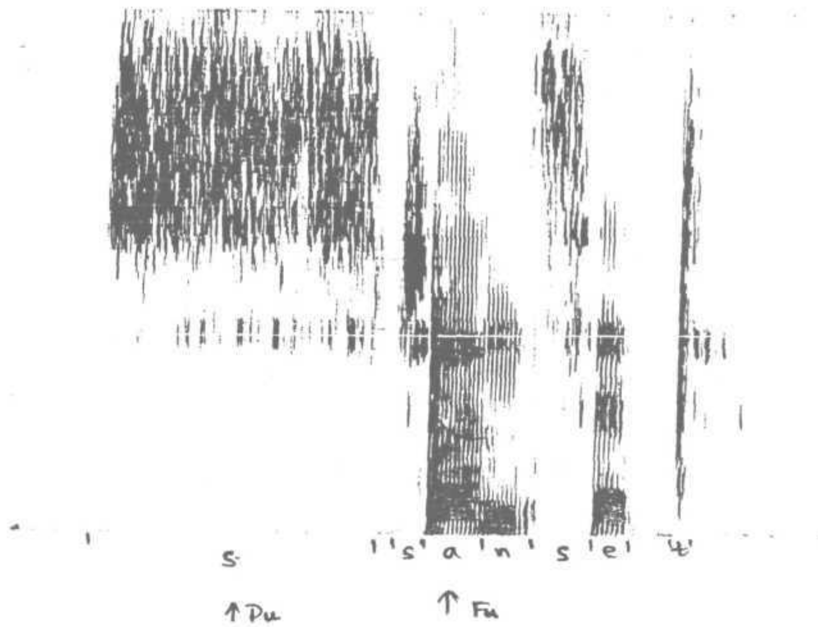


Fig-25: Spectrogram depicting lack of formant transition in the word /sunset/ (lack of formant transition indicated by Du and arrow)

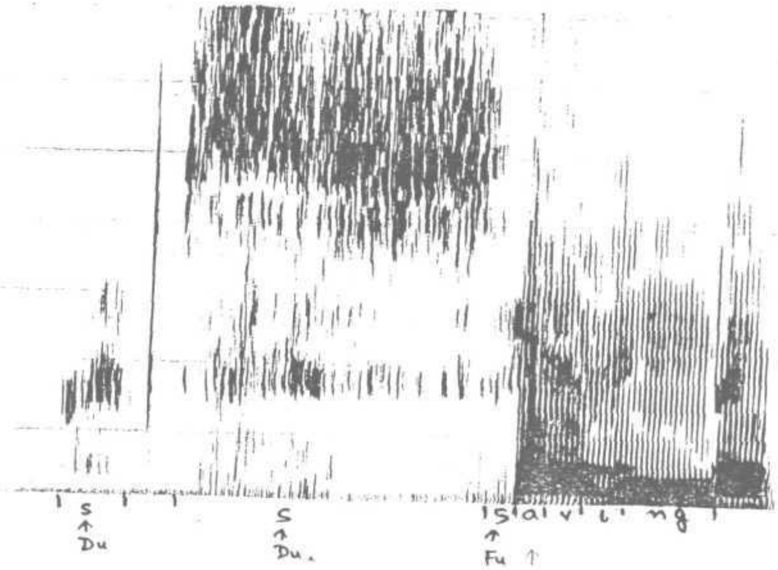


Fig-26: Spectrogram depicting lack of formant transition in the word /saving/ (lack of formant transition indicated by Du and arrow)

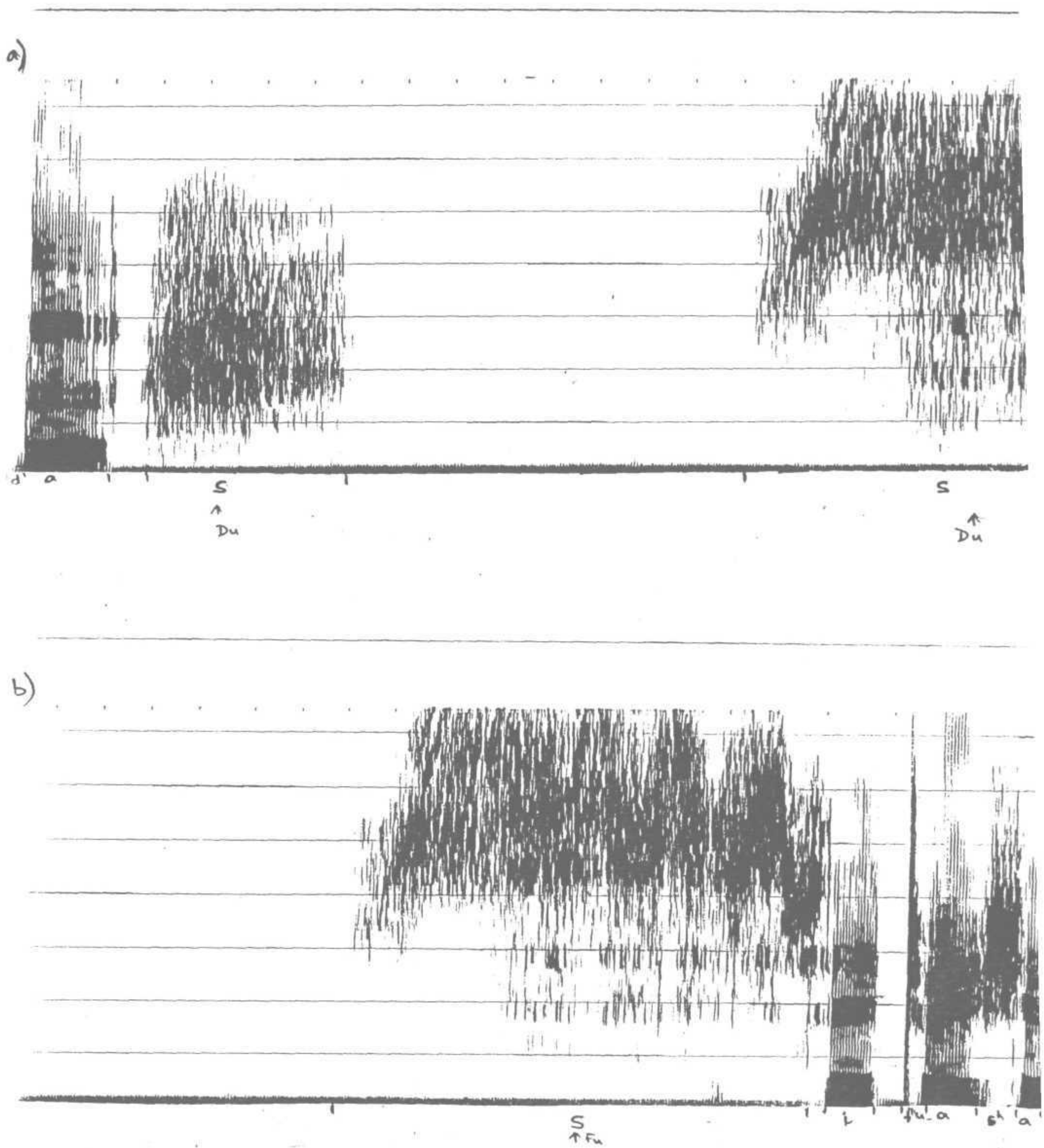


Fig-27: Spectrogram depicting lack of formant transition in
a, b. the word /situation/ (lack of formant transition
indicated by Du and arrow)

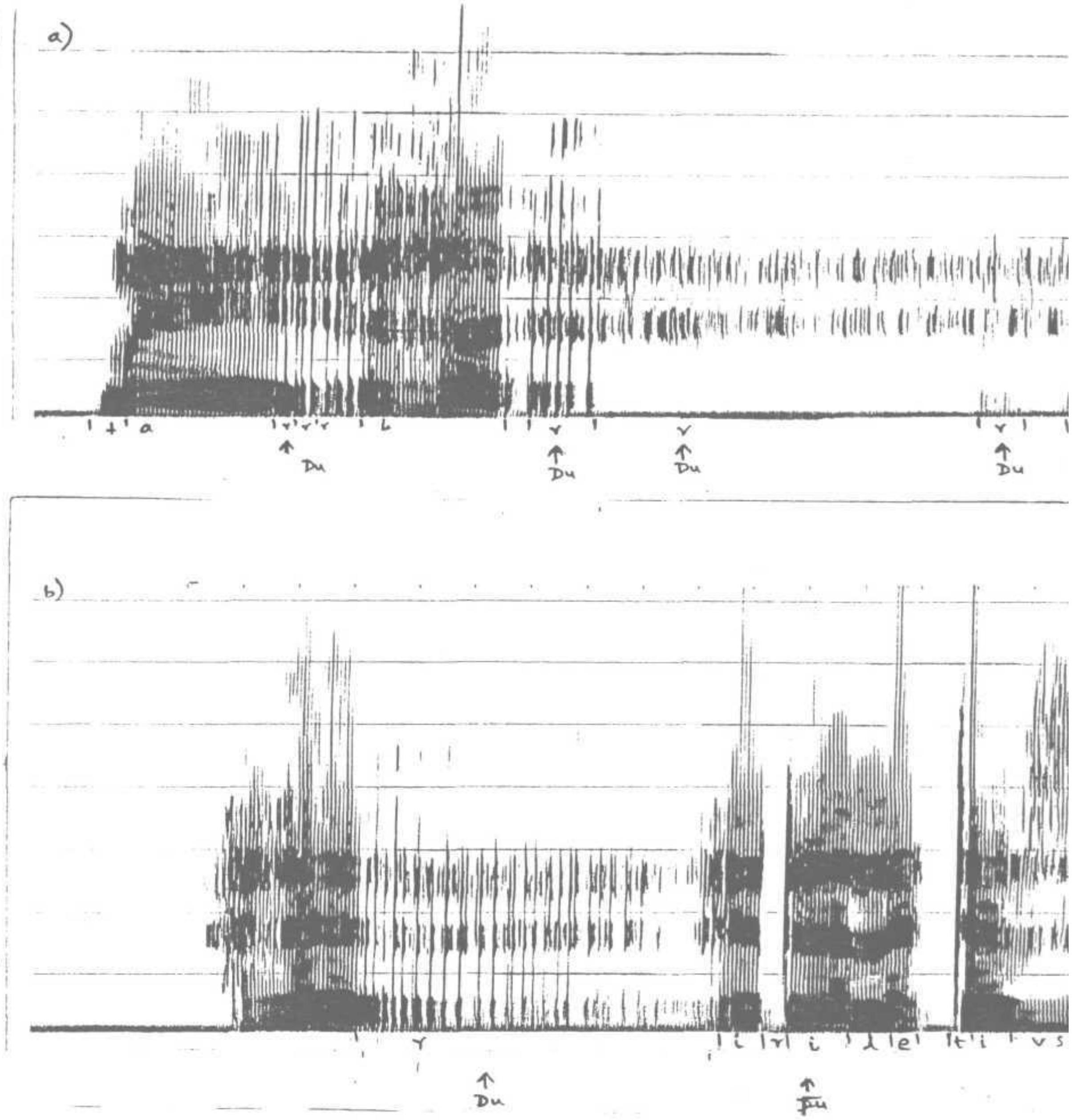


Fig-28: Spectrogram depicting lack of formant transition in
a, b the word |relatives| (lack of formant transition indicated by Du and arrow)

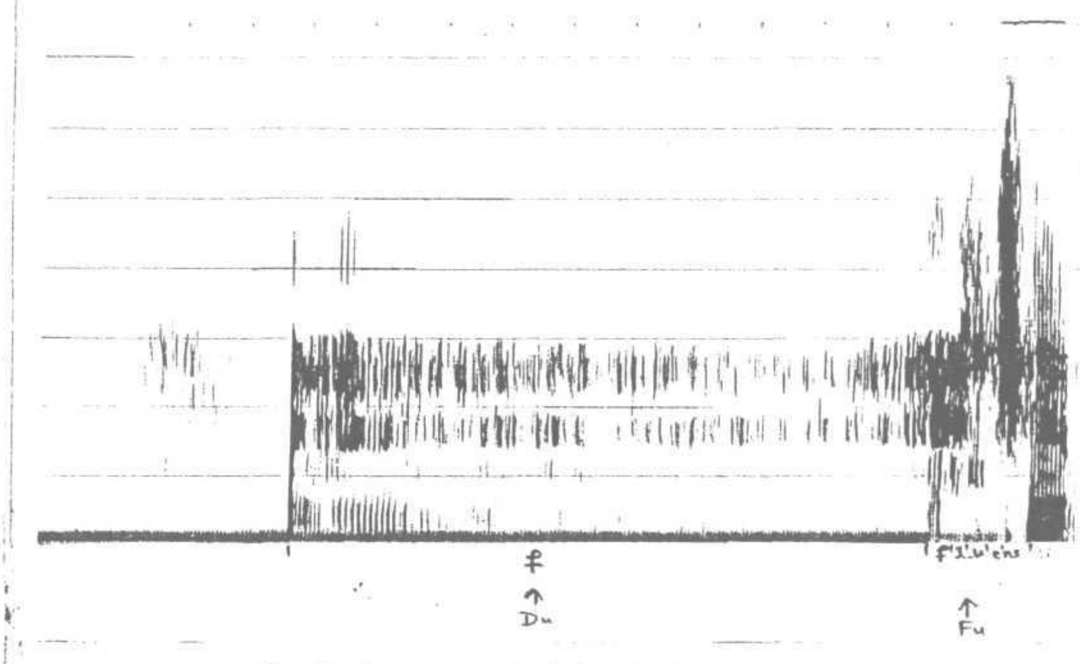


Fig-29: Spectrogram depicting lack of formant transition in the word |fluency| (lack of formant transition indicated by Du and arrow)

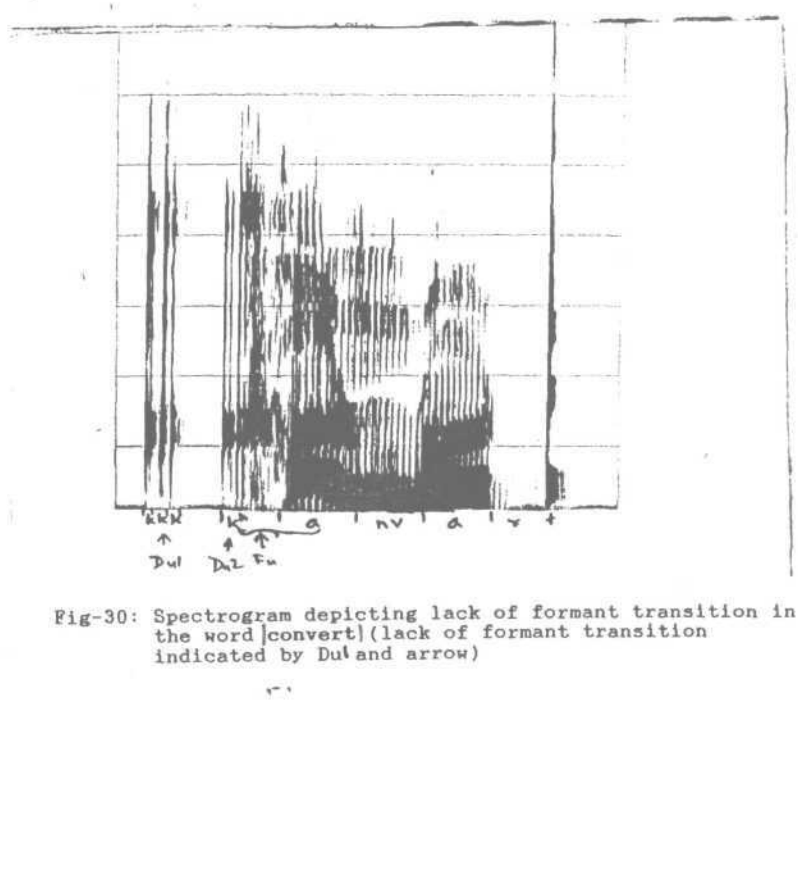


Fig-30: Spectrogram depicting lack of formant transition in the word |convert| (lack of formant transition indicated by Du1 and arrow) movements of formants which indirectly conveys about the articulatory movements. The absence of formant transition indicates that stutterers are unable to transit or move from one phoneme to another.

For instance, in the dysfluent utterance of "stammering" (spectrogram in Fig-18) the subject is not able to transit from the phoneme /t/ to /a/. This is clearly indicated by the presence of only a burst for /t/ and no transition to /a/.

b) Longer transition durations:

Three subjects S1, S3 and S4 had longer transition durations of F2 for dysfluent utterances than the corresponding fluent utterance. Spectrograms in Figs.31-36 depicts longer transition duration of F2 for dysfluent utterances. This indicates that the time required to move from one phoneme to another phoneme is long or the time lapse between the movement of articulators from one target to another is long.

Table-4 depicts the F2 transition durations and speed of transitions of fluent and dysfluent utterances. It could be noticed that longer transition durations generally tend to be associated with reduced speed of transitions.

While the F2 transition duration of fluent and dysfluent utterances was significantly different, the speed of transition between fluent and dysfluent utterances though different were not significant.

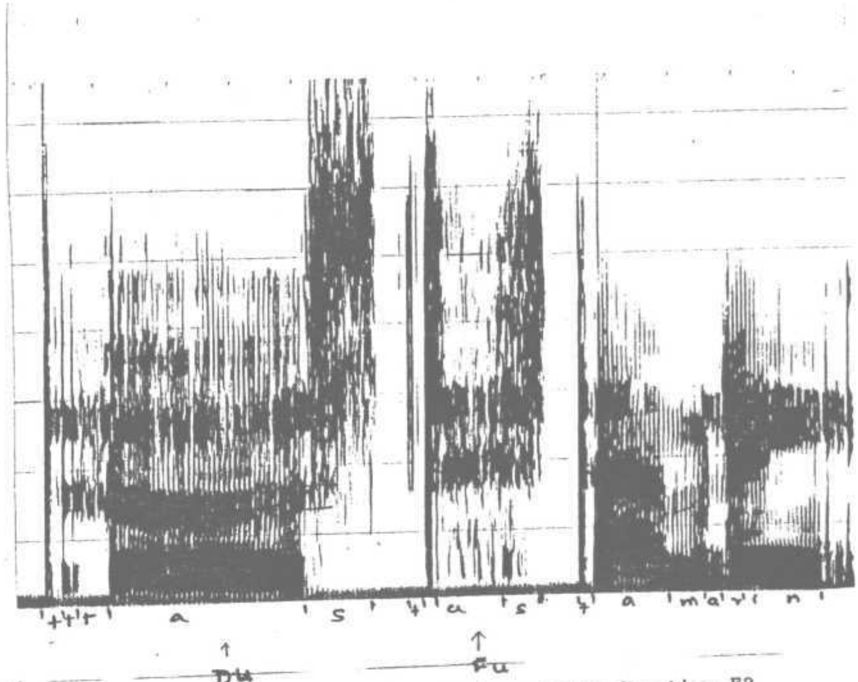


Fig-31: Spectrogram depicting longer transition duration F2 in the word |stammering| (longer transition duration of F2 indicated by Du and arrow)

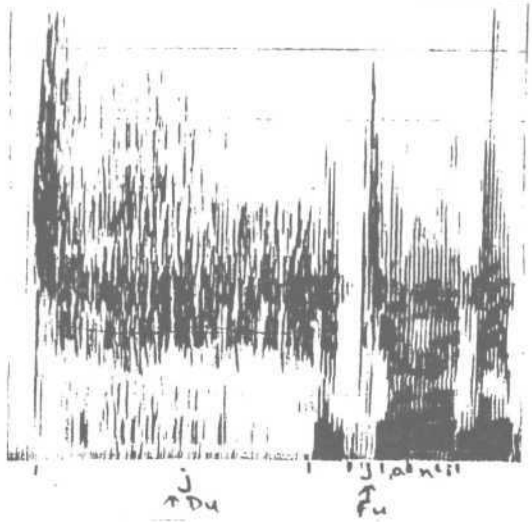


Fig-32: Spectrogram depicting longer transition duration F2 in the word |journey| (longer transition duration of F2 indicated by Du and arrow)

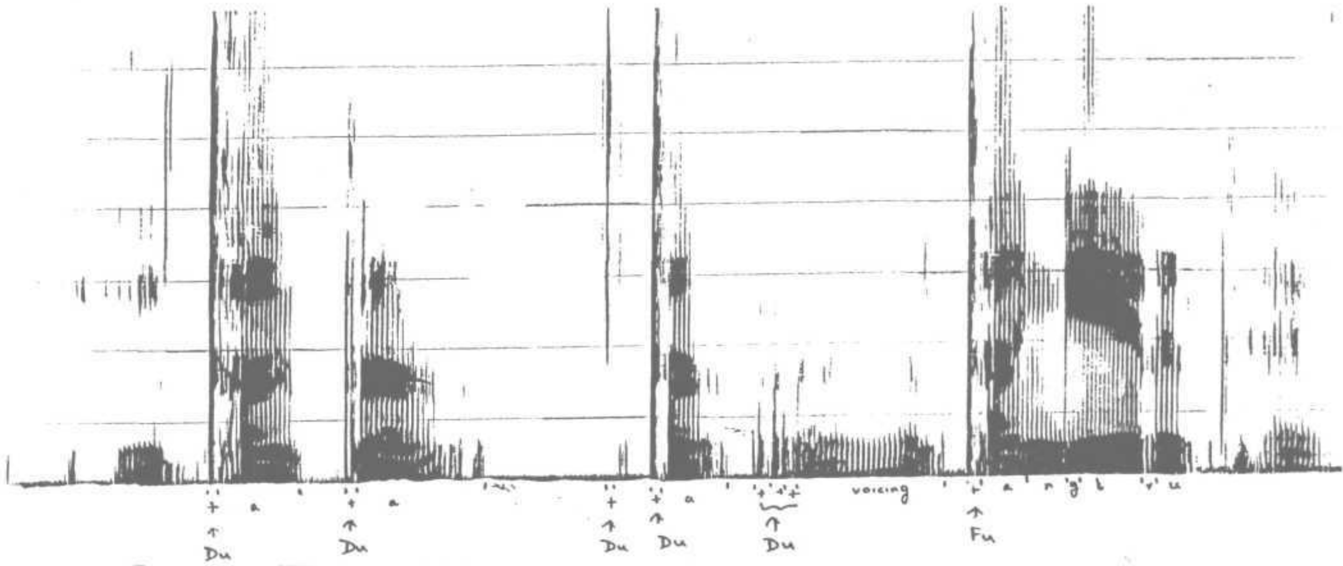


Fig-33: Spectrogram depicting longer transition duration F2 in the word |tangiyaru| (longer transition duration of F2 indicated by Du and arrow)

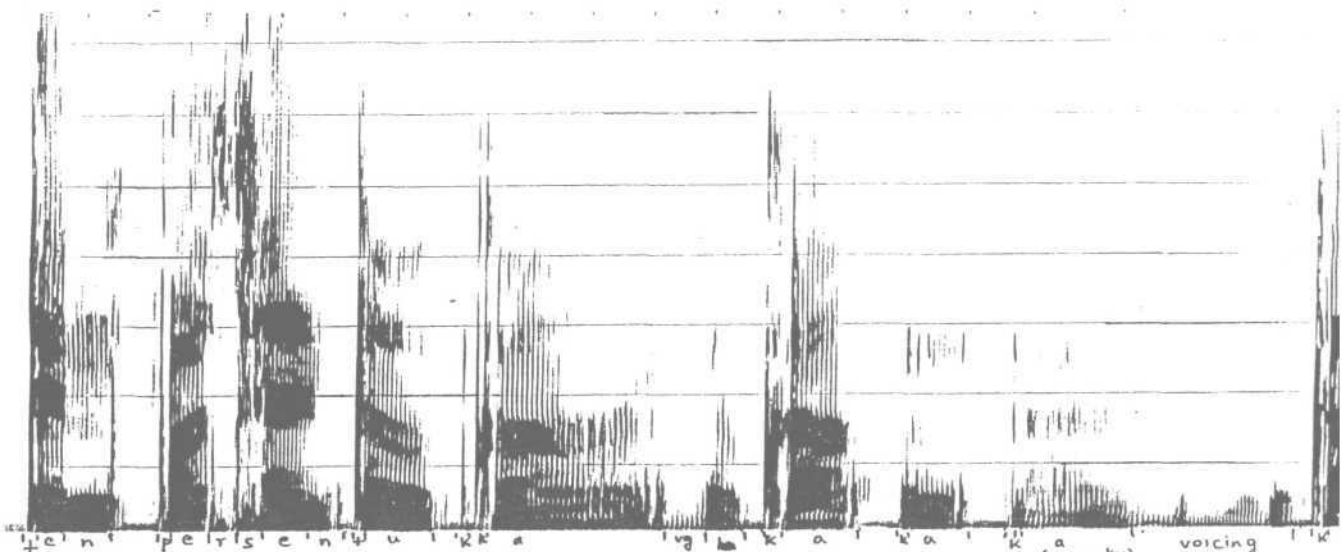


Fig-34: Spectrogram depicting longer transition duration F2 in the phrase |ten percentu kami| (longer transition duration of F2 indicated by Du and arrow)

