SPEECH SOUND CHARACTERISTICS OF STUTTERERS AND CHILDREN WITH NORMAL NONFLUENCY

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Dedication

You were my strength when I was weak
You were my voice when I couldn't speak
You were my eyes when I couldn't see