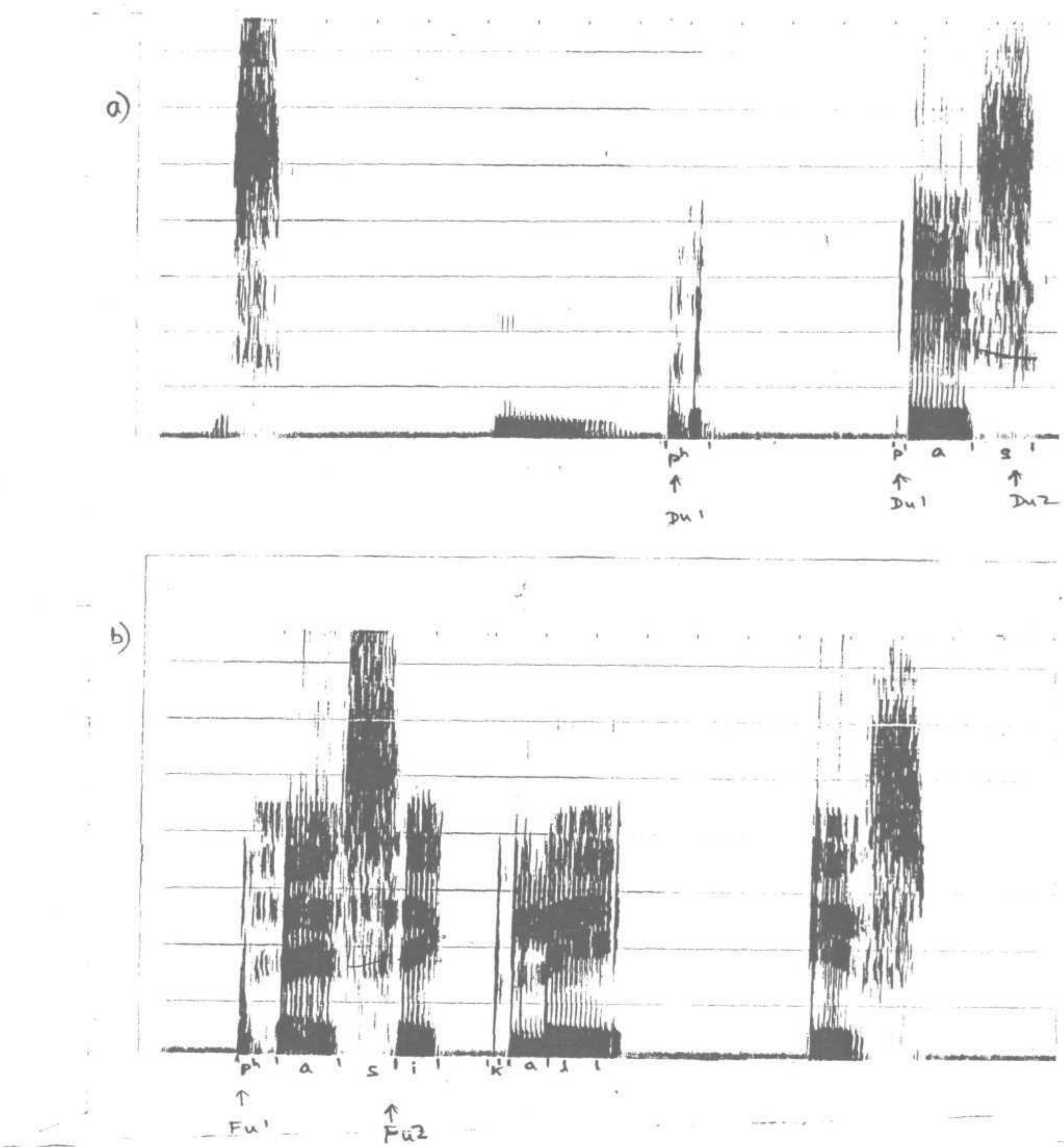


Fig-35: Spectrogram depicting longer transition duration F2 in the word /basically/ (longer transition duration of F2 indicated by Du1 and Du2 arrow)

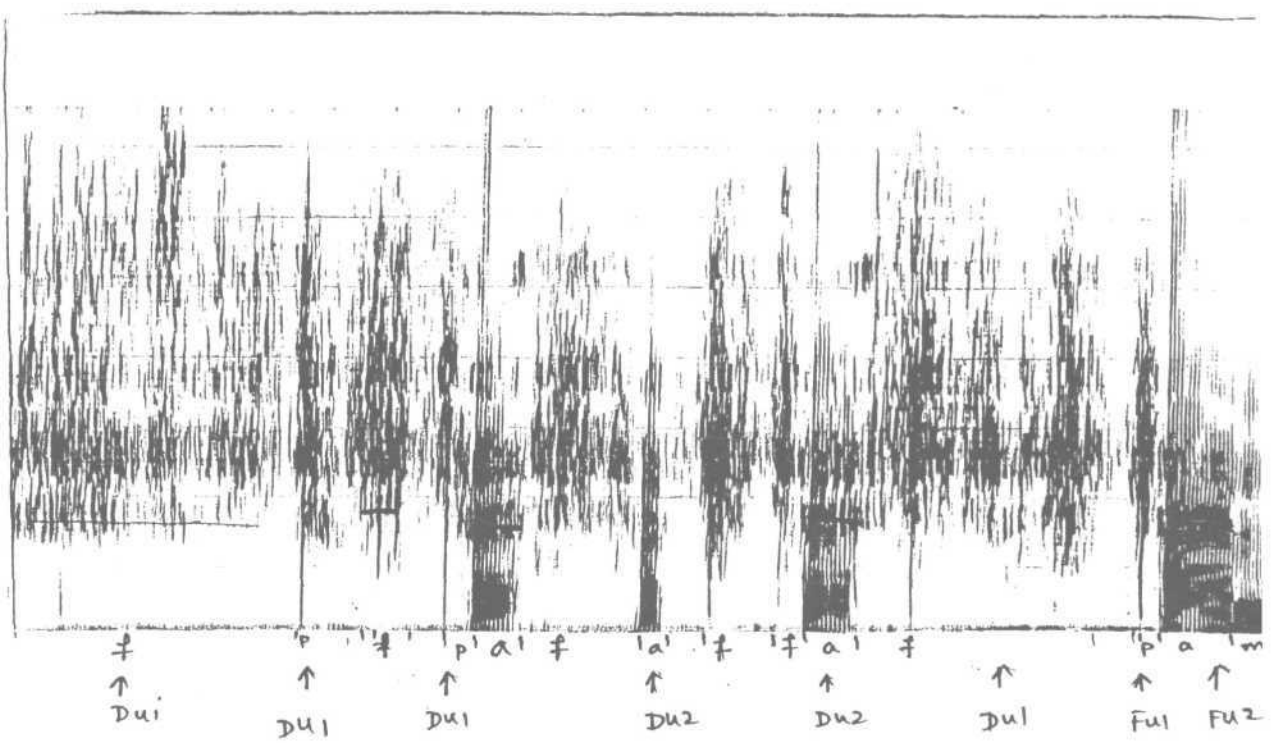


Fig-36: Spectrogram depicting longer transition duration F2 in the word /family/ (longer transition duration of F2 indicated by Du2 and arrow)

	Transition duration of F2 (msec)		Speed of transition of F2 (Hz/msec)	
	Dysfluent	Fluent	Dysfluent	Fluent
Mean	112.06	81.765	3.106	6.085
F value (ANOVA)	1.145		7.28	

TABLE-4: Mean and F value for transition duration of F2 (msec) and speed of transition of F2 Hz/msec.

c) Shorter Transition duration:

Shorter transition duration of F2 for dysfluent utterances was found in three subjects S1, S2 and S4. In the spectrograms in Figs.37-41 the time between the onset of transition of F2 to the steady state of F2 in vowel of dysfluent utterance is shorter than that of fluent utterance. This indicates shorter time lapse between the movement of articulation from one target to another.

d) Inappropriate transition:

Two of the four stutterers S2 and S3 had inappropriate transitions for dysfluent utterances. This has been depicted in spectrograms in Figs. 42 and 43. In spectrogram in Fig-42 the subject was unable to transit from /s/ to /i/ whereas the fluent utterance clearly indicates a smooth transition from /s/ to /i/. Similarly, in the dysfluent utterance depicted in spectrogram in Fig-43 there was inappropriate transition from /f/ to /a/. This implies that the articulators mistargeted the production of the following vowel /a/.

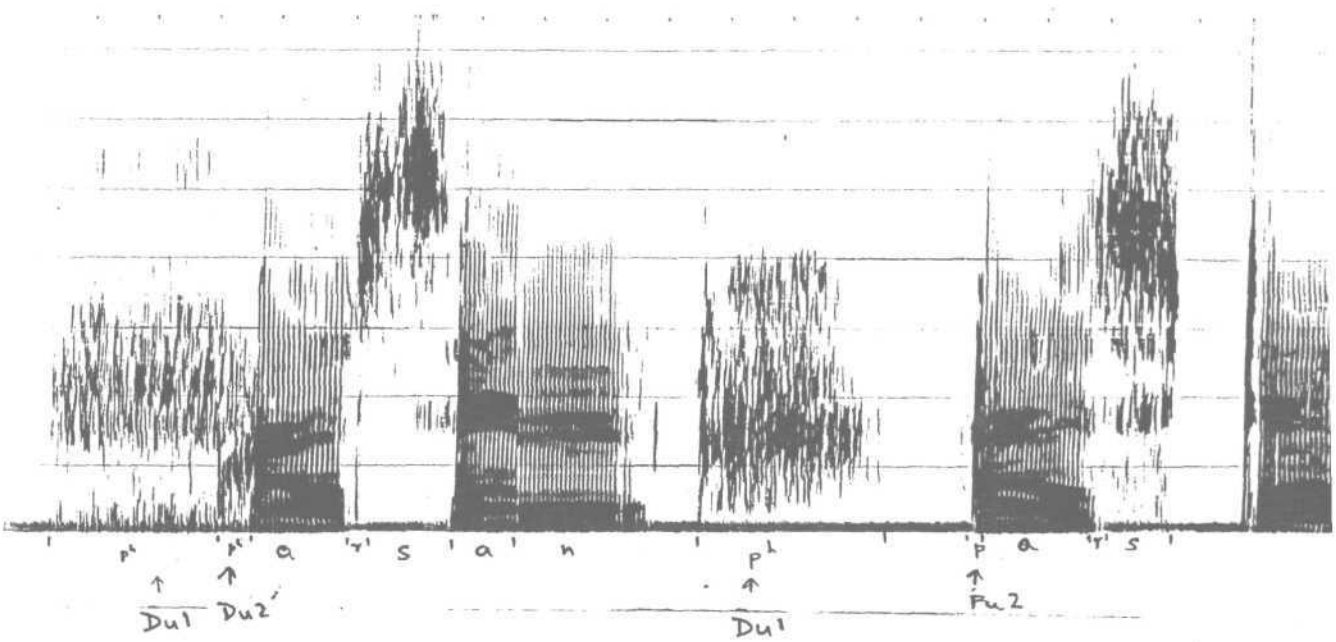


Fig-37: Spectrogram depicting shorter transition duration F2 in the word |person|(shorter transition duration of F2 indicated by Du2 and arrow)

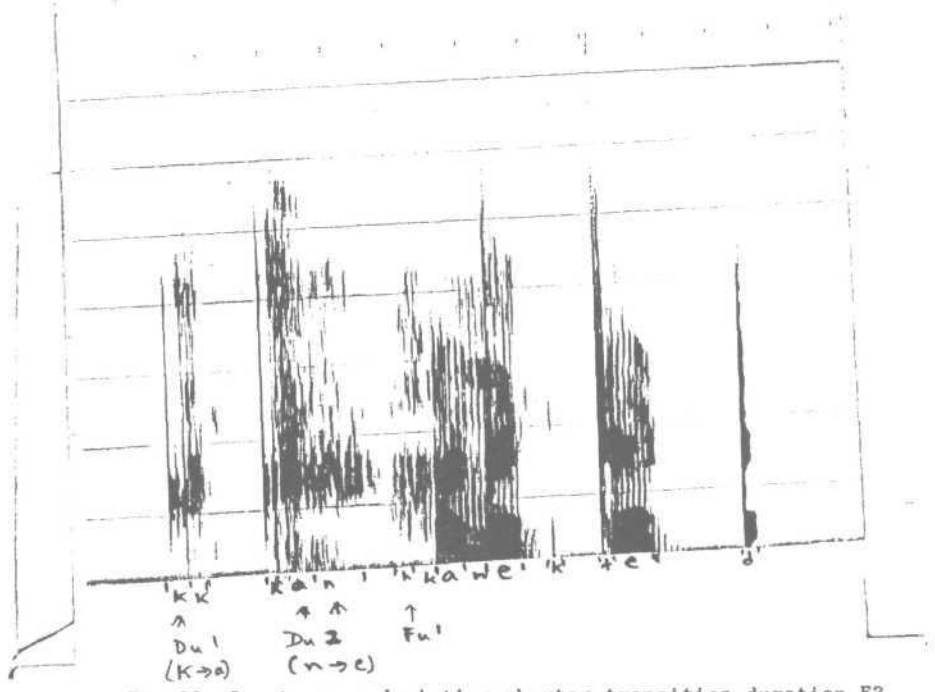


Fig-38: Spectrogram depicting shorter transition duration F2 in the word |connected|(shorter transition duration of F2 indicated by Du2 and arrow)

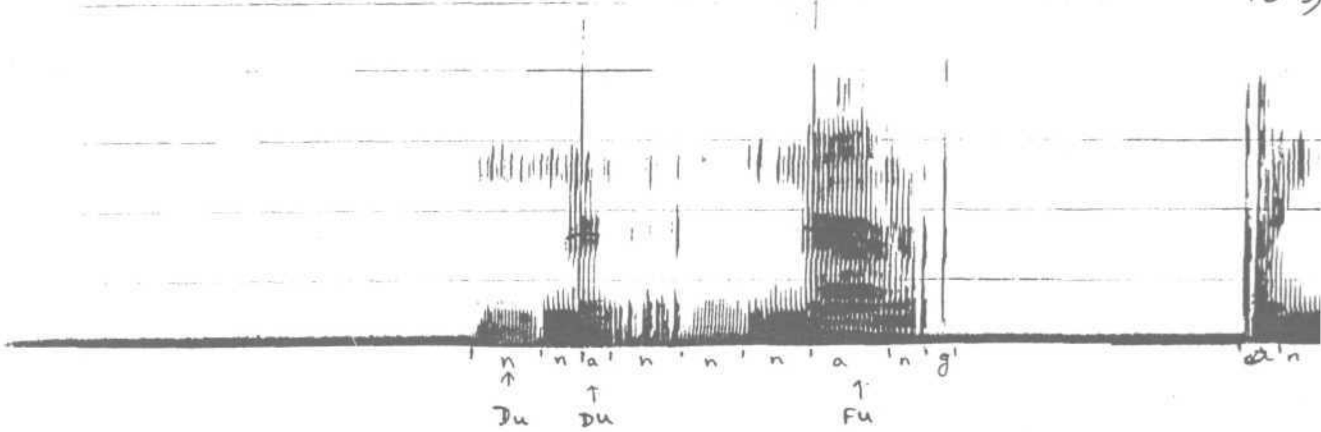


Fig-39: Spectrogram depicting shorter transition duration F2 in the phrase|nanage anubhava|(shorter transition duration of F2 indicated by Du and arrow)

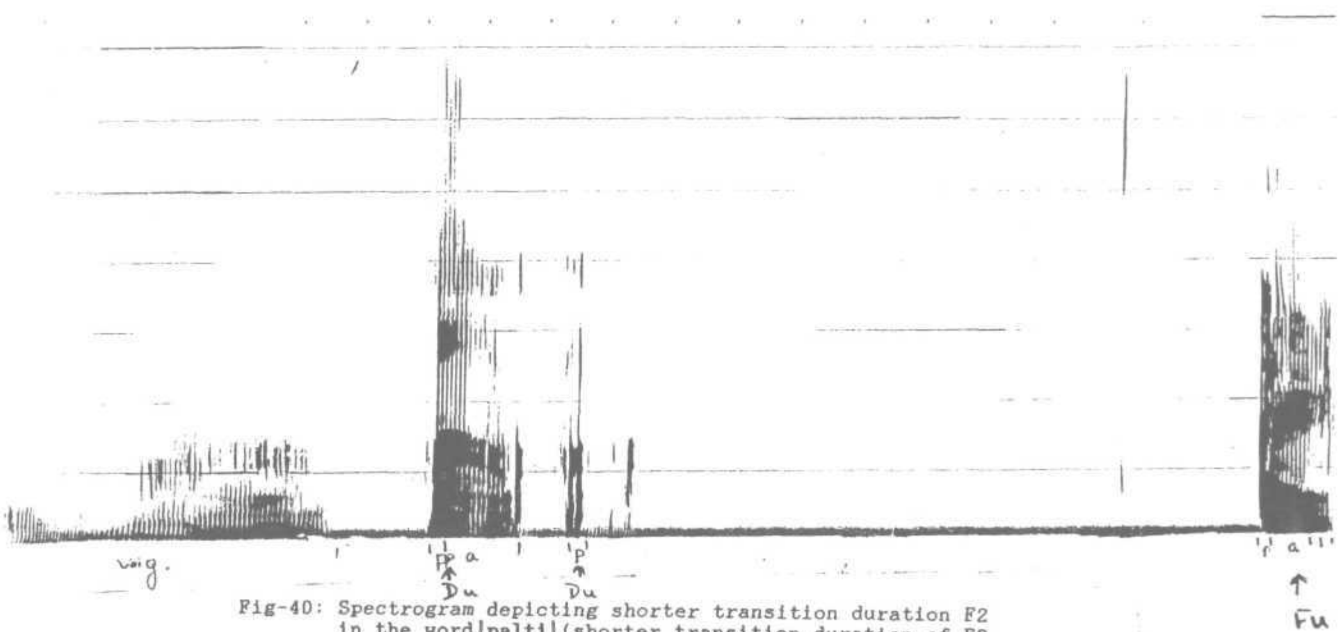


Fig-40: Spectrogram depicting shorter transition duration F2 in the word|palti|(shorter transition duration of F2 indicated by Du and arrow)

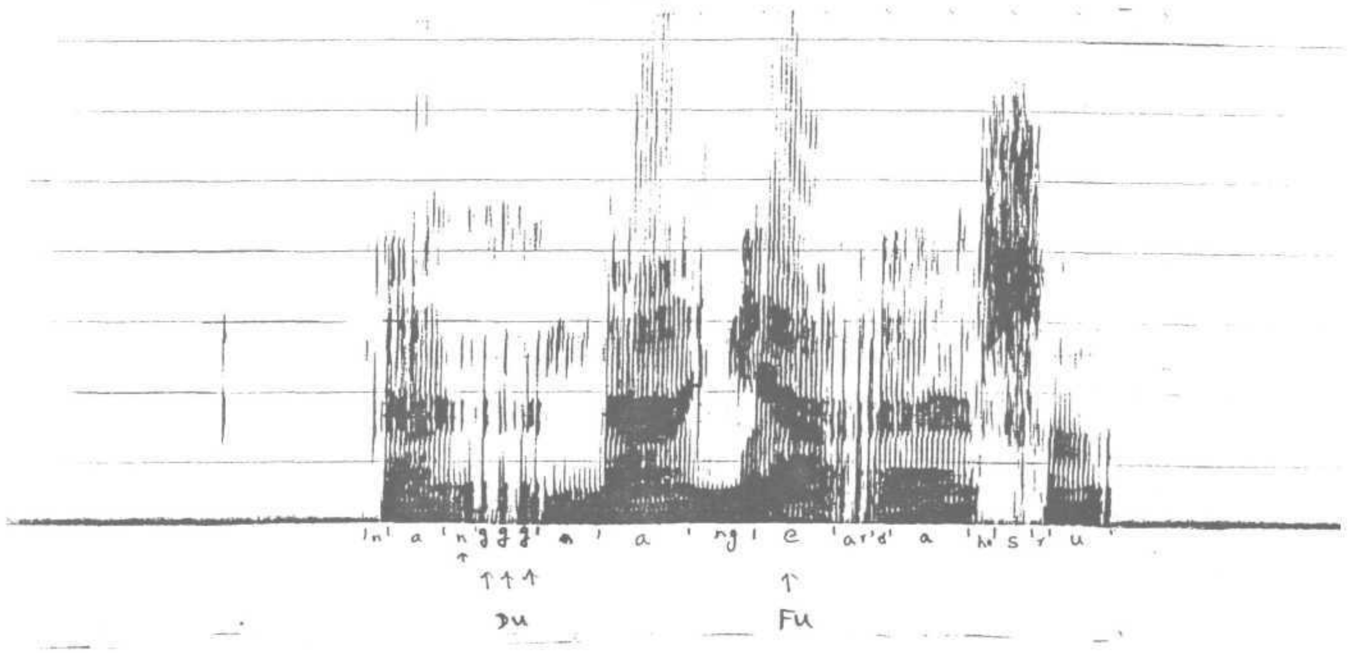


Fig-41: Spectrogram depicting shorter transition duration F2 in the phrase|nange arda hesru|(shorter transition duration of F2 indicated by Du and arrow)

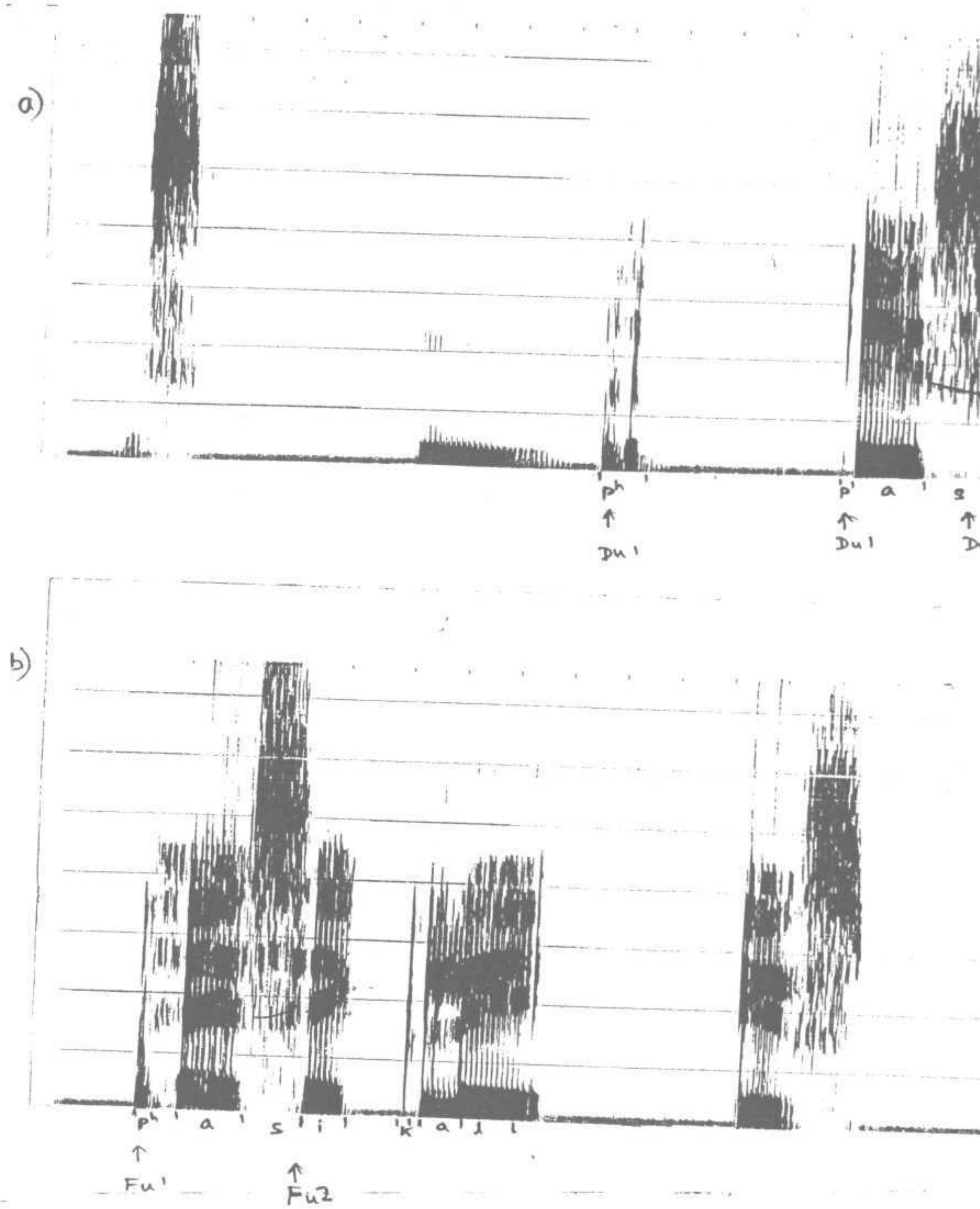


Fig-42: Spectrogram depicting inappropriate transition in
a & b the word |basically| (inappropriate transition
indicated by Du2 and arrow)

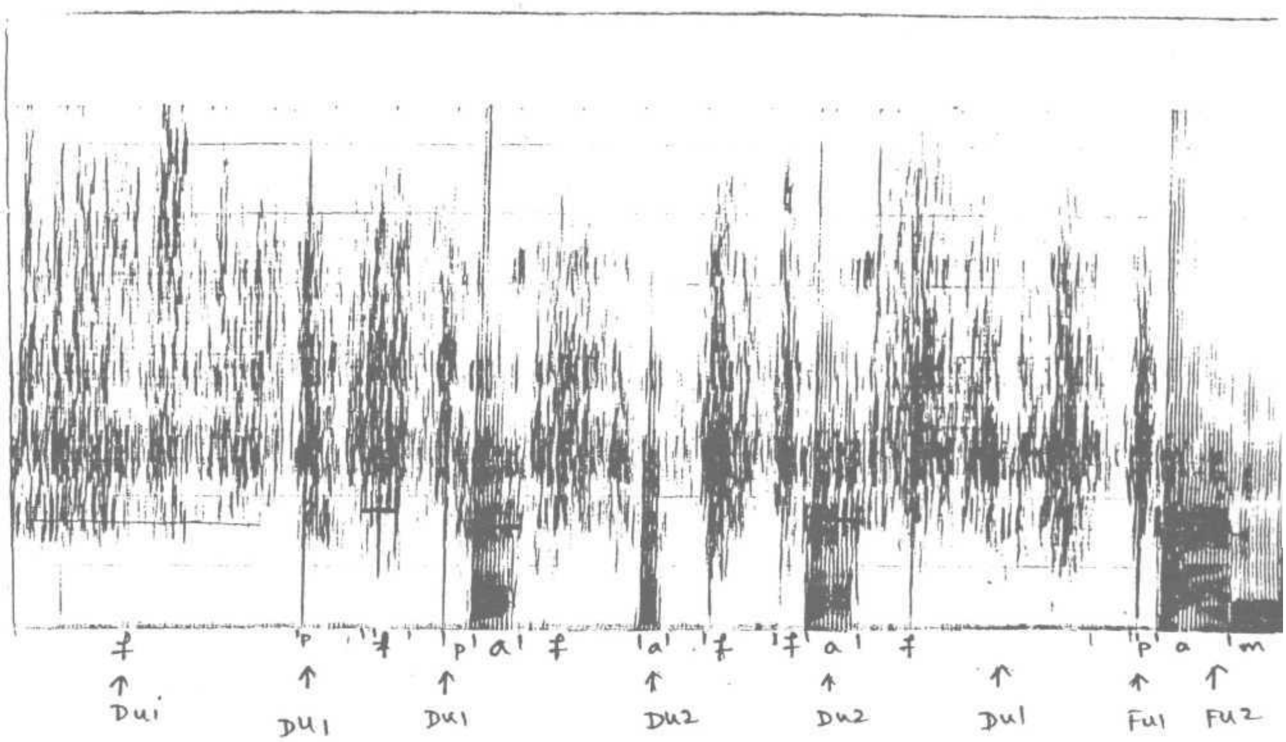


Fig-43: Spectrogram depicting inappropriate transition in the word /family/ (inappropriate transition indicated by Du1 and arrow)

The results obtained are in agreement with the studies of Stromsta (1965), Agnello et al (1974) and Van Riper (1982) who have reported absence of formant transitions in the dysfluent utterances of stutterers. Starkweather and Meyers (1979) and Zimmermann (1980a) have reported longer transition durations in the dysfluent utterance of stutterers. Healey et al (1981) based on the spectrographic study found that adult stutterers were slower in completing the transitions from frication onset to peak amplitude during the production of the /s/ phoneme. The same observation can be made in spectrogram in Fig-35. The speed of transition of F2 from /s/ and /i/ is 1.2Hz/msec for dysfluent utterance and 8.3Hz/msec for fluent utterance. Also, shorter transition times was indicated in the study of Mohan Murthy (1988). The results are also in consonance with the study of Howell et al (1987) who, based on the analysis of thirty dysfluent episodes revealed that the speech lacked normal formant transition.

These different errors of coarticulation imply the variability found in the stutterers. While at one moment a stutterer is unable to move the articulator from one position of another, at another moment he takes longer time to move his articulator at still another moment shorter time is taken and at other moment the articulators are unable to move to the place of the target phoneme.

3) Addition or interjection:

Interjection like "urn" or "a" were depicted by subjects S1 and S4 (spectrogram 44-50). S1 exhibited glottal clicks in between the words (spectrogram in Fig-44) phonemes like /s/ were added in between the words which could be either a placement error or an addition (spectrogram in Fig-48a,b &c).

4) Errors in manner of articulation:

All the four stutterers exhibited manner of articulation errors (spectrograms 51-57). All these errors were present in the initial subsegment of the dysfluent utterance and were of six different types (Table-5).

a) Devoicing the initial subsegment of dysfluent word.
b) Voicing the initial subsegment of dysfluent word.
c) Substitution of stop for fricative.
d) Substitution of fricative for stop.
e) Substitution of stops for nasals.
f) Substitution of stop for vowels.

TABLE-5: Errors of manner of articulation.

a) Devoicing the initial subsegment of dysfluent utterance:

Devoicing of the initial subsegment of dysfluent utterance was seen in three words /bangalore/ (spectrogram in Fig-51), /diesel/ (spectrogram in Fig-52) and /basically/ (spectrogram in Fig-53). In the spectrogram in Figs.51 and 53 devoicing of the initial phoneme /b/ is indicated by the absence of voiced bars. Similarly, in the spectrogram in Fig-52 the initial phoneme /d/ was substituted by its voiceless cognate /t/.

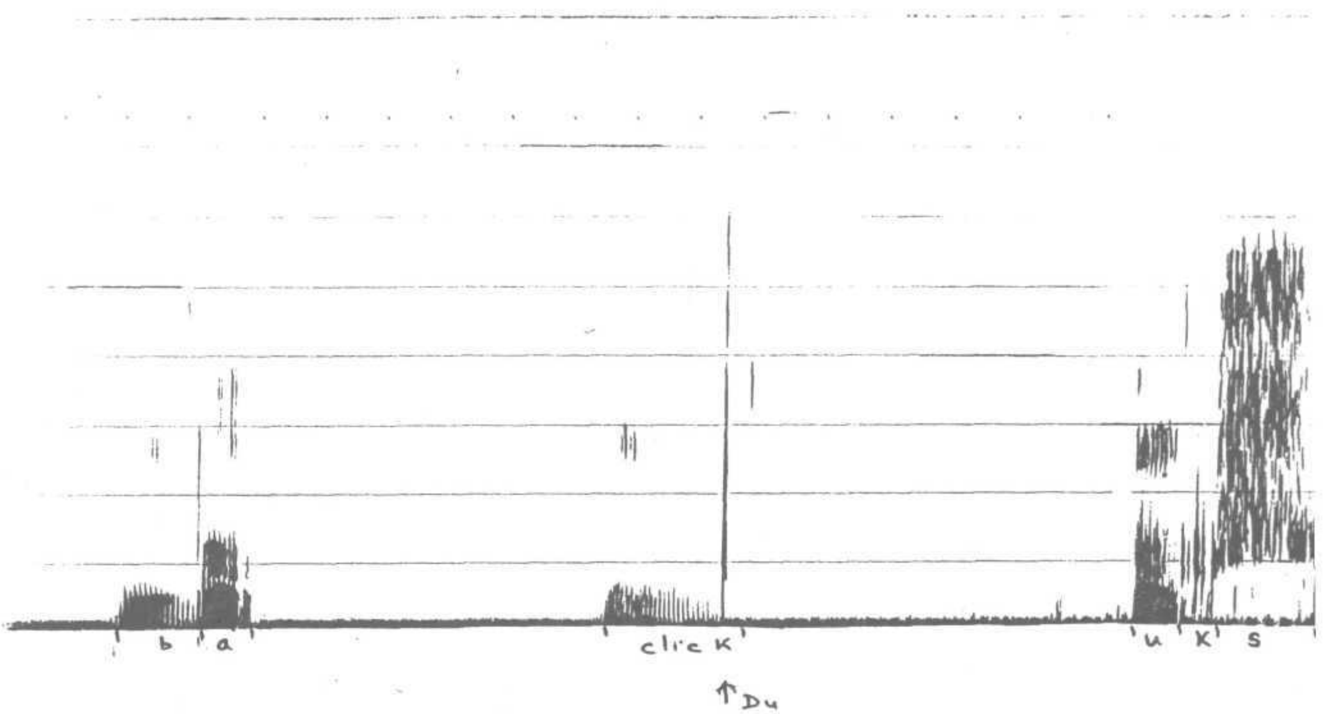


Fig-44: Spectrogram depicting addition of glottal stops within the word /books/ (addition is indicated by Du and arrow)

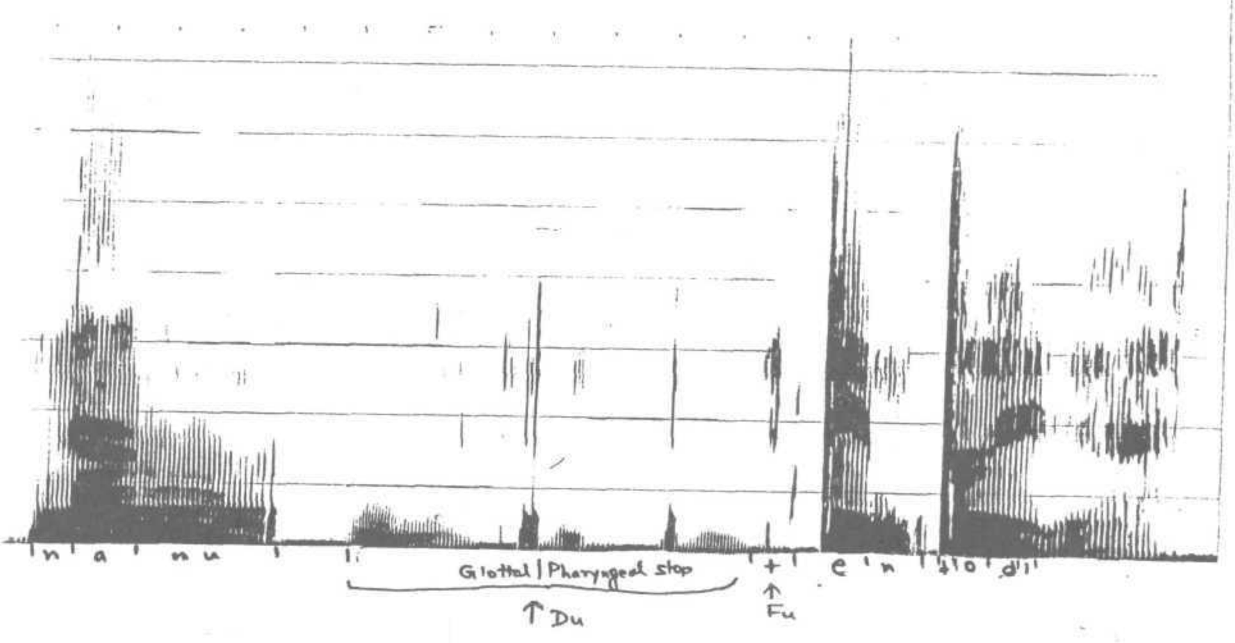


Fig-45: Spectrogram depicting addition of click within the phrase /nanu tenth odidini/ (addition is indicated by Du and arrow)

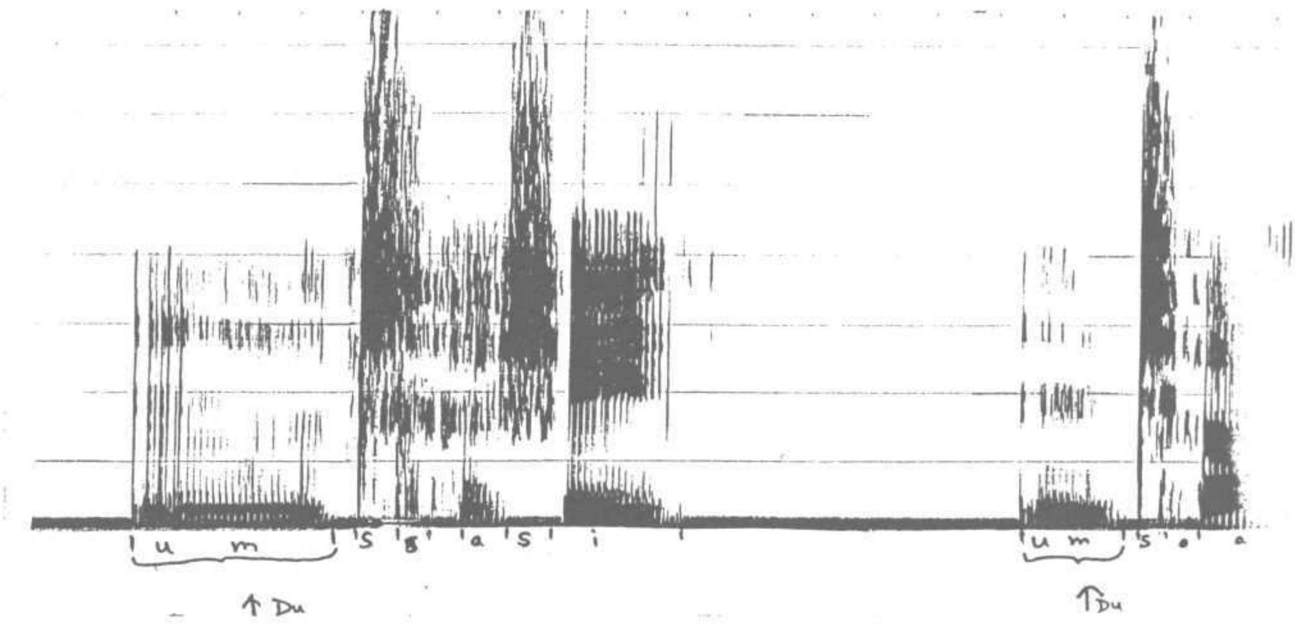


Fig-46: Spectrogram depicting addition of 'um' in the word |sasi|(addition is indicated by Du and arrow)

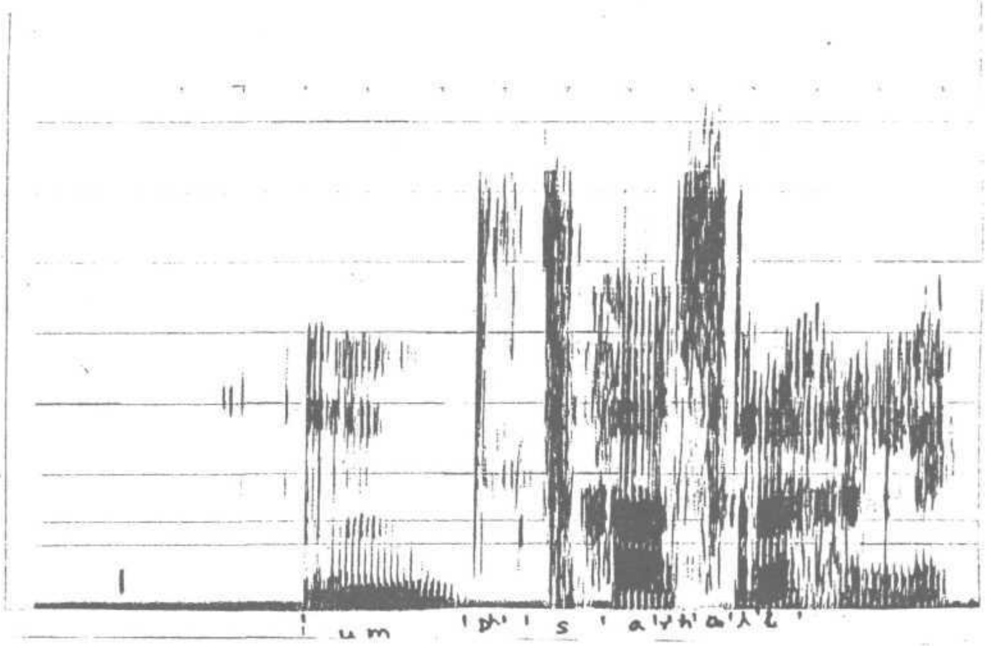


Fig-47: Spectrogram depicting addition of 'um' in the word |dasarahalli|(addition is indicated by Du and arrow)

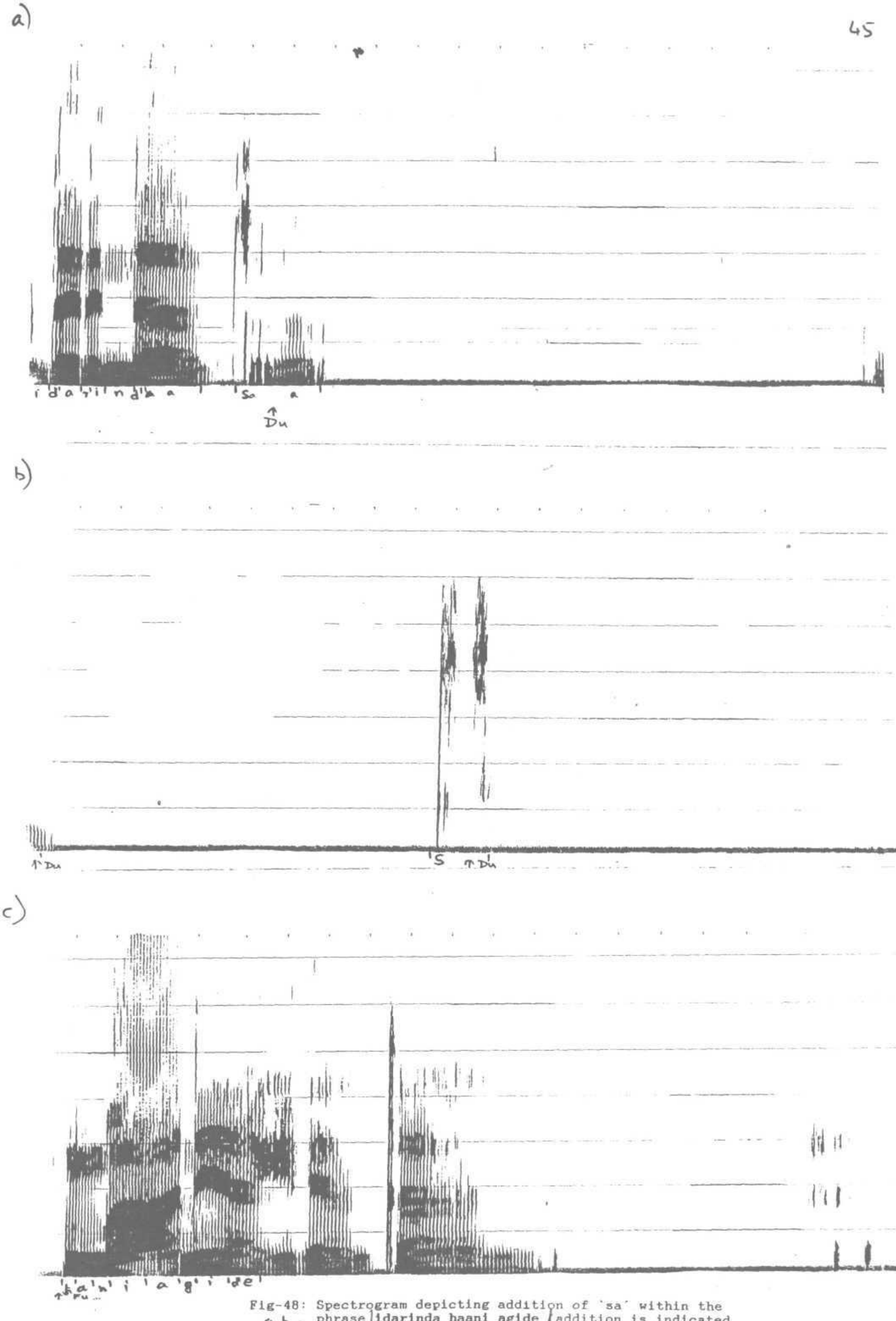


Fig-48: Spectrogram depicting addition of 'sa' within the
a, b, c phrase [idarinda haani agide [addition is indicated
by Du and arrow)

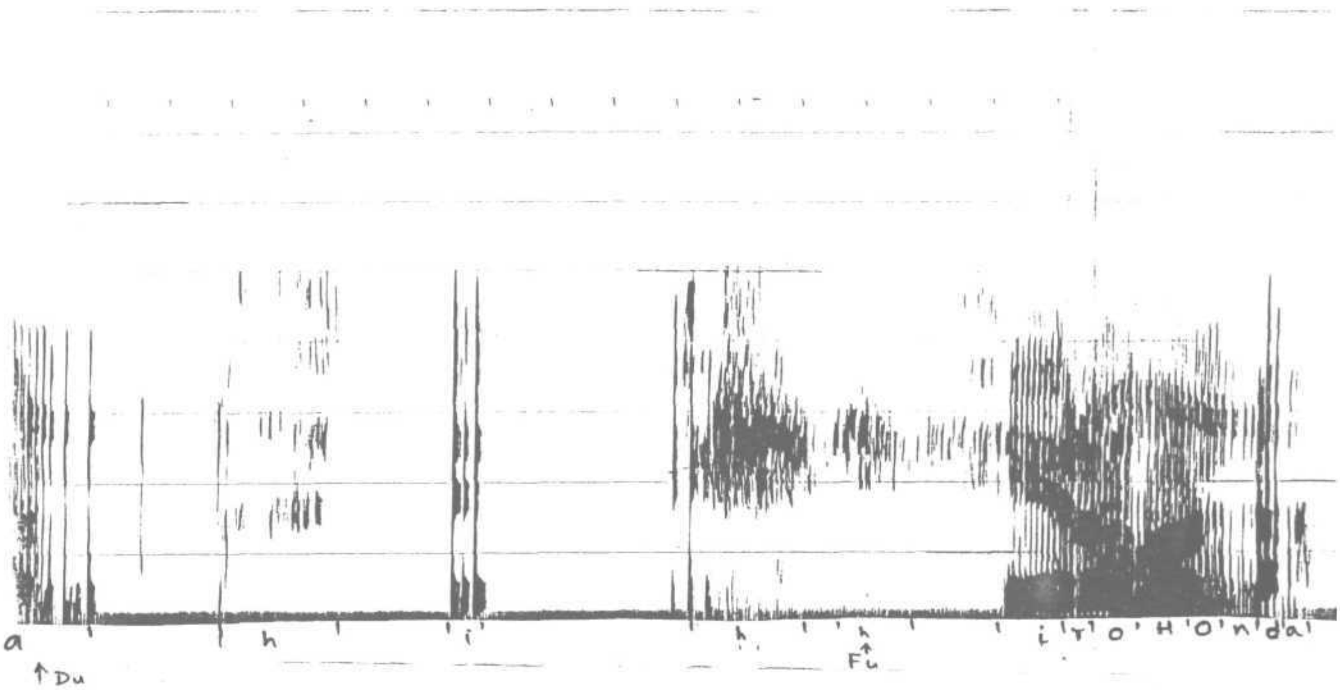


Fig-49: Spectrogram depicting addition of 'a' within the word/hero honda/ (addition is indicated by Du and arrow)

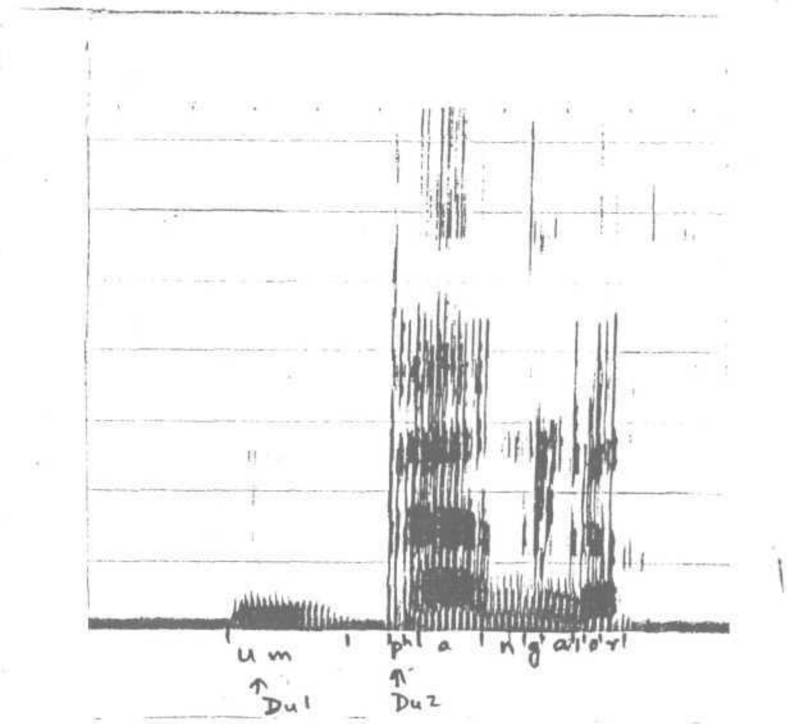


Fig-50: Spectrogram depicting addition of 'um' in the word |Bangalore/(addition is indicated by Du1 and arrow)

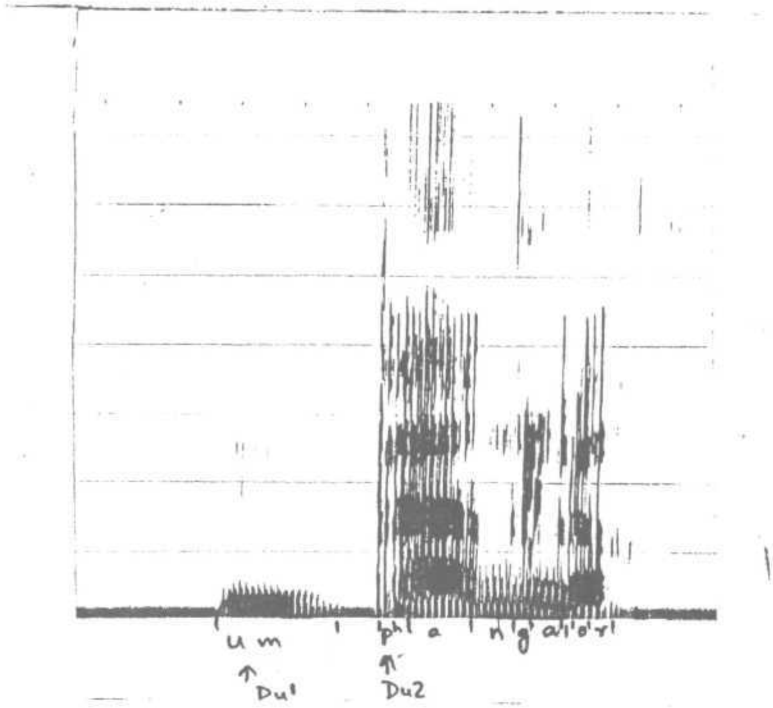


Fig-51: Spectrogram depicting devoicing of the initial subsegment of the word /Bangalore/ (devoicing is indicated by Du2 and arrow)

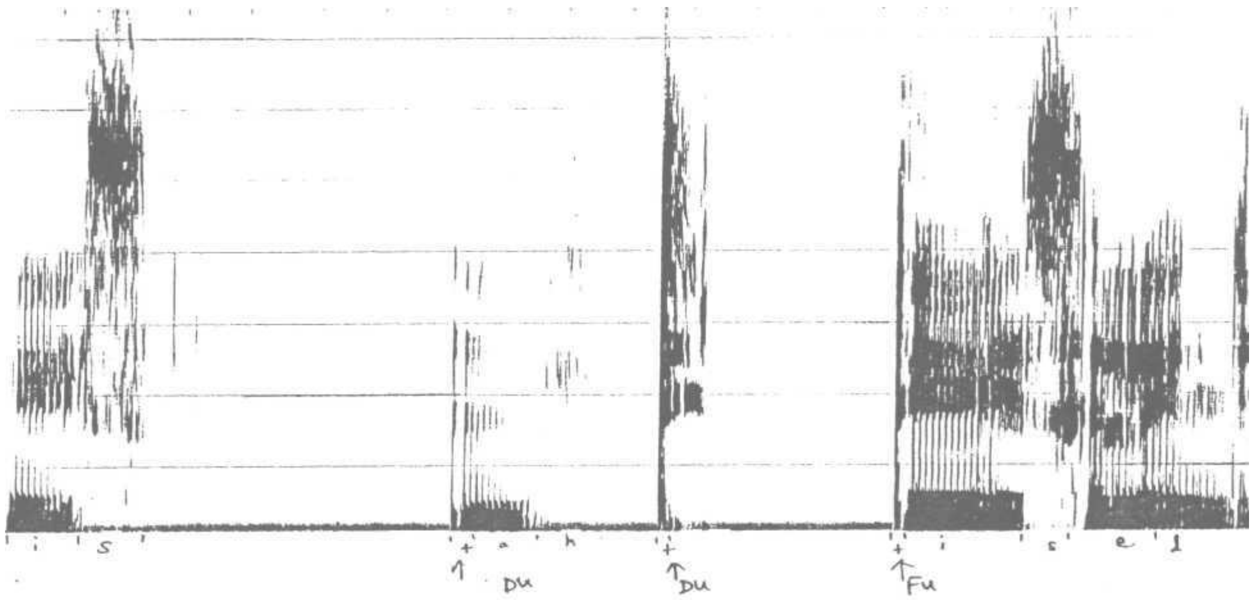


Fig-52: Spectrogram depicting devoicing of the initial subsegment of the word)diesel ^(devoicing is indicated by Du and arrow)

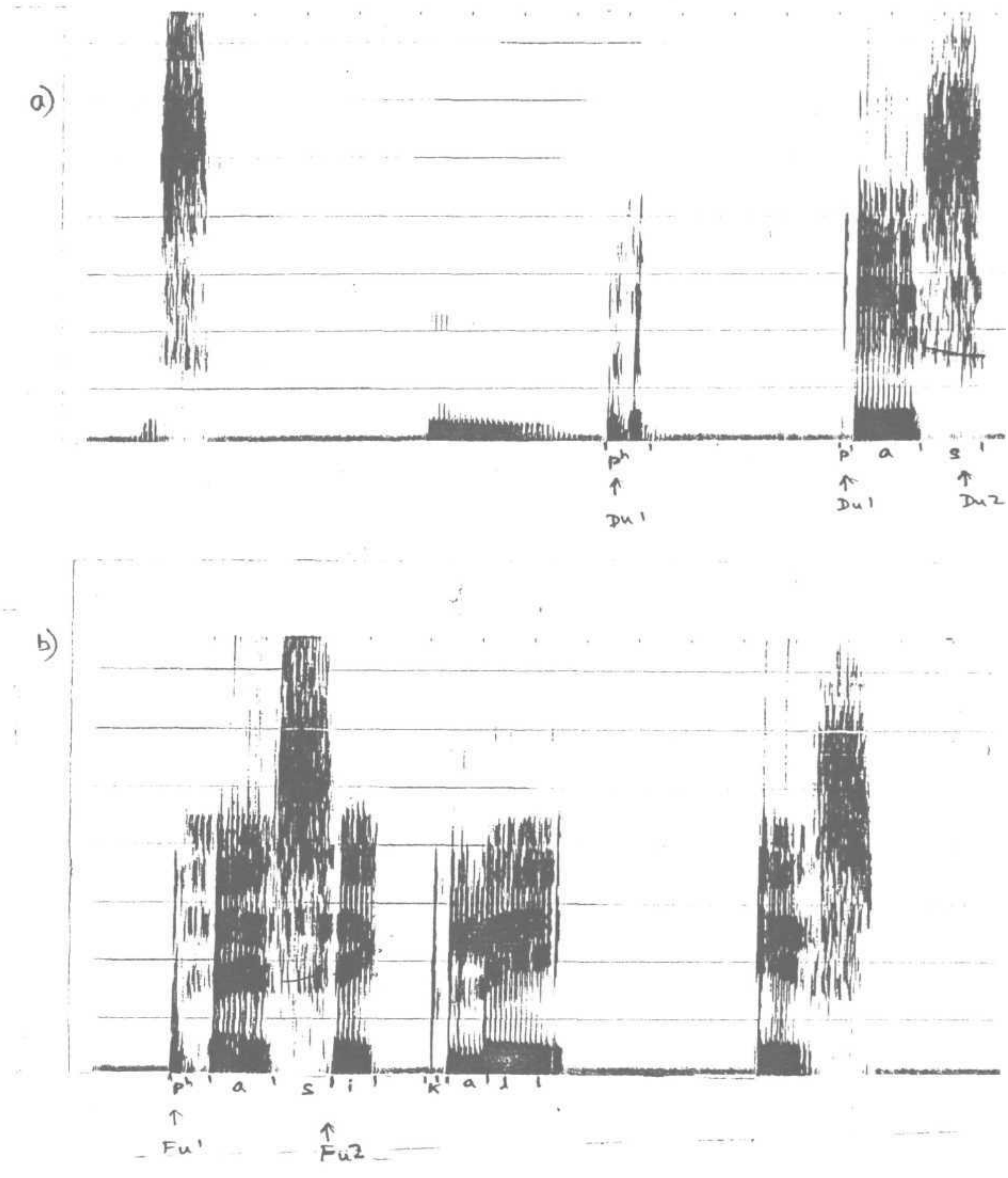


Fig-53: Spectrogram depicting devoicing of the initial
a & b subsegment of the word /basically/ (devoicing is
indicated by Du and arrow)

b) Voicing the initial subsequent of dysfluent word:

Spectrogram in Fig-54 represents the utterance /kalodiodu/. The dysfluent utterance is /g/ which is the voiced cognate of the initial phoneme /k/. In the spectrogram voice bars and bursts are evident. This is also indicated by the lag VOT.

c) Substitution of stops of fricatives:

Subjects S2 and S3 substituted stops for fricatives. This could be observed for the utterances "full down" and "family" depicted in the spectrograms in Figs.55 and 56 respectively. In both these utterances the initial phoneme /f/ is substituted by the stop /p/. Instead of producing a minimal constriction at the level of lips there was a complete closure of lips leading to production of a bilabial stop. In other words, there was excessive muscular activity and forceful articulatory movement leading to the production of a bilabial stop.

d) Substitution of fricatives for stops:

Subject S2 in one instance substituted fricative sound /f/ for the stop /p/ in the utterance /problem/ (spectrogram in Fig-57). There was a minimal constriction at the level of lips instead of complete closure.

e) Substitution of stops for nasal:

Spectrograms in Fig-58a, b & c depict the utterance "mini computer". As can be observed in this spectrogram, the

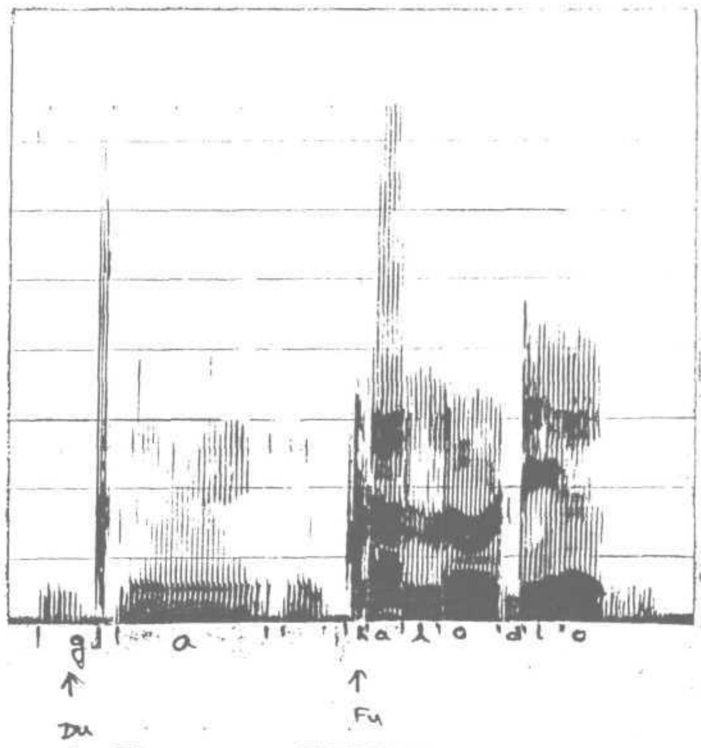
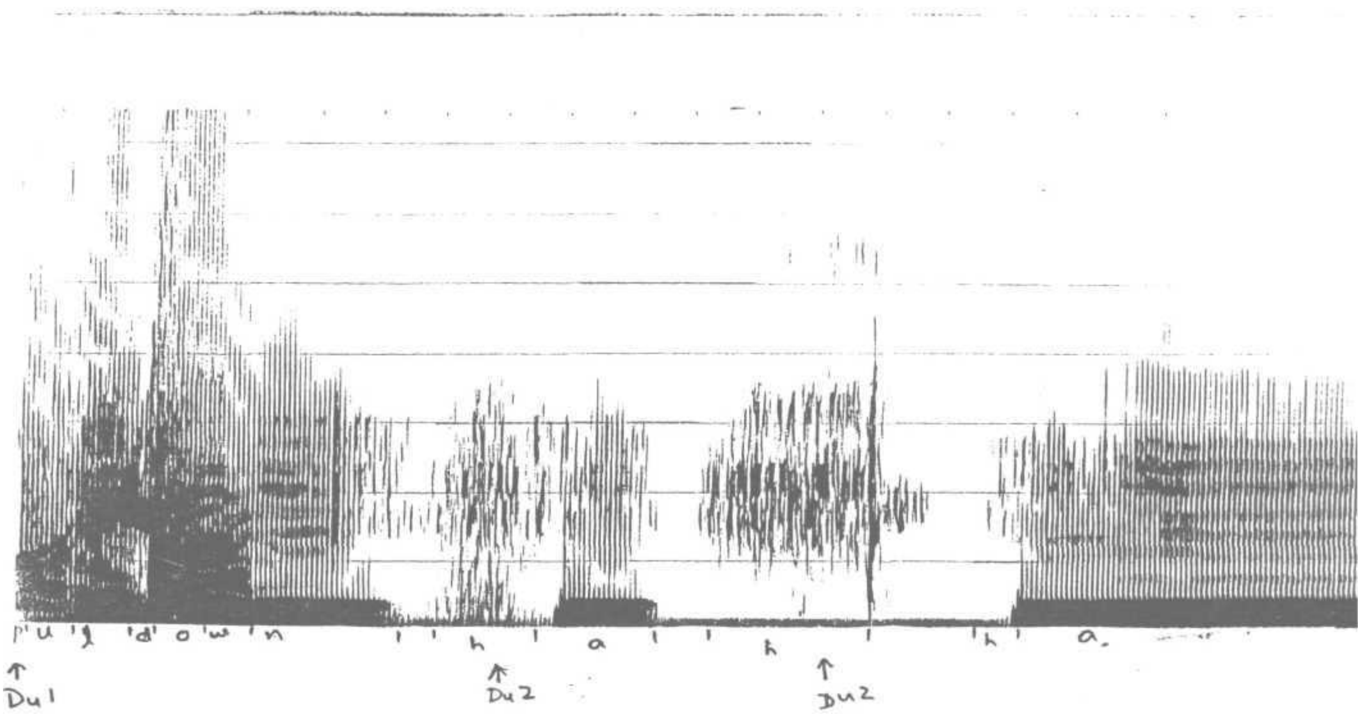


Fig-54: Spectrogram depicting voicing of the initial subsegment of the word |kalodiyedu| (voicing is indicated by Du and arrow)



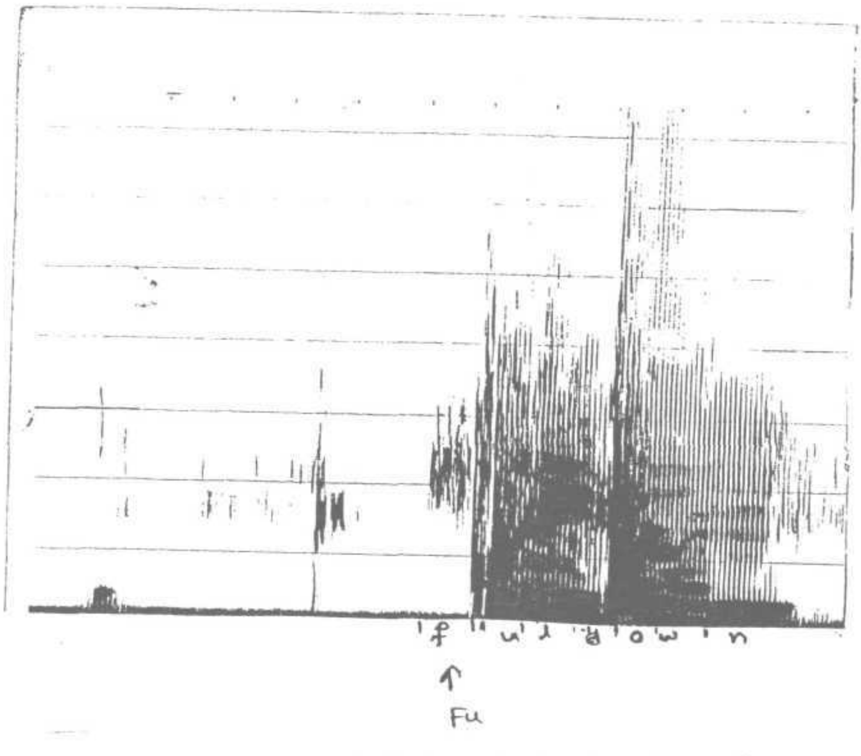


Fig-55: Spectrogram depicting substitution of stop for fricative in the word |full down| (substitution is indicated by Du and arrow)

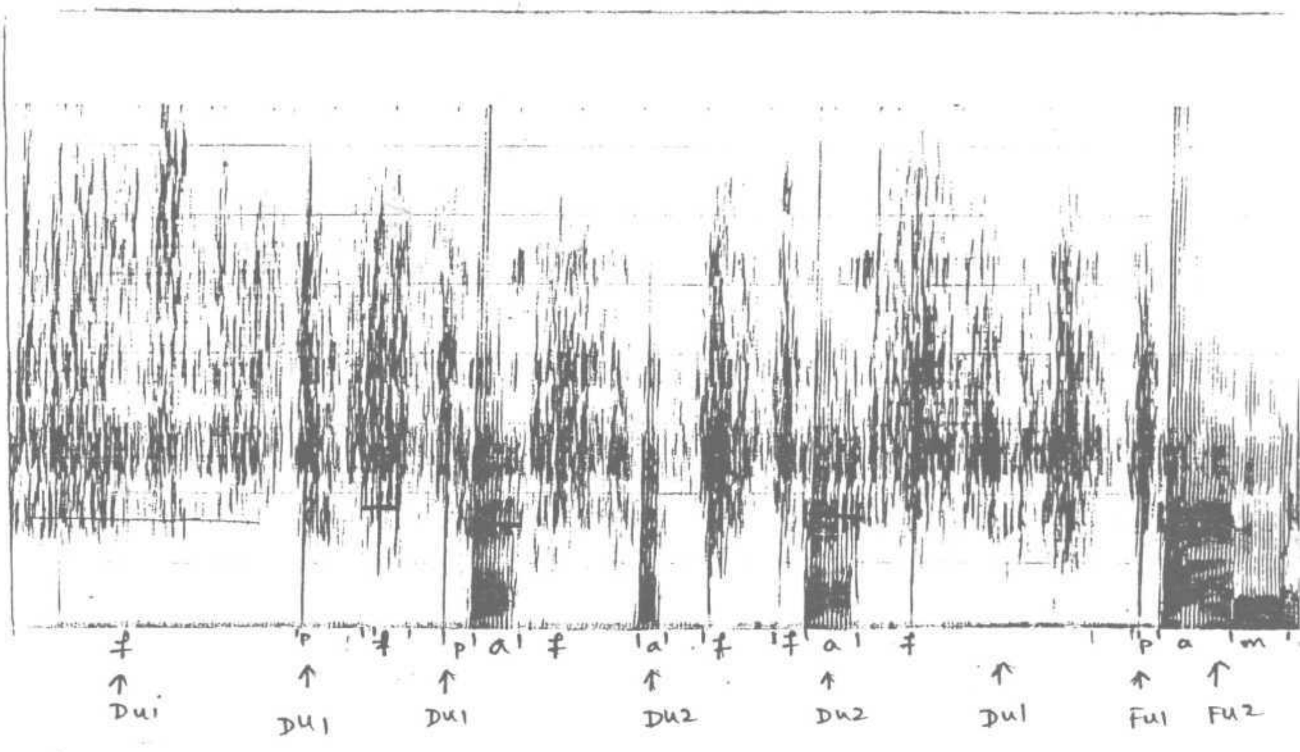


Fig-56: Spectrogram depicting substitution of stop for fricative in the word |family| (substitution is indicated by Du1 and arrow)

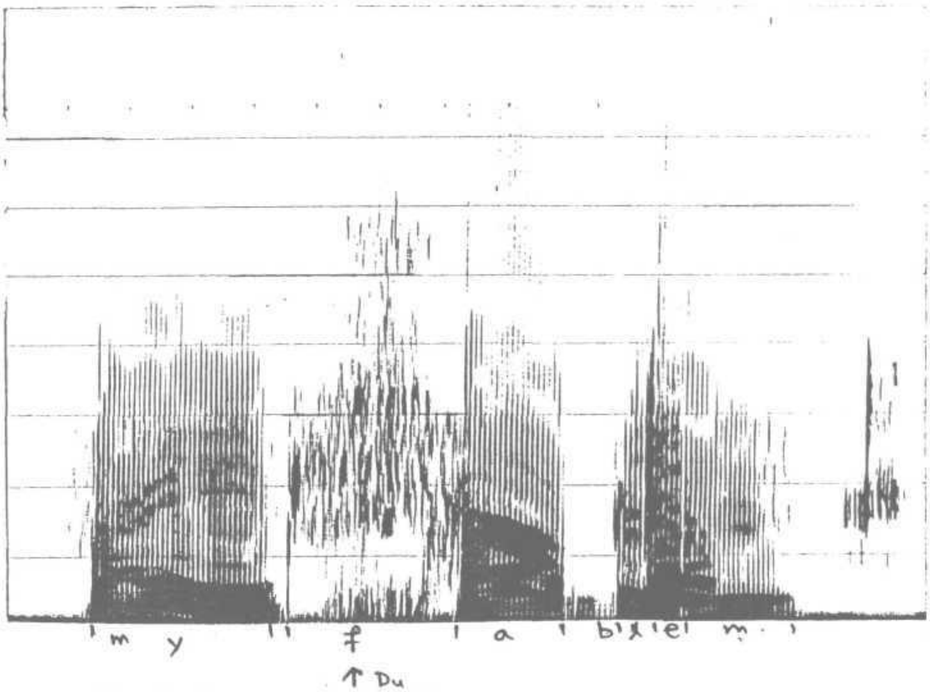


Fig-57: Spectrogram depicting substitution of fricative for stop in the word [problem] (substitution is indicated by Du and arrow) subject had dysfluent utterances comprising of voiced and voiceless bilabial stops. This error can be explained as due to miscoordination of the velopharyngeal system. The velopharyngeal port which is opened for the production of /m/ was inappropriately opened during the dysfluent utterance.

f) Substitution of stop for vowel:

This kind of error is depicted in spectrogram in Fig-59. The actual utterance was "avanu" but the subject produced "gavanu". The spectrogram clearly indicates a burst in addition to the voice bars indicating that the vowel manner is substituted by the stop manner.

These results are in consonance with the results of Borden and Aronson (1987) who reported errors of voicing, Shapiro (1980) who reported excessive muscular activity, Webster (1974) who indicated forceful articulatory patterns and Van Riper (1982) who noticed inappropriate articulatory gestures.

It could be observed that the stutterer has problem in making appropriate constriction for the production. While at some instances, the constriction areas were less than necessary, at some other constriction areas were more than necessary.

5) Errors in place of articulation:

Place of articulation errors were recorded in the dysfluent utterances produced by S1 and S2. Spectrograms in Figs.60 and 61 represent place of articulation errors.

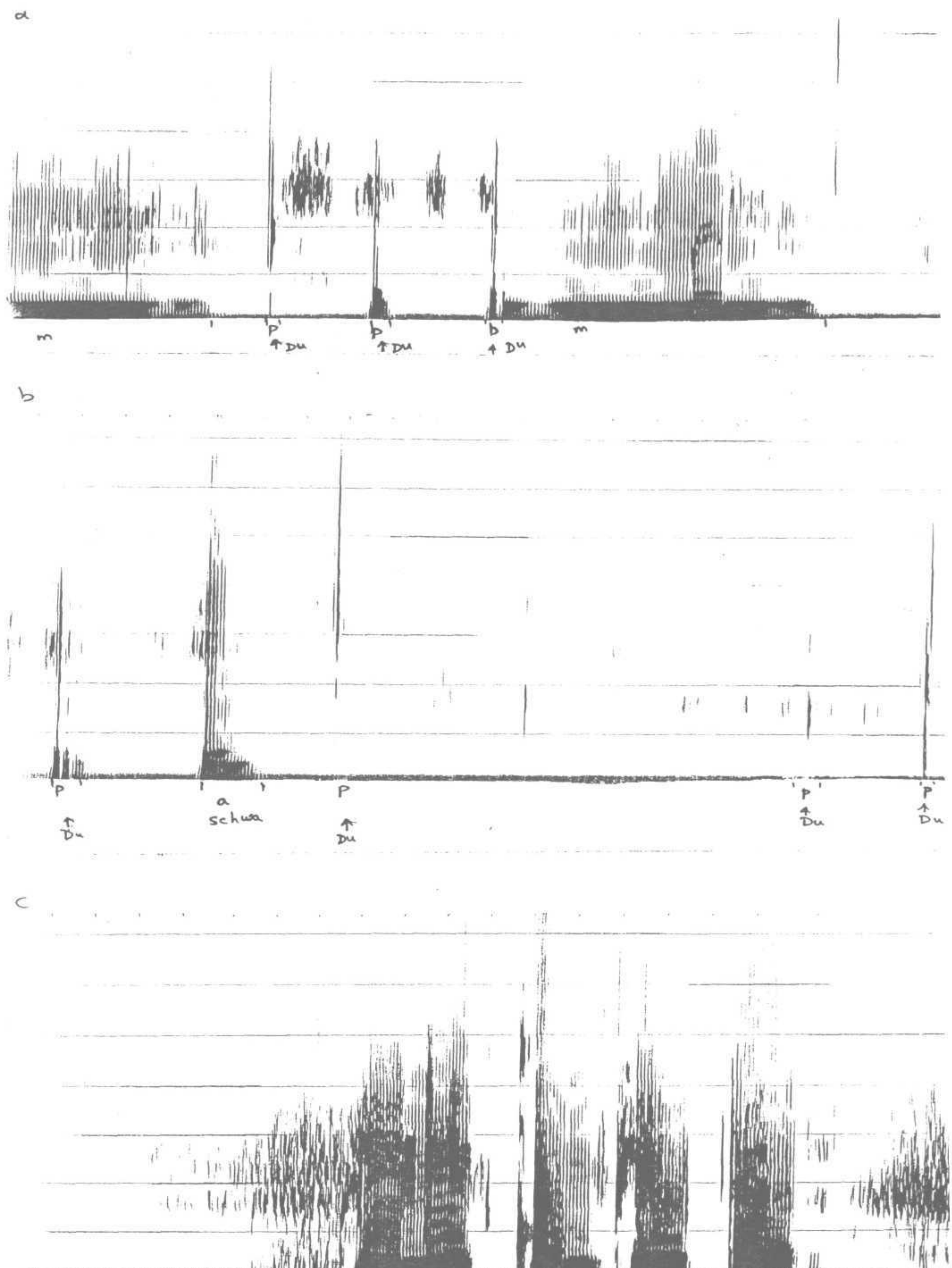


Fig-58: Spectrogram depicting substitution of stop for nasal in the word /minicomputer/ (substitution is indicated by Du and arrow)
abc

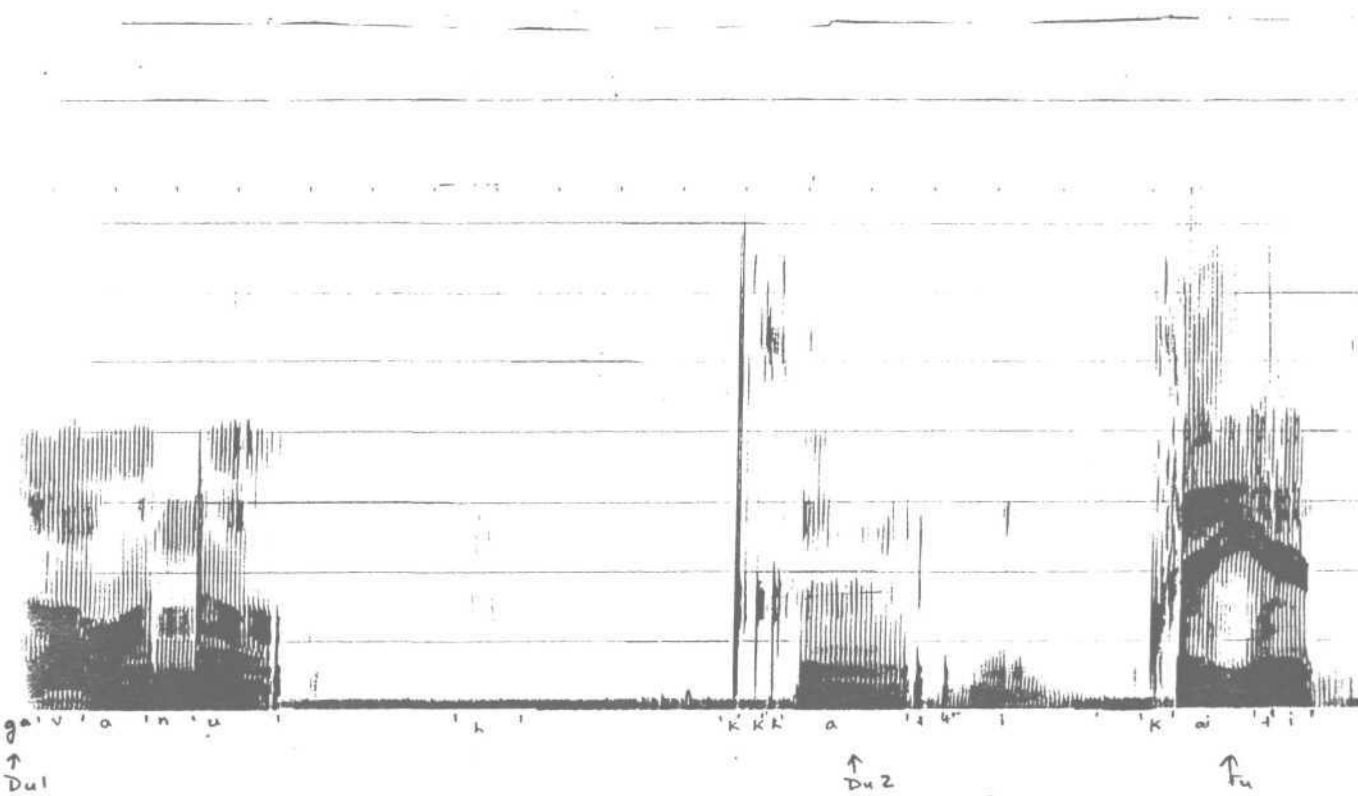


Fig-59: Spectrogram depicting substitution of stop for vocal in the phrase |avanu kaiyatti| (substitution is indicated by Du and arrow)

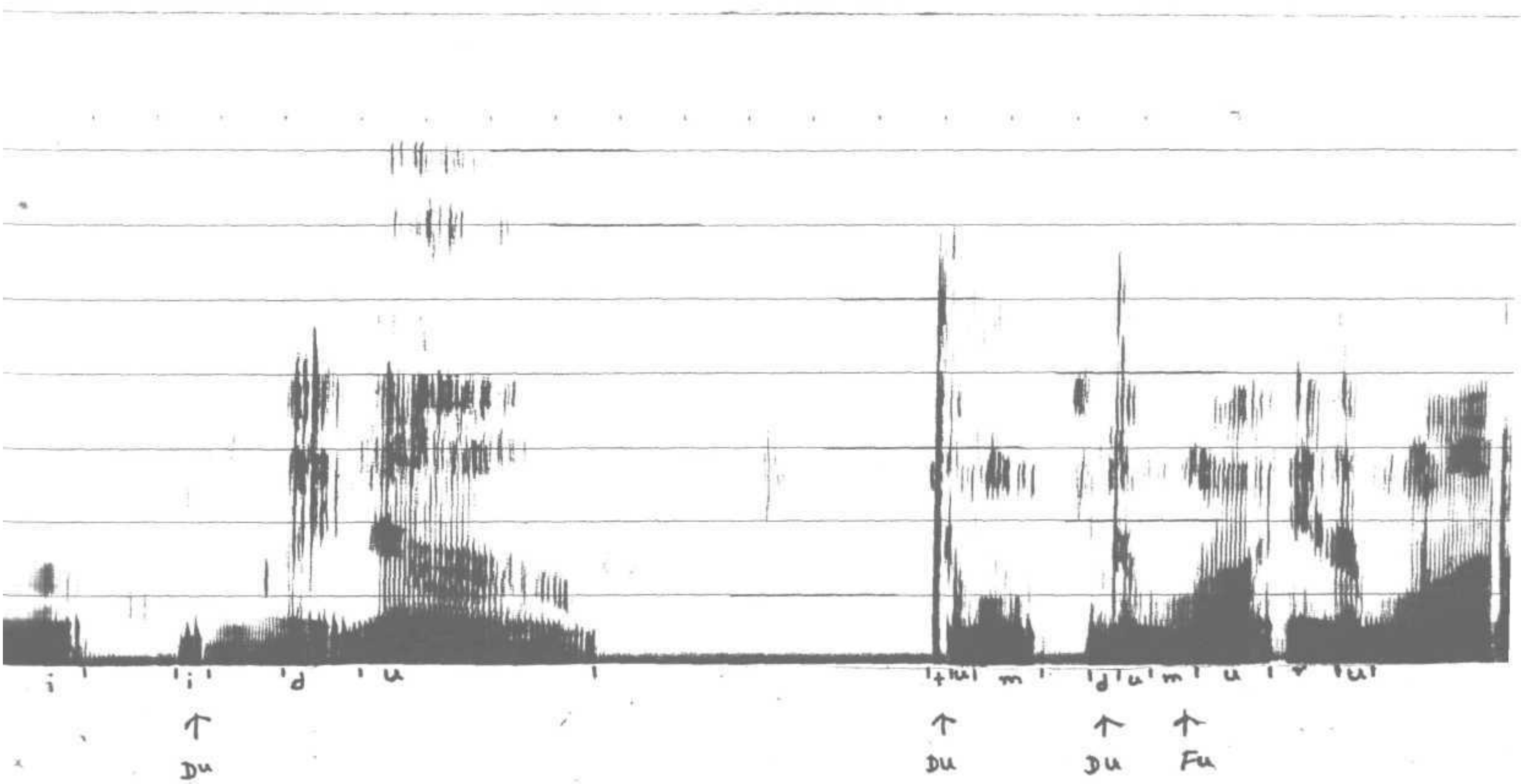


Fig-60: Spectrogram depicting substitution of bilabial sound /m/ by dental /t/ & /d/ in the word /idu muru/ (substitution is indicated by Du and arrow)

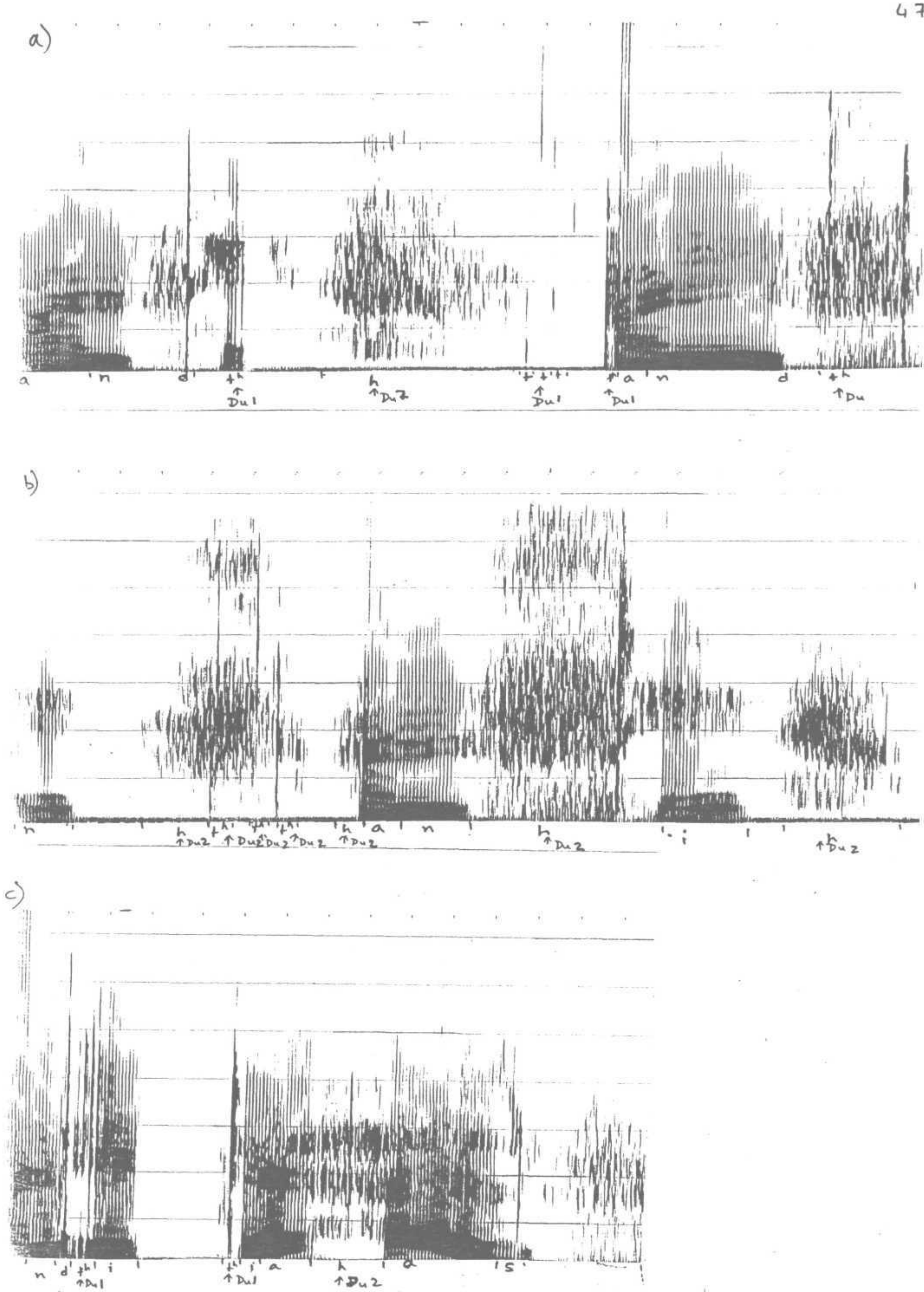


Fig-61: Spectrogram depicting substitution of aspirated
a,b,c. dental stop for vowel in the phrase |and it has|
(substitution is indicated by Du1 and arrow)

Considering utterance "idu muru" (spectrogram in Fig-60), it was produced as "idu turn du mu ru". The spectrogram indicates that the bilabial sound /m/ is substituted by the dental /t/ and /d/.

In the utterance "and it has" represented in spectrogram Fig-61, subject S2 substituted aspirated dental stop for the vowel /i/. /i/ is a front high vowel and the dental stop /t/ is produced by raising the tip of tongue. It is possible that the subject moved the articulator to /t/ position instead of to /i/.

6) Errors of manner and place of articulation

Spectrograms in Figs-62 and 63 taken from utterances of subject S1 indicate the errors of both the place and manner of articulation. Considering the utterance depicted in spectrogram in Fig-62 "tirugi bantu", it could be observed that the dysfluent utterance comprises of varying duration of the phoneme /t /. /t / is a voiceless affricate which was substituted for the voiceless dental stop /t/. In the spectrogram in Fig-63 the utterance depicted is "globes". The subject substituted the voiced palatal affricate /dz/ for the voiced velar stop /g/. Hence, both place and manner errors were observed.

The errors in place of articulation and or manner of articulation in stutterers support Van Riper's (1982) observation. He reported highly inappropriate articulatory gesture in the dysfluent utterances of stutterers.

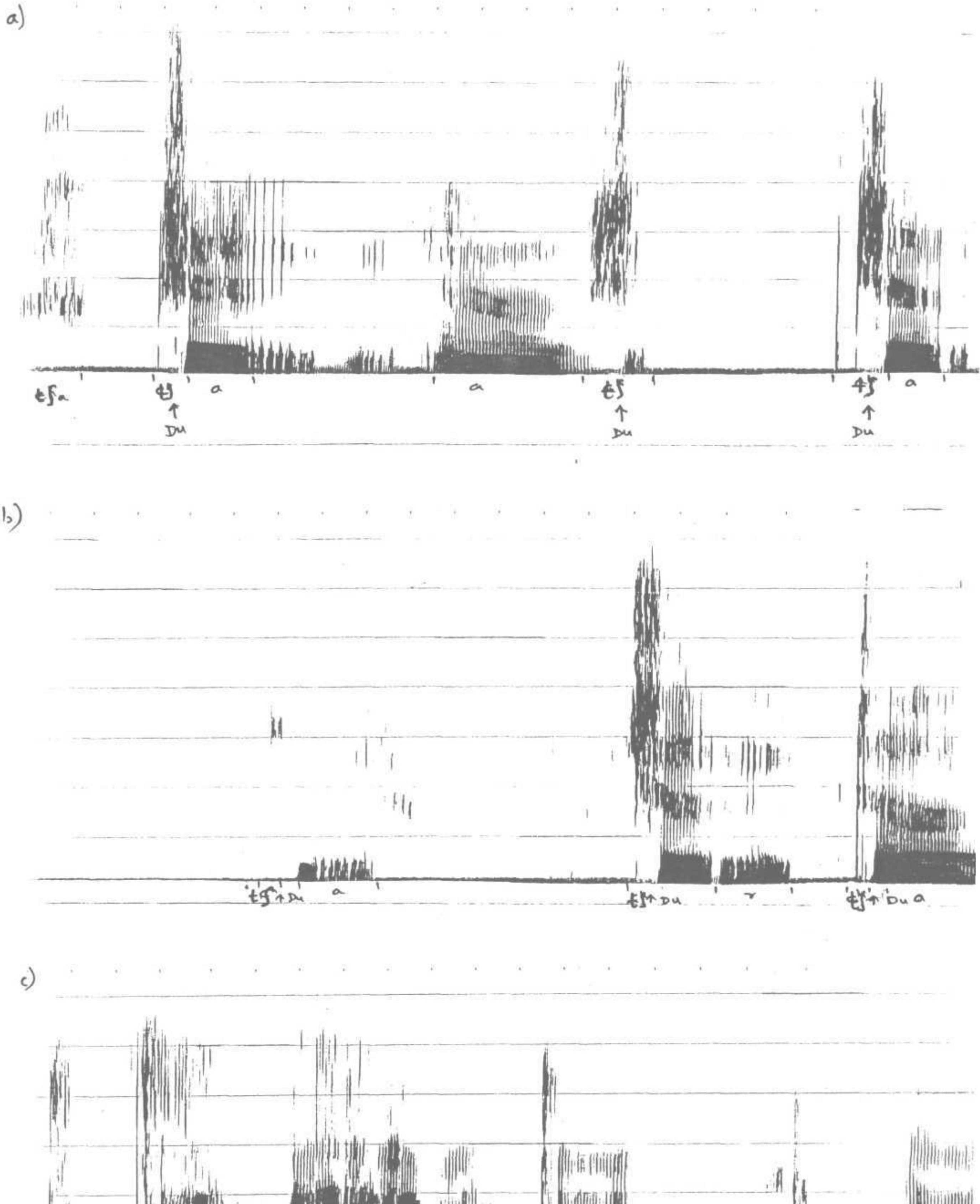


Fig-62: Spectrogram depicting both place and manner of
a,b,c articulation errors in the word |tirugi bantu|
(error indicated by Du and arrow)

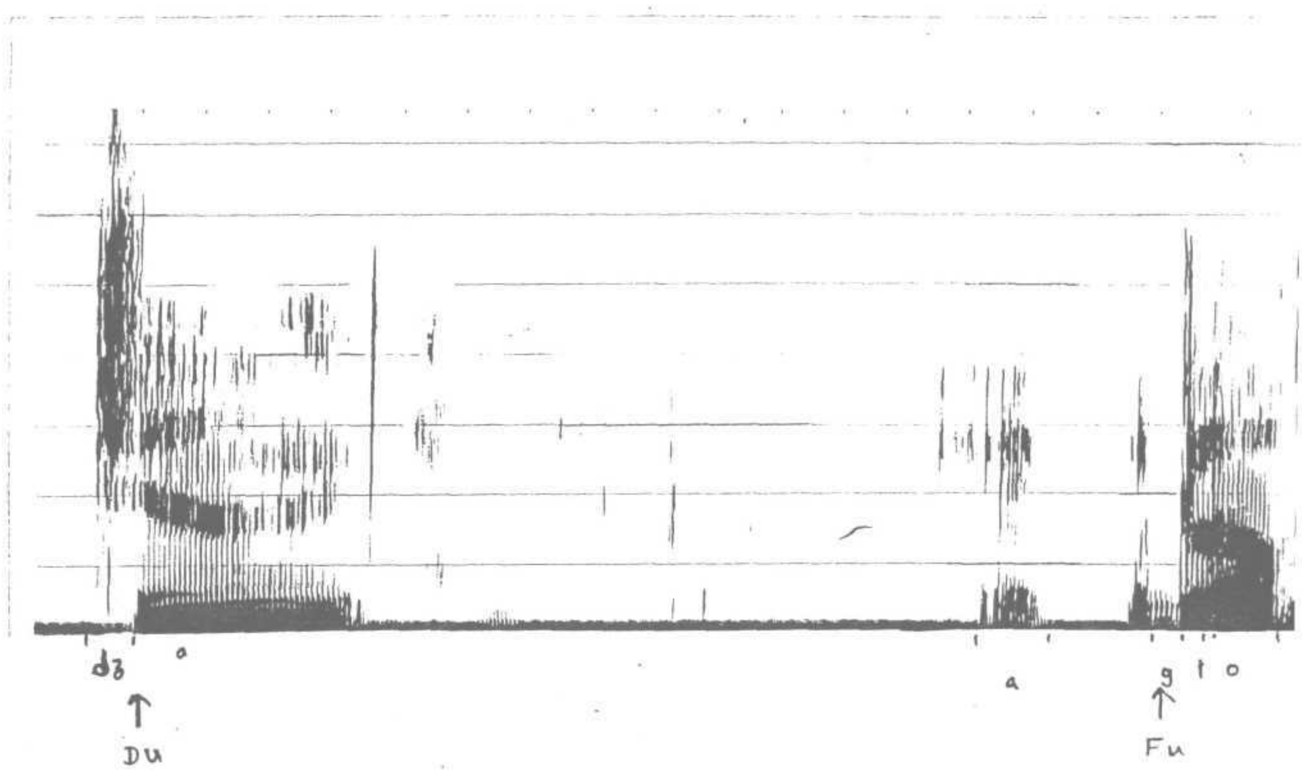


Fig-63: Spectrogram depicting both place and manner of articulation errors in the word /globes/ (error is indicated by Du and arrow)

7) Prolongation:

All the four stutterers prolonged the initial phoneme of the dysfluent word. The initial phonemes prolonged were fricatives and liquids (spectrograms in Figs.64-69). Prolongation is characterized by long duration of the initial subsegment of the dysfluent word. The mean values and F values of phoneme duration are in Table-6.

	Phoneme duration (in msec)	
	Dysfluent	Fluent
Mean	363.9msec	67.5 msecs
F value	4.1612	

TABLE-6: Mean and F value for phoneme duration.

The mean phoneme duration of dysfluent utterances were more than the mean phoneme duration of the fluent utterance and significant difference was observed between the phoneme duration of the fluent and dysfluent words.

This result is in agreement with the studies of DiSimoni (1974), Montgomery and Cooke (1977), Healey and Adams (1981), Prosek and Runyan (1982) and Metz et al (1990). All these researchers have reported longer phoneme durations for the dysfluent utterance of stutterers. However, it is not in consonance with the results of the studies by Klich and May (1982), Holland and Starkweather (1982) and Pindzola (1987). The variability in the results may be attributed to different methodologies used. Healey and Ramig (1986) suggested that the length and complexity of the phonetic speech task play an a)

b)

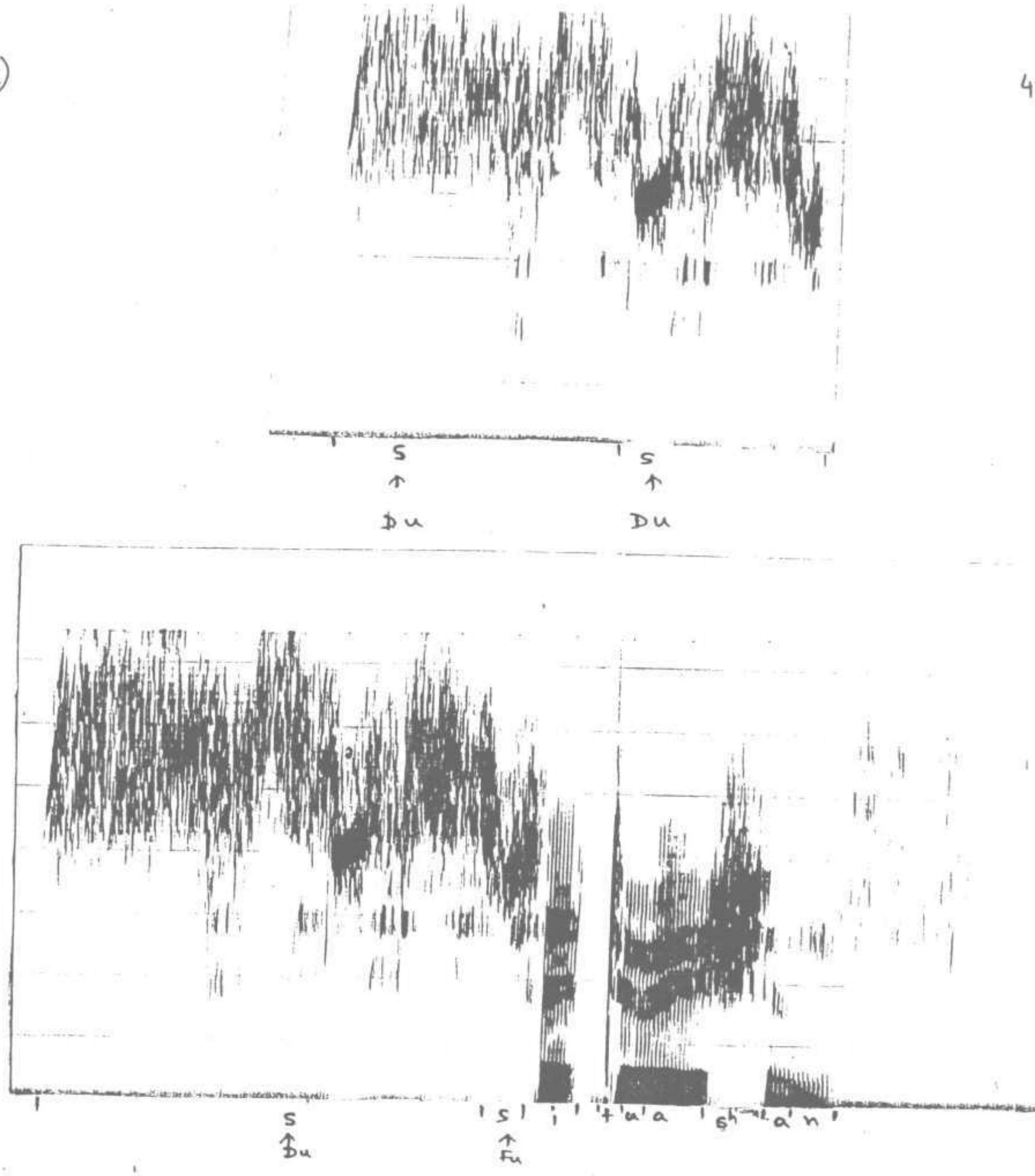


Fig-64: Spectrogram depicting prolongation of the initial
a, b. subsegment of the dysfluent word /situation/
(prolongation indicated by Du and arrow)

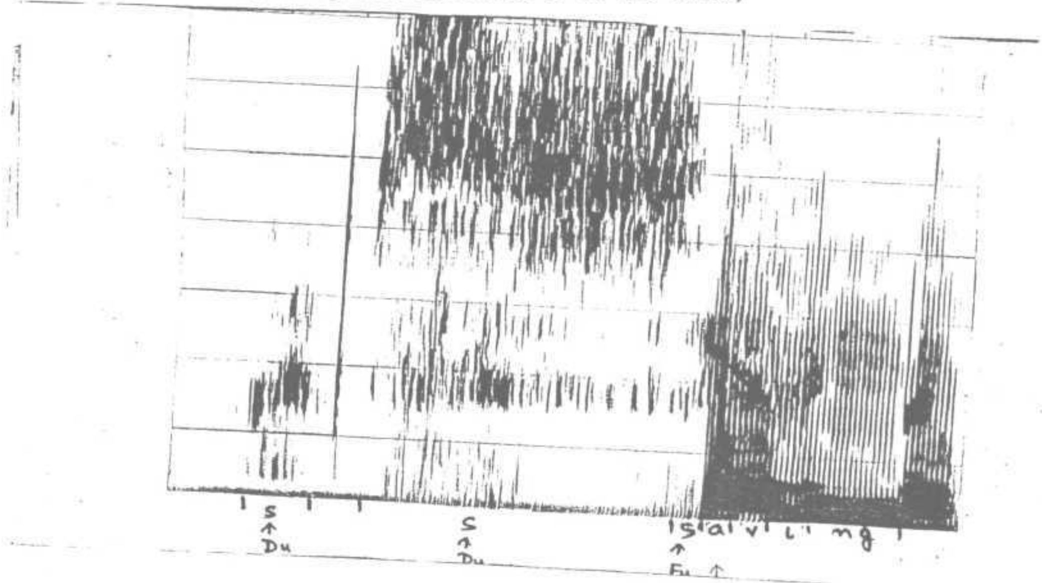


Fig-65: Spectrogram depicting prolongation of the initial
subsegment of the dysfluent word /saving/
(prolongation indicated by Du and arrow)

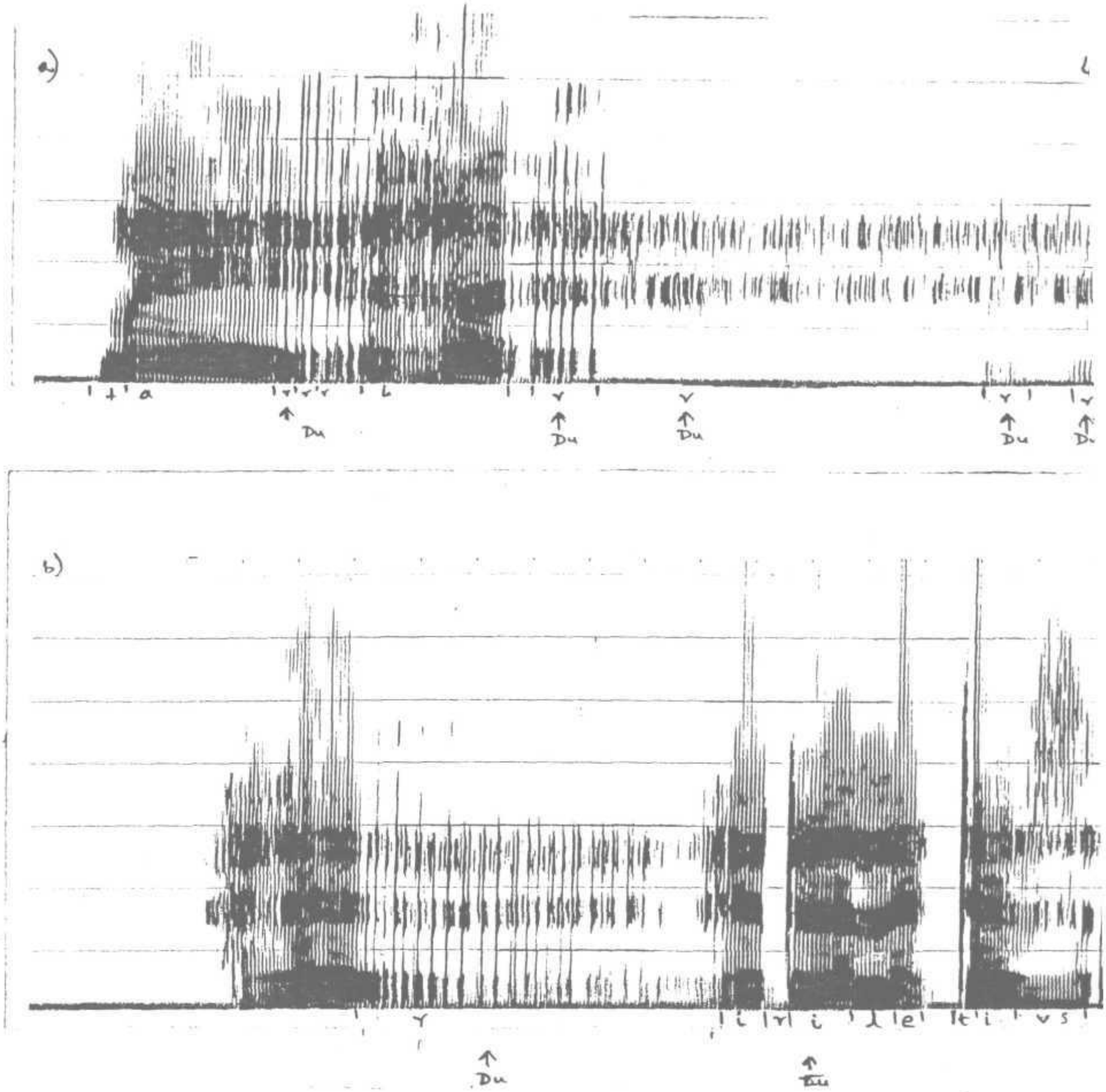


Fig-66: Spectrogram depicting prolongation of the initial subsegment of the dysfluent word /relatives/
a,b (prolongation indicated by Du and arrow)

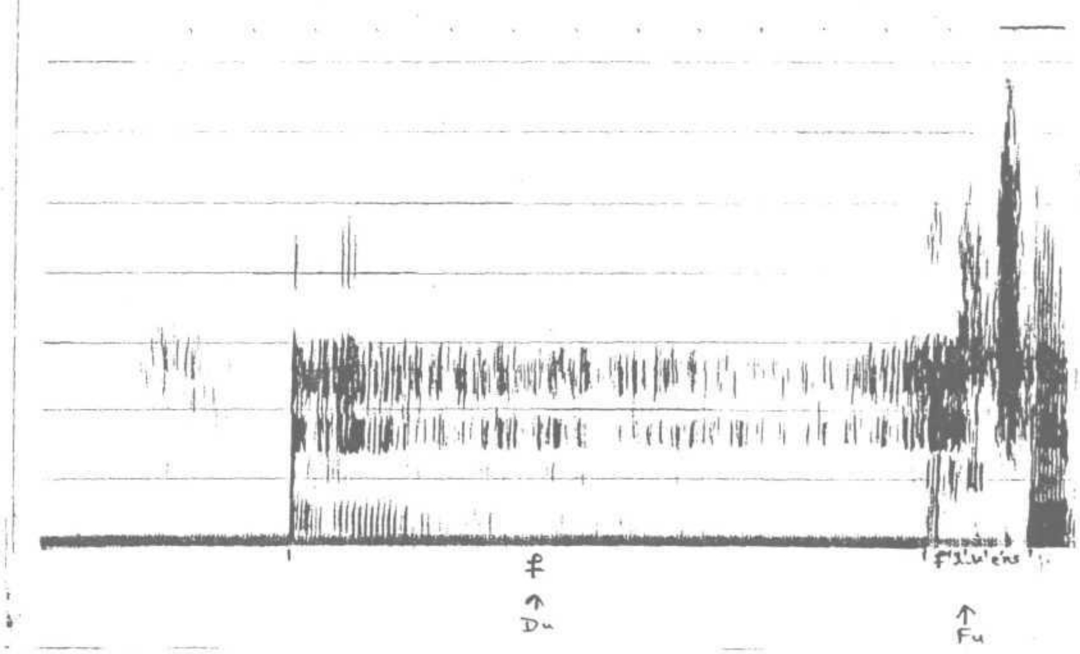


Fig-67: Spectrogram depicting prolongation of the initial subsegment of the dysfluent word /fluency/
(prolongation indicated by Du and arrow)

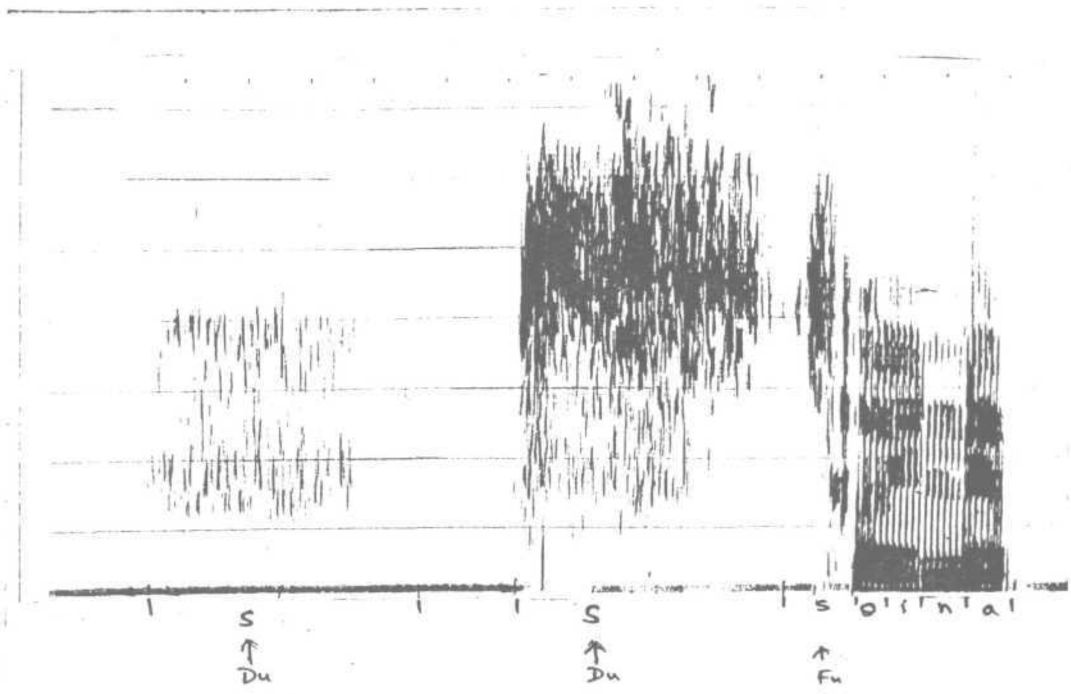


Fig-68: Spectrogram depicting prolongation of the initial subsegment of the dysfluent phrase /so in a/ (prolongation indicated by Du and arrow)

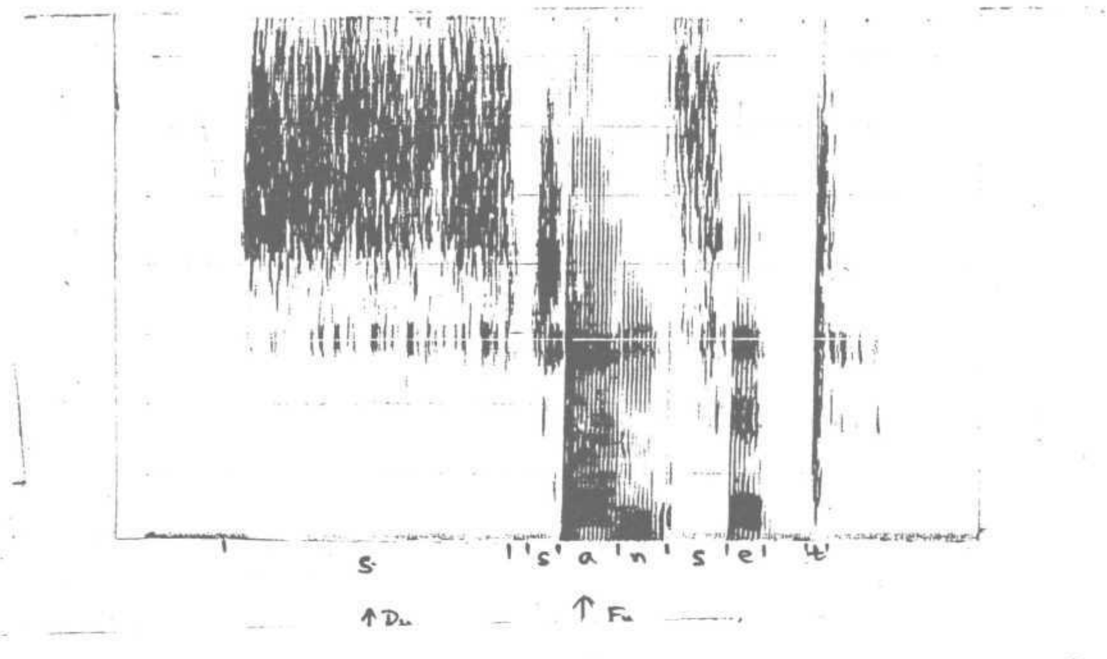


Fig-69: Spectrogram depicting prolongation of the initial subsegment of the dysfluent word /sunset/ (prolongation indicated by Du and arrow) important role in acoustic measures of fluency of stutterers and non-stutterers. The prolongation error can be attributed to longer steady state posture during the phonetic gesture.

Apart from the above, combination of two errors were also found. "This includes errors of aspiration and coarticulation, (spectrograms in Figs.70-76) errors of coarticulation and place of articulation, (spectrogram in Fig.77) errors of coarticulation and manner of articulation (spectrograms in Figs.78-79) and errors of coarticulation and prolongation (spectrograms in Figs.80-84).

11) Error in coordination of articulatory and glottal gesture

The coordination between articulatory and glottal gesture is indicated by voice onset time. The voice onset time of the initial segment of dysfluent and fluent utterances are in table-7.

	Voice onset time (in msec)	
	Dysfluent	Fluent
Mean	21.923msec	36.154msecs
F value	2.93	

TABLE-7: Mean and F value for voice onset time.

The mean values indicate longer voice onset time for fluent utterances. However, the F value does not indicate significant difference between the VOT of dysfluent and fluent utterance. This finding is in agreement with those of Metz et al (1979) and Watson and Alfonso (1982) who have

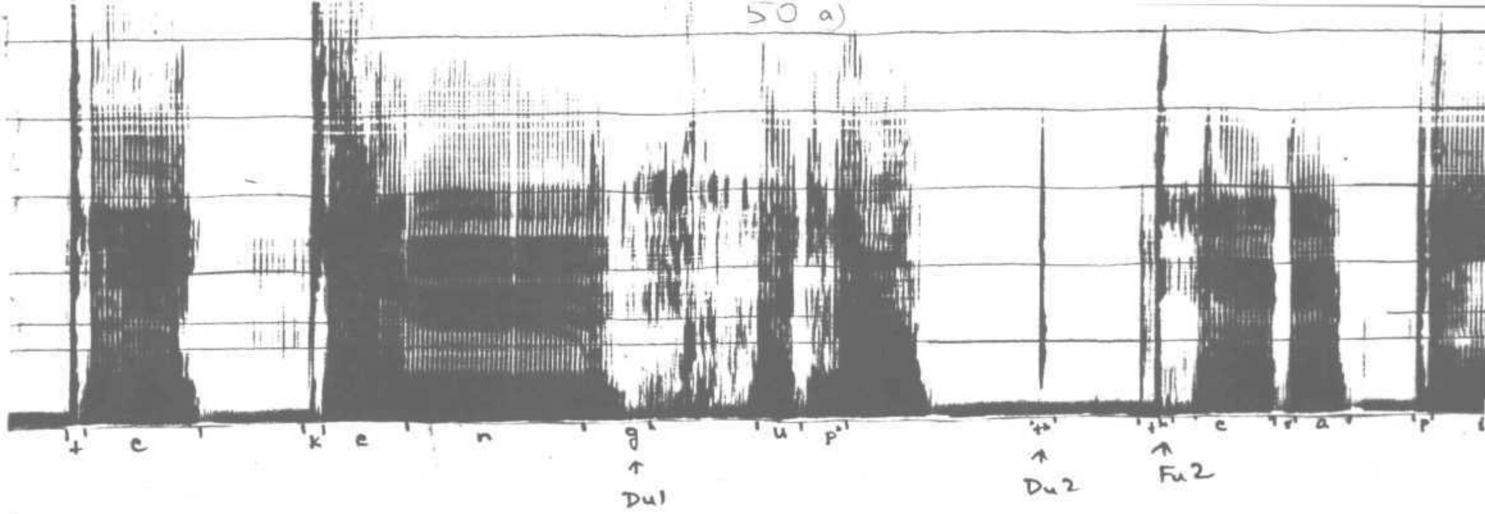


Fig-70: Spectrogram depicting aspiration and coarticulation error in the phrase /**taken group therapy**/ (indicated by Du1, Du2 and arrow)

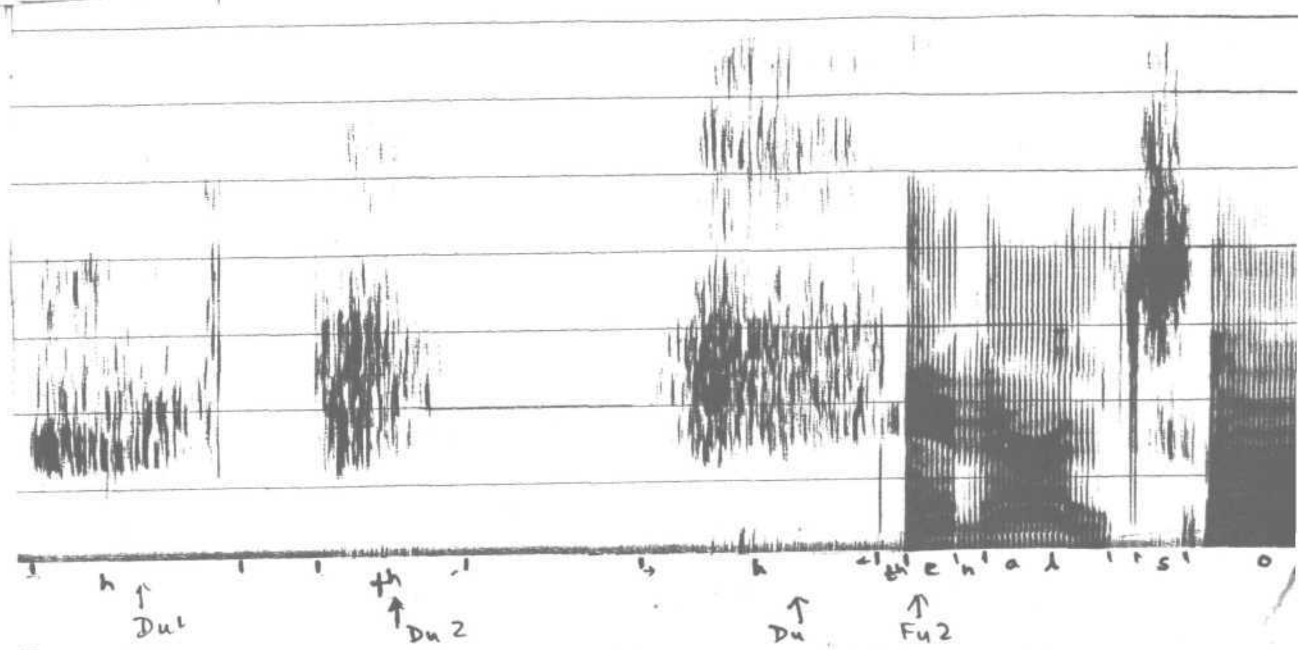


Fig-71: Spectrogram depicting aspiration and coarticulation error in the phrase /**then also**/ (indicated by Du1, Du2 and arrow)

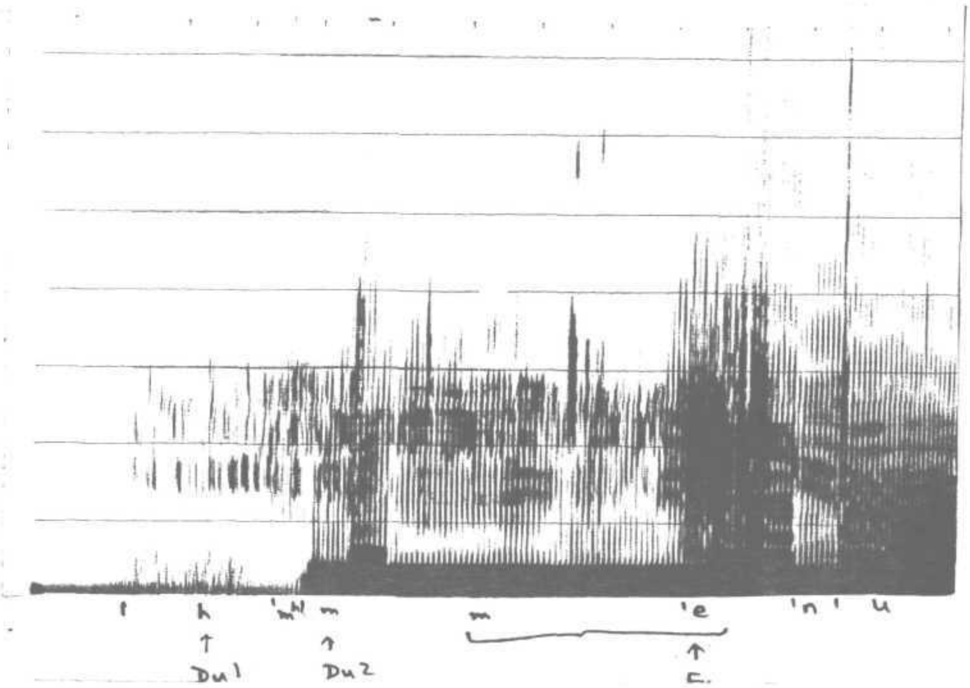


Fig-72: Spectrogram depicting aspiration and coarticulation error in the word /**menu**/ (indicated by Du1, Du2 and arrow)

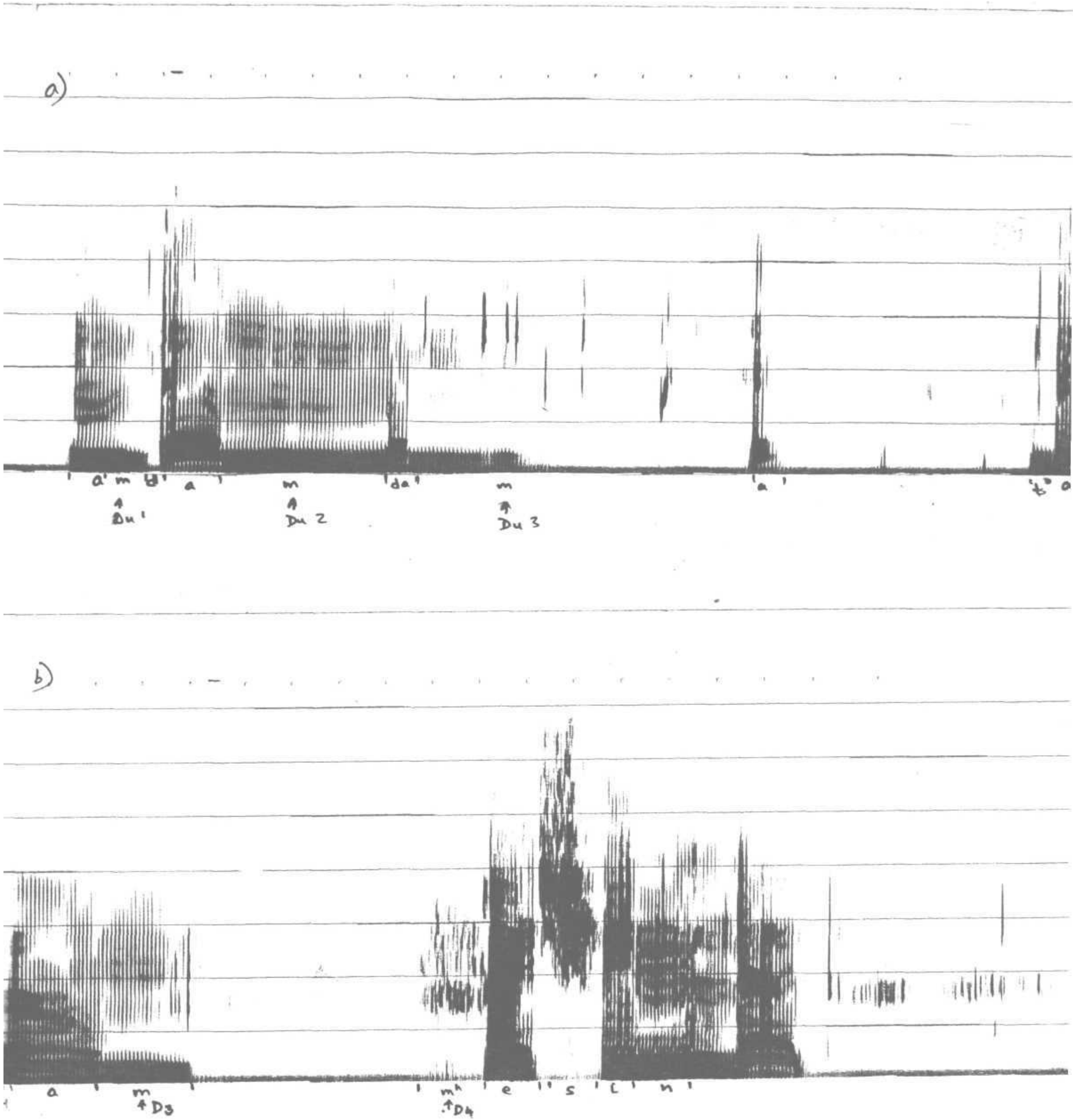


Fig-73: Spectrogram depicting aspiration and coarticulation error in the phrase the |**machine**| (indicated by Du1, Du2 and arrow)

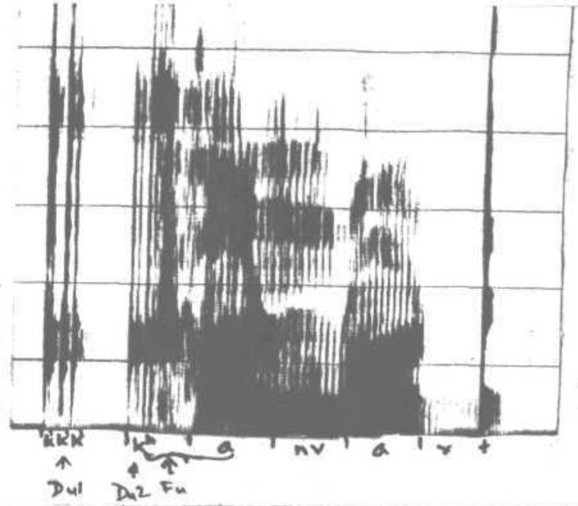


Fig-74: Spectrogram depicting aspiration and coarticulation error in the word /**convert**/ (indicated by Du1, Du2 and arrow)

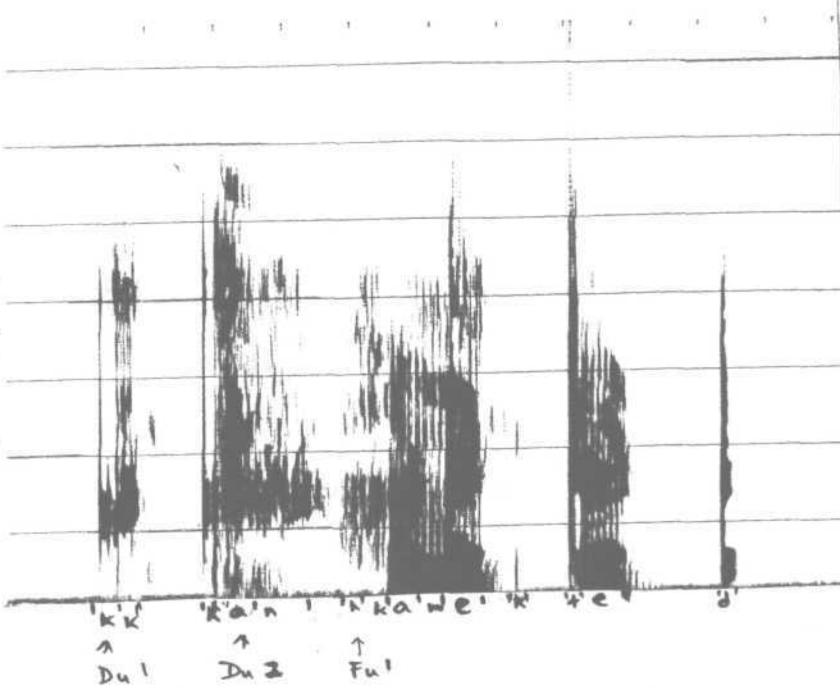


Fig-75: Spectrogram depicting aspiration and coarticulation error in the word /**connected**/ (indicated by Du1, Du2 and arrow)

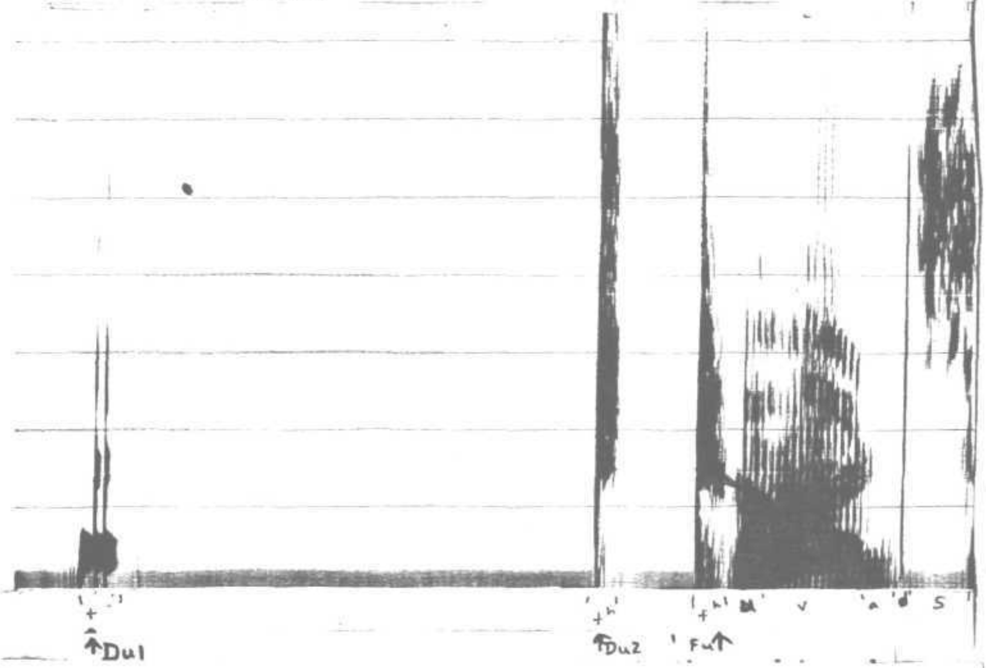


Fig-76: Spectrogram depicting aspiration and coarticulation error in the word /**towards**/ (indicated by Du1, Du2 and arrow)

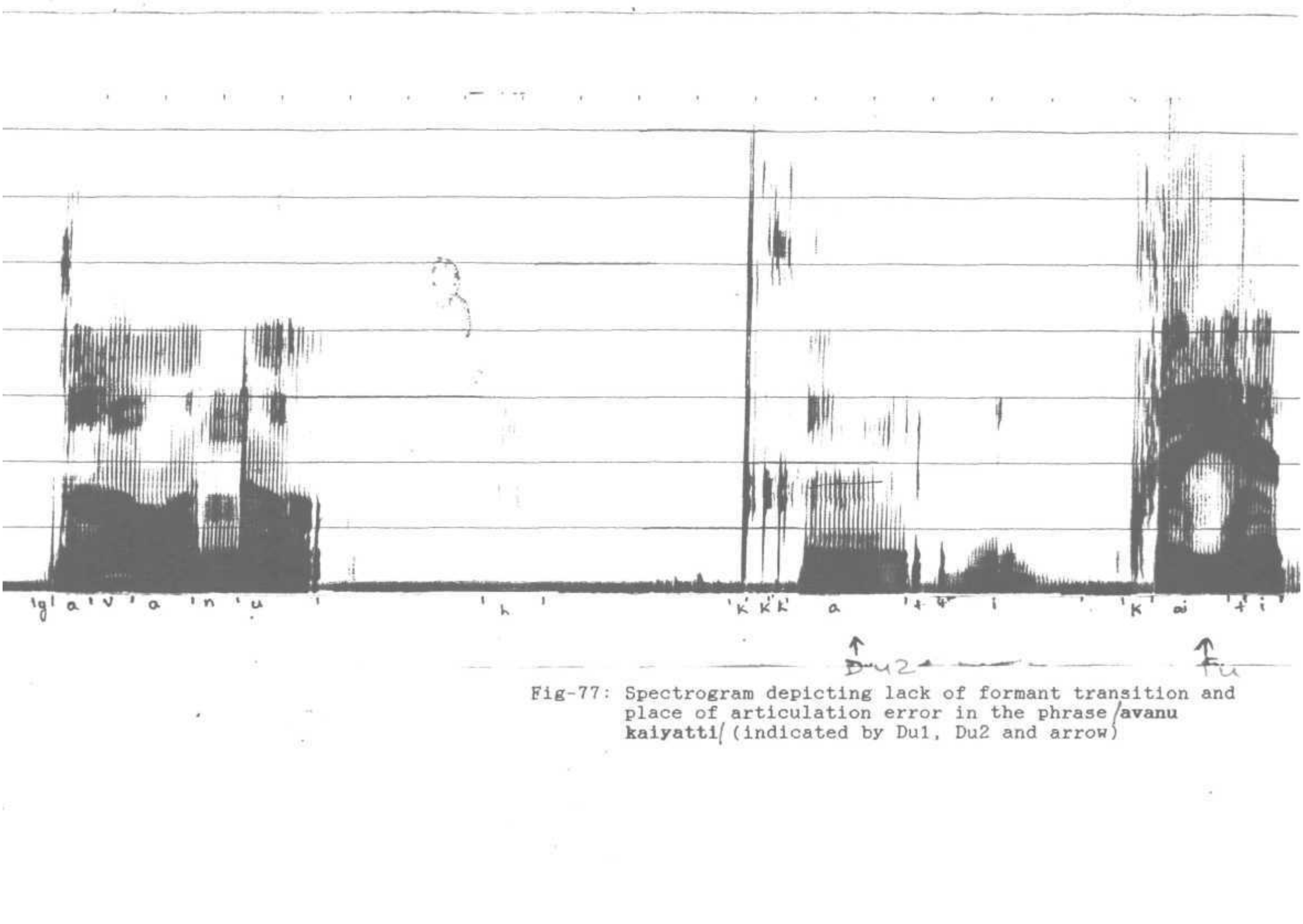
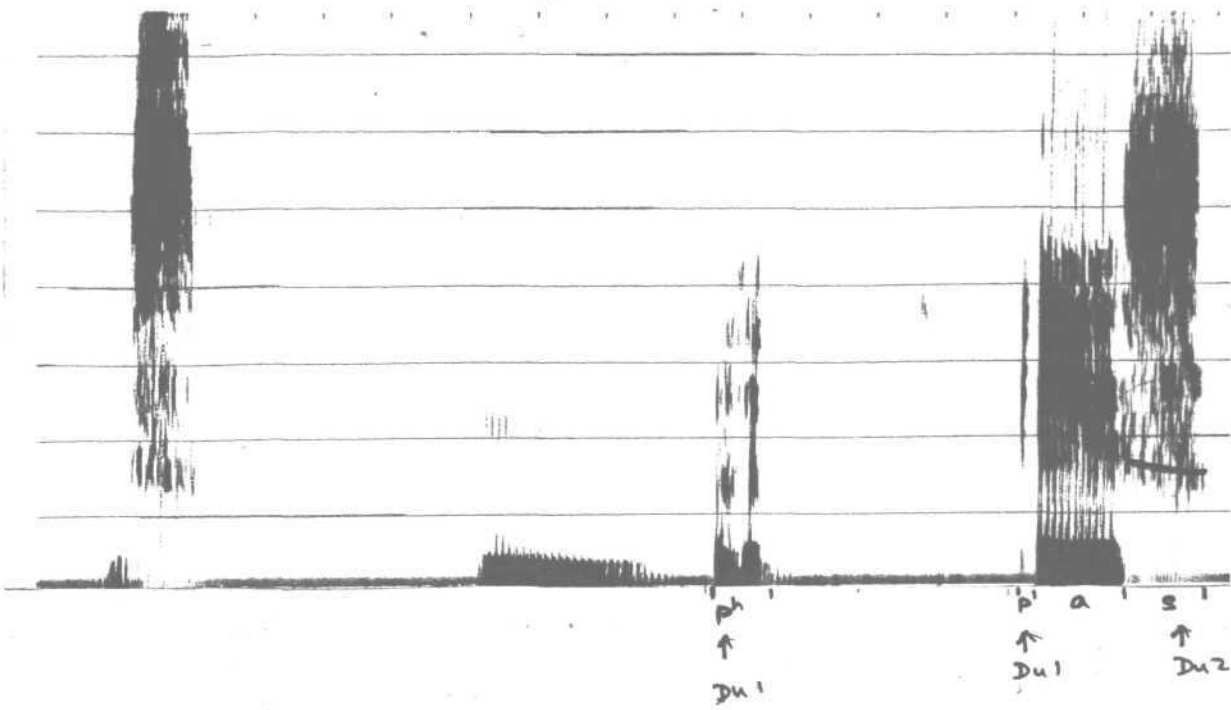


Fig-77: Spectrogram depicting lack of formant transition and place of articulation error in the phrase /**avanu kaiyatti**/ (indicated by Du1, Du2 and arrow) a)



b)

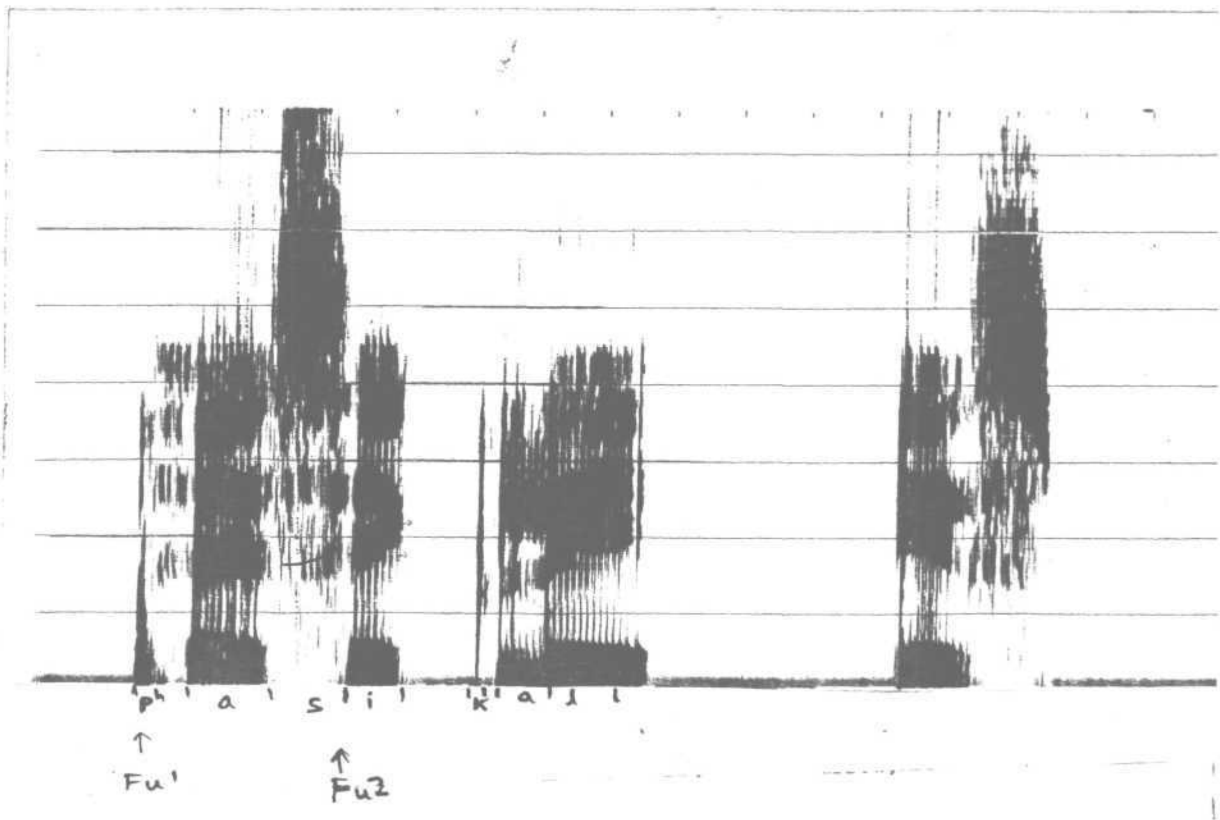


Fig-78: Spectrogram depicting longer transition duration F2 and manner of articulation error in the word a&b /basically/(indicated by Du1, Du2 and arrow)

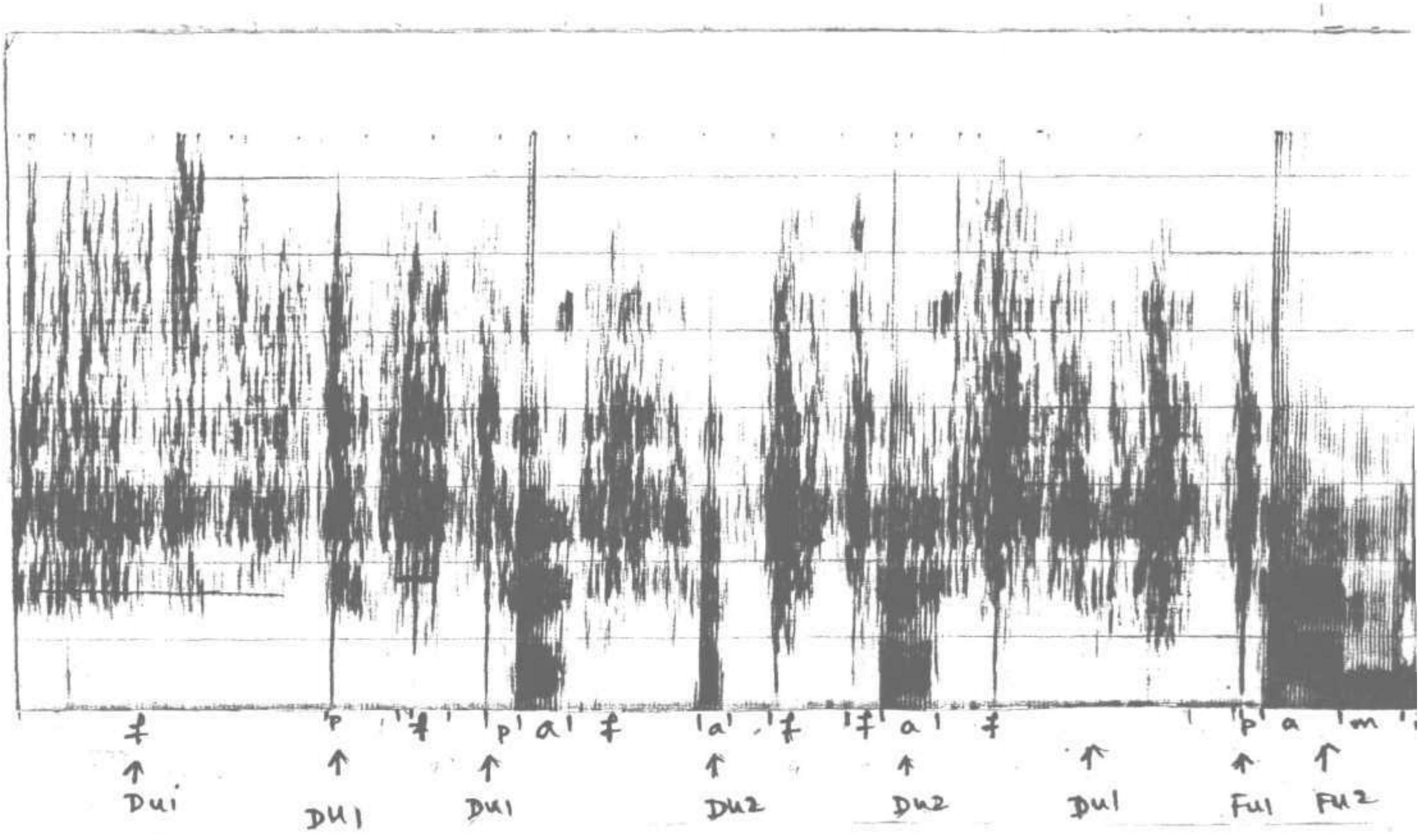


Fig-79: Spectrogram depicting longer transition duration F2 and manner of articulation error in the word /**family**/ (ndicated by Du1, Du2 and arrow)

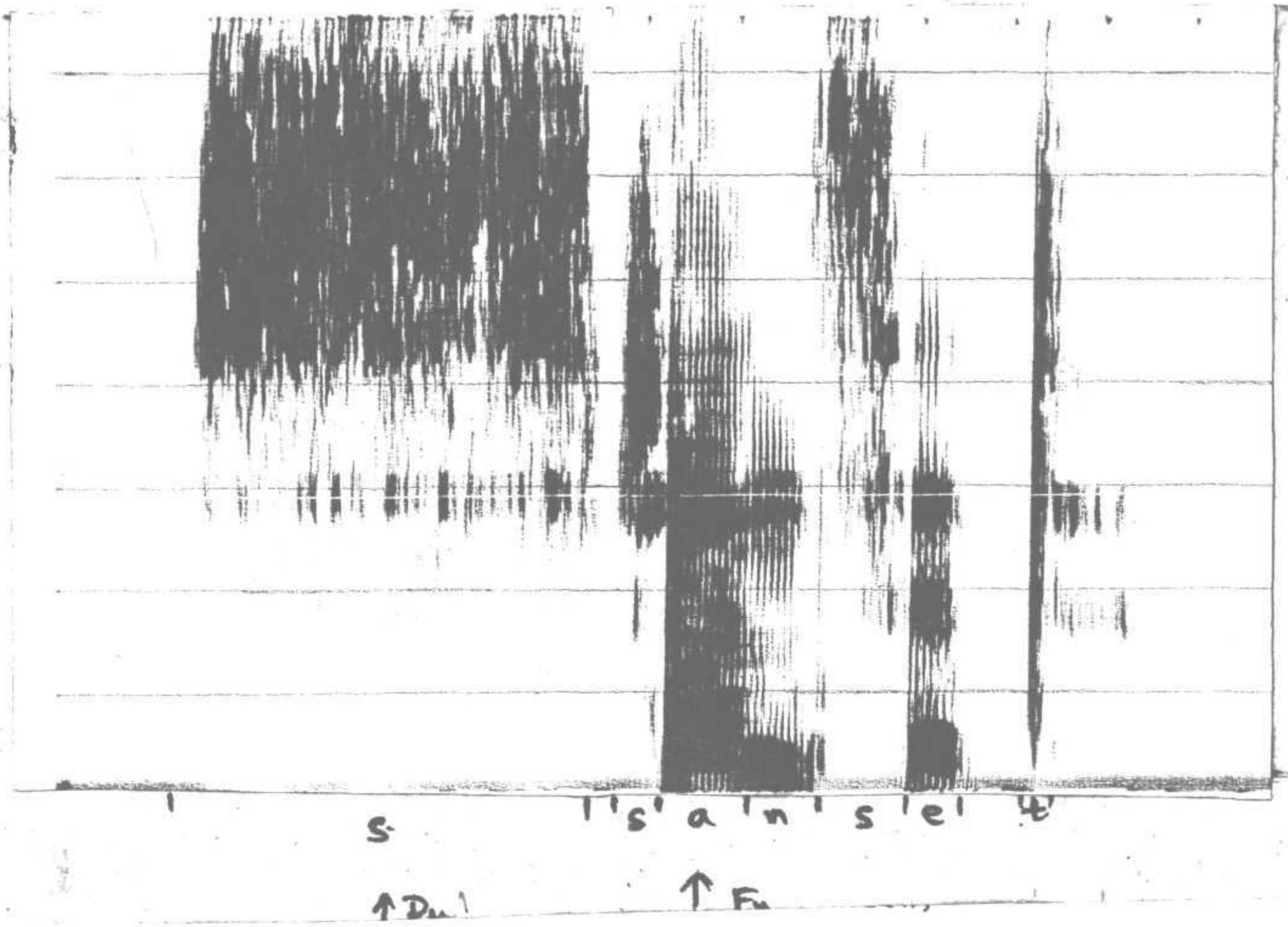


Fig-80: Spectrogram depicting lack of formant transition and prolongation in the word /sunset/ (indicated by Du1, ~~Du2~~ and arrow)

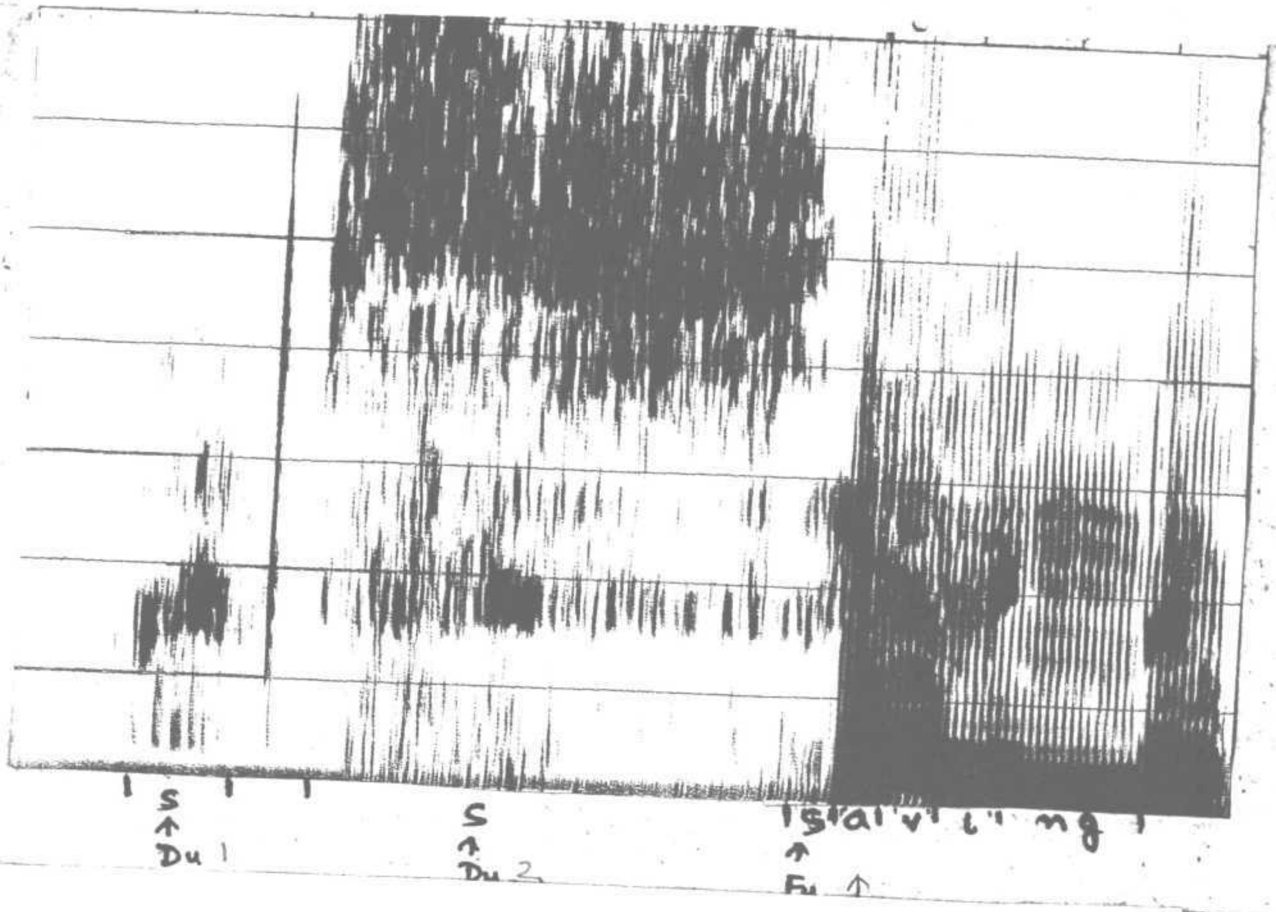


Fig-81: Spectrogram depicting lack of formant transition and prolongation in the word /saving/ (indicated by Du1, Du2 and arrow)

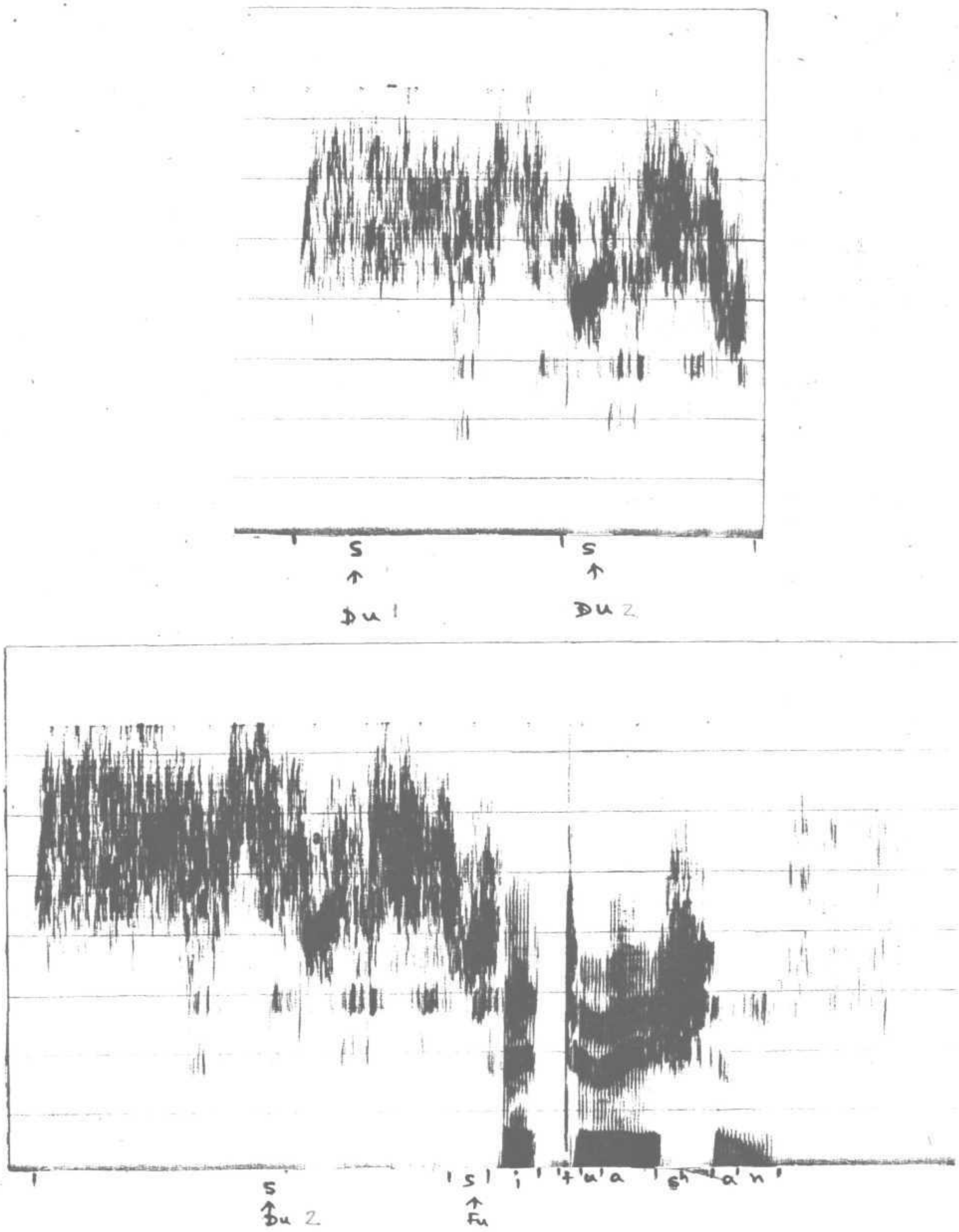


Fig-82: Spectrogram depicting lack of formant transition and prolongation in the word/**situation**/(transition indicated by Du1, Du2 and arrow)

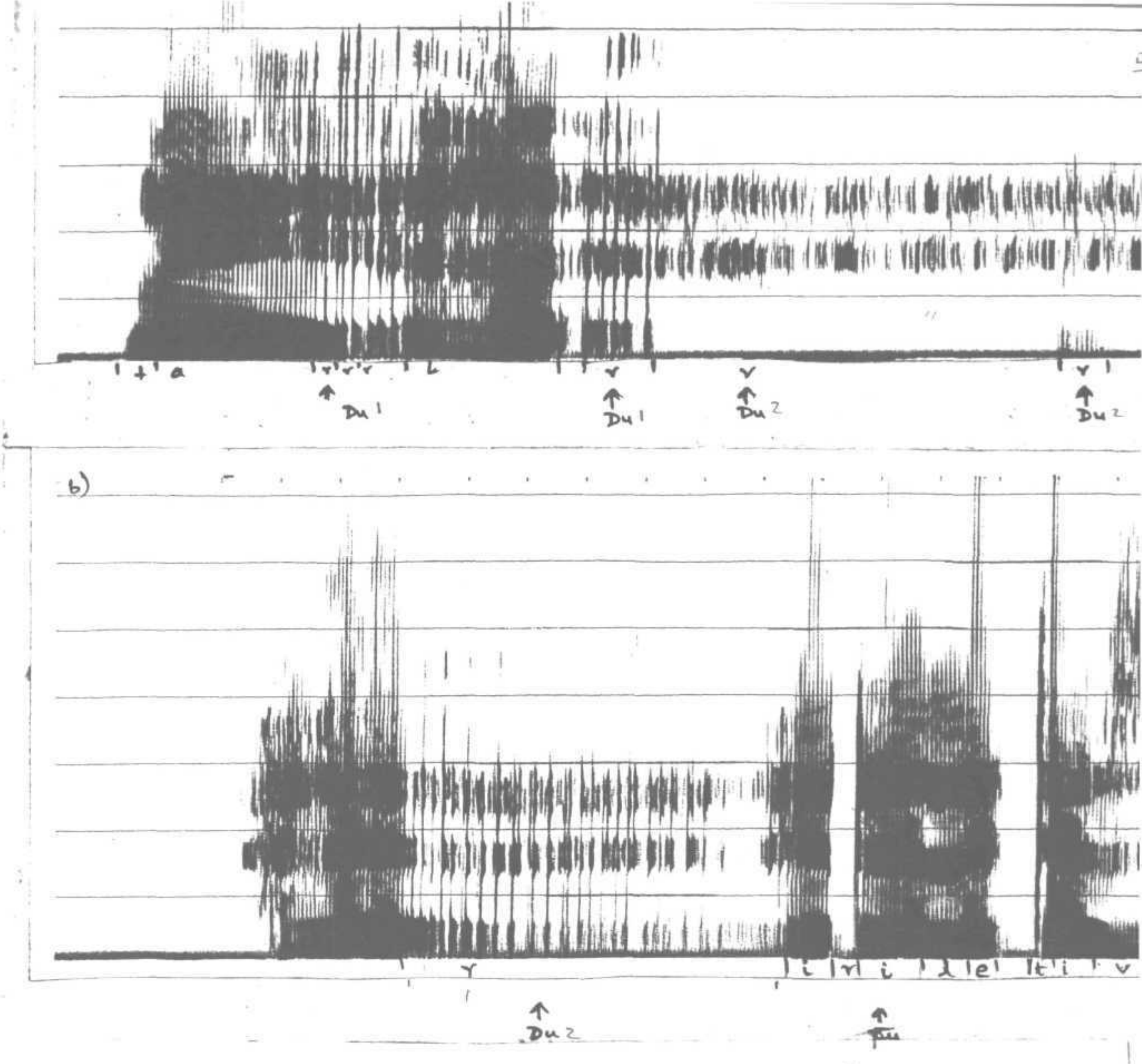


Fig-83: Spectrogram depicting lack of formant transition and prolongation in the word /relatives/ (indicated by Du1, Du2 and arrow)

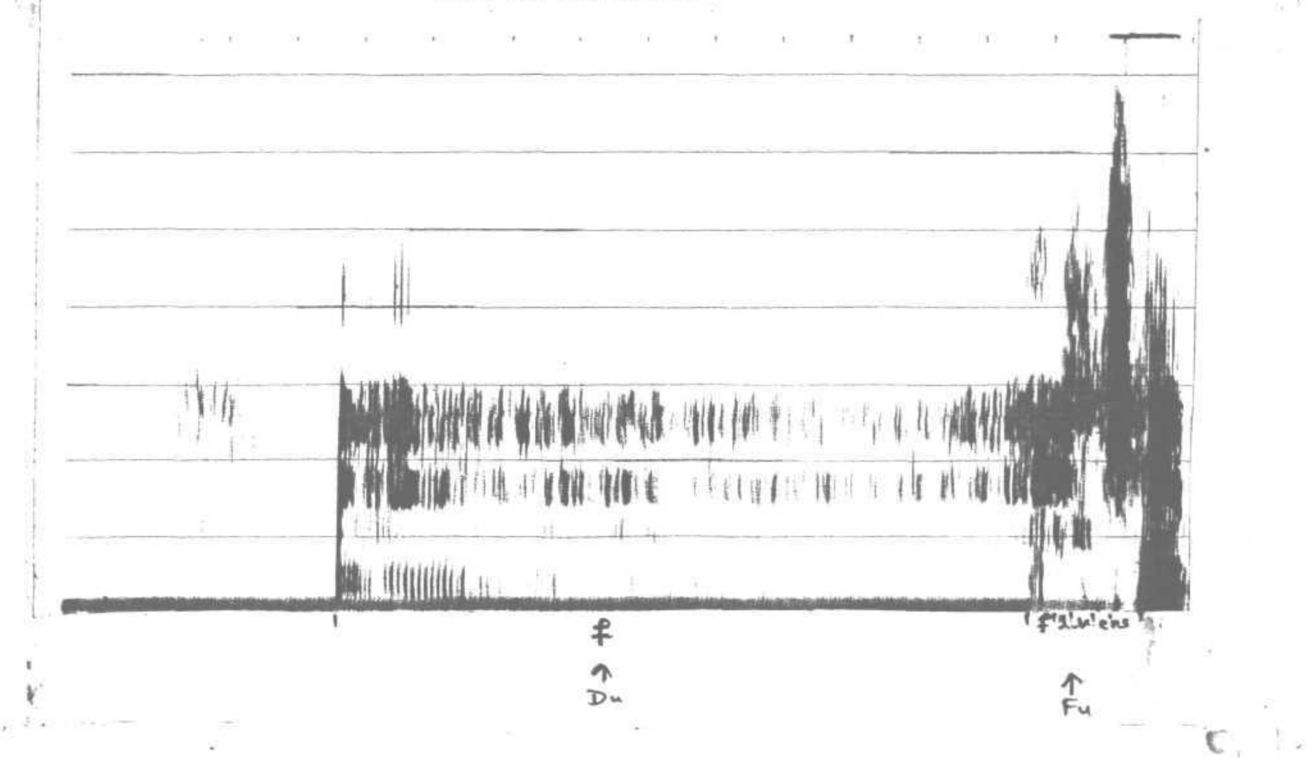


Fig-84: Spectrogram depicting lack of formant transition and prolongation in the word /fluency/ (indicated by Du1, Du2 and arrow) found no significant difference between the stutterer's and non-stutterers VOTs. However, it does not support the results of the studies by Agnello and Wingate (1972), Wendell (1973), Agnello (1974), Hillman and Gilbert (1977), Basu (1979), Zimmermann (1980a) and Healey and Gutkin (1984) who reported significantly longer voice onset time for stutterers compared to normals. The variability in the value of voice onset time can be attributed to the procedural differences among these studies. This difference is most notably in the use of non-sense syllables versus meaningful words and isolated versus continuous speech. Also controlled speech rate and phonetic context and subject training are involved in these studies.

DISCUSSION

The results reveal several interesting points. First of all stutterers speech has been found to be characterized by several articulatory abnormalities. These errors observed emphasize the notion that stuttering is an articulatory disorder.

The locus of defect is speculated to be in some unknown higher centre of the nervous system. The occurrence of dysfluencies in stutterers speech can be explained by the Sequencing and Timing model proposed by Mackay (1982). According to this model the basic components underlying speech motor control are content nodes, each consisting of one or more neurons. These content nodes are organized into three independently controllable systems - the muscle movement system, the phonological system and the sentential system. Content nodes within the muscle movement system represent muscle specific pattern of movement involving the respiratory, phonatory and articulatory system. Content nodes within the phonologic and sentential systems represent the cognitive units for controlling the movements making up a programmed sequence such as a word or a phrase. The speech is produced after priming and activation of nodes. The node which is most primed gets activated first. The dysfluencies or errors occur whenever another node in the domain has greater priming than the intended to be activated node, when the triggering mechanism is applied. As a consequence, the wrong node becomes activated under the "most primed wins" principle and an error occurs. Applying this model to the stuttering moments, for example, in spectrogram in Fig-52 /it/ is uttered as /th/ which perhaps explains the most priming principle. It indicates that the node for /i/ was not primed and instead the node for /th/ was the most primed. The prolongations also support this model and the model explains that a node is triggered for a longer time than necessary.

Consider the first two phonemes in "practice". The nodes and connections between them which are relevant to this example are shown in Fig-85. Unknown connections are excitatory and the dotted connections between the sequence nodes (rectangles) is inhibitory. The node representing the super-ordinate component /Pr/ (initial consonant cluster) is activated first. This simultaneously primes two subordinate content nodes /p/ (initial stop) and /r/ (initial liquid) which in turn prime their corresponding sequence nodes INITIAL STOP and INITIAL LIQUID. The inhibitory link temporarily reduces the priming of INITIAL LIQUID relative to INITIAL STOP and the latter is activated with the first pulse from the phonological time node. Once activated, INITIAL STOP strongly primes. The entire domain of initial stop nodes and one of these, /P/ (initial stop), having just been primed, has greatest priming and becomes activated under the "most primed wins" principle.

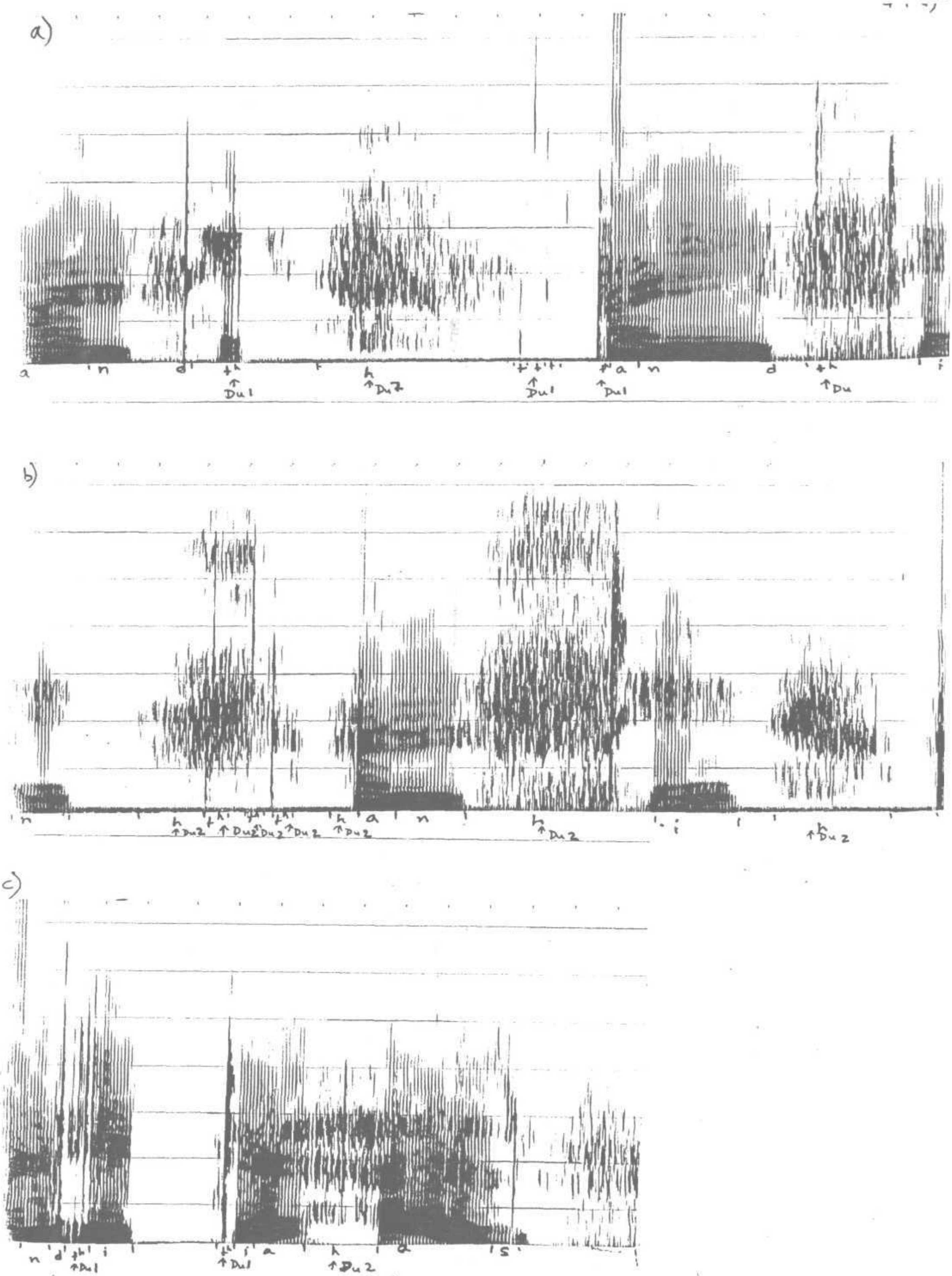


Fig-61: Spectrogram depicting substitution of aspirated
a,b,c. dental stop for vowel in the phrase /and it has/
(substitution is indicated by Du and arrow)

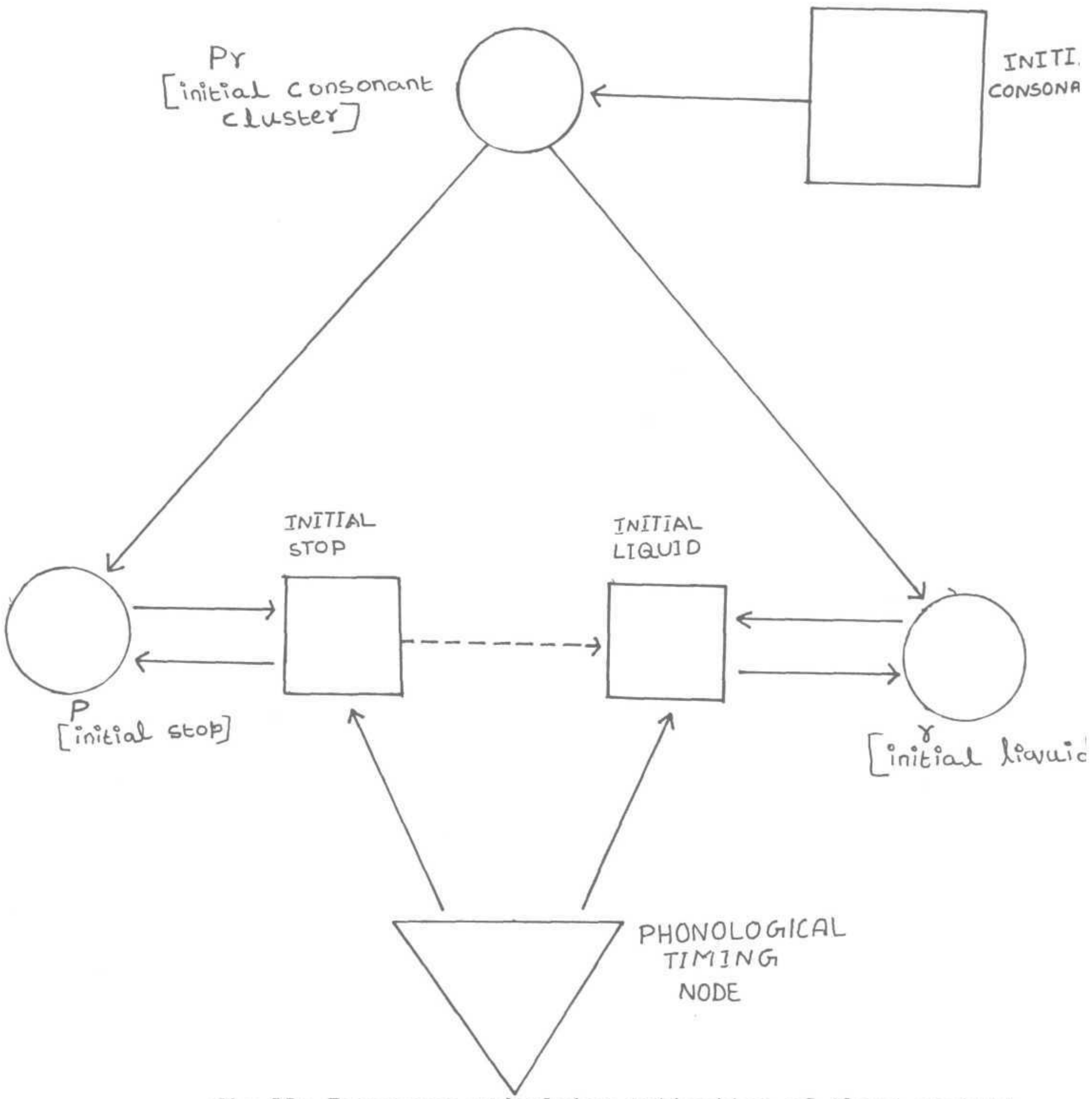


Fig-85: Processes underlying activation of three content nodes in the phonological system (circles), their corresponding sequence nodes (rectangle) and timing node (triangle)

Following activation, INITIAL STOP becomes self inhibited. This releases the inhibition on the INITIAL LIQUID which now achieve the most priming in the domain of phonologic sequence nodes and becomes activated with the next pulse from phonologic time. INITIAL LIQUID therefore, strongly primes its domain of nodes.

Error free output occurs under this theory when an intended to be activated content node has greater priming than any other node in its domain when the triggering mechanism is applied, that is, whenever the sequence node for the domain of content nodes is activated. The "intended to be activated" node is the one that is receiving priming from a superordinate node in the output sequence, that is, the directly connected content node immediately higher in the hierarchy.

Error occurs whenever another node in the domain has greater priming than the intended to be activated node when the triggering mechanism is applied. The fundamental cause of errors is that other extraneous sources contribute priming which sometimes can exceed the systematically increasing priming for the intended to be activated node, when the triggering mechanism is applied. As a consequence the wrong node becomes activated under the "most primed wins" principle and an error occurs. Stutterers exhibit three characteristic phenomena-repetitions, prolongation and blocks which can be explained by this model.

The second interesting point in this study is the individual differences observed in the occurrence of dysfluencies. Each of the four stutterers studied had some characteristic dysfluencies. For instance, subject S1 exhibited addition of glottal clicks in between the words and S2 exhibited inappropriate opening of the velopharyngeal port. It appears that stutterers can be classified based on the errors obtained from acoustic analysis, provided a sufficiently large sample is used. While some could have articulatory errors restricted to the oral tract some could exhibit articulatory errors extended to vocal folds and some could have articulatory errors extended to nasal tract.

Third, the results, indicate that the perceptual analysis which is usually employed in the assessment of stuttering is not sensitive in detecting the errors in production of dysfluency. Hence, it is suggested that assessment of stuttering could include both perceptual and acoustical analysis. Since these is a lot of individual variability in the speech of stutterers the comprehensive analysis of speech symptoms enables the clinician to design specific fluency enhancing techniques.

Aspiration errors were attributed to high subglottic pressure causing air to pass through glottis. So, the air flow therapy, with gradual exhalation of air along with utterance seems to be appropriate to reduce errors of aspiration. The errors of coarticulation are due to inappropriate movement or lack of ability of the articulators to move from one phoneme to another.

The prolongation therapy thus gest justified as it involves prolongation of the phonemes of the words and smooth transition to other phrases. Addition errors and errors in place and manner of articulation were attributed to inappropriate articulatory gestures. Auditory feedback along with soft articulatory contacts can be suggested to avert such errors.

It could be concluded that stutterers exhibit several individual articulatory errors, the cause of which could be at higher centres. However, as the higher centres are not accessible either in diagnosis or in therapy for stuttering, it would be appropriate at this time to atleast evaluate the external systems-articulatory laryngeal and respiratory. However, the present systems of therapies do not explain how and why stutterers overcome these aberrant errors. This warrants the need for new therapy techniques, which could, if not remove the cause, remove the external symptoms.

SUMMARY AND CONCLUSION

The present study was aimed at acoustically analyzing the articulatory dynamics in four stutterers to obtain a wholistic and conclusive observation on articulatory dynamics in stutterers.

Four adult male stutterers as diagnosed by a Speech Pathologist were selected for this study. The age range of the four stutterers was 20-30 years. The subjects were instructed to speak/read into the microphone (cardioda, unidirectional) and these utterances were audio-recorded on a high fidelity magnetic 7 1/2 tape using the internal taperecorder of the sound spectrograph VII 700. The speech and reading samples were listened to and the perceptually dysfluent and their counterpart fluent utterances (if any) were selected. Wide band bar type of spectrograms were obtained for all these utterances. Using the wide band bar type spectrograms, measurements of five temporal parameters for both dysfluent and fluent utterances were made. These parameters were - phoneme duration, voice onset time aspiration duration, transition duration of F2 of the following vowel and speed of transition of F2. The five temporal measures of dysfluent and fluent utterances were compared. Analysis of variance (ANOVA) was applied to find out the significant difference between the fluent and dysfluent utterances. Descriptive analysis was also performed to delineate the results.

Based on the descriptive and inferential statistical analysis, twelve kinds of articulatory errors were identified. These were as follows:

1) Errors of aspiration: Wherein the initial subsegment of the dysfluent utterances were aspirated. The mean aspiration duration was 186.5msec. The aspiration error in stutterer's utterances could be attributed to high subglottic pressure and inappropriate glottal gesture, causing air to pass through glottis.

2) Errors of coarticulation: CV formant transition errors were observed in both initial and medial segment of stuttered words. Four kinds of coarticulatory errors were noticed - :viz.-

a) Lack of formant transition: The spectrograms of some dysfluent utterance were characterized by the absence of formant transition. This indicates that a stutterer is unable to transit or move from one phoneme to another.

b) Longer transition duration: The transition duration of F2 was longer for dysfluent utterances than the corresponding fluent utterance. This implies that the time lapse between the movement of articulator from one target to another is long.

c) Shorter transition duration: Some dysfluent utterances were characterized by shorter transition duration of F2 than the corresponding fluent utterance. This indicates shorter time lapse between the movement of articulators from one target to another.

d) Inappropriate transition: Inappropriate formant transition were observed in two dysfluent utterances. This indicates that the articulator mistargeted the production of the following vowel.

3) Addition or interjection: Interjections like "um", "a" and phonemes like /s/ were added in between the words which could be either a placement error or an addition.

4) Errors in manner of articulation: All the four subjects had errors in manner of articulation. This included errors such as devoicing the initial subsegment of dysfluent word, voicing the initial subsegment of dysfluent word, substitution of stops for fricatives, substitution of fricatives for stops, substitution of stops for nasals and substitution of stops for vowels. These results indicates inappropriate articulatory gestures, forceful articulatory patterns and excessive muscular activity in stutterers.

5) Errors in place of articulation: Errors in place of articulation like substitution of dental stop for bilabial stop, substitution of dental stop for the vowel were observed in certain utterances.

6) Prolongation: All the four stutterers prolonged the initial phoneme of the dysfluent word. The mean phoneme duration of the dysfluent utterance was found to be significantly longer than the phoneme duration of fluent utterance.

7) Error in coordination of articulatory and glottal gesture: The coordination between articulatory and glottal gesture is indicated by voice onset time. The voice onset time of the initial segment of dysfluent and the corresponding fluent utterances was measured and compared. The mean voice onset time of the fluent utterance was greater than that of dysfluent utterance. However, there was no significant difference between them.

Apart from the above, combination of two errors were also found. This included;

6) Errors of place and manner of articulation.

7) Prolongation.

8) Errors of aspiration and coarticulation.

9) Errors of coarticulation and place of articulation.

10) Errors of coarticulation and prolongation.

11) Errors of coarticulation and manner of articulation.

The results thus reveal that stutterers exhibit several articulatory abnormalities which emphasize the notion that stuttering is an articulatory disorder. The cause of the disorder is speculated to be in some unknown higher centre of the nervous system. The Sequencing and Timing model by Mackay (1982) seems to explain the occurrence of dysfluencies in stutterers. The analysis of errors indicate individual differences observed in the occurrence of dysfluences. Each of the four stutterers studied had some characteristic dysfluencies. This suggests that stutterers can be classified based on the errors obtained from the acoustic analysis provided a sufficiently large sample is used. The results also indicate some diagnostic and therapeutic implications. Acoustic analysis seems to be sensitive in detecting the articulatory abnormalities in dysfluent productions and could be employed in the assessment of stuttering. This warrants the clinician to design specific fluency enhancing techniques to eliminate the external symptoms.

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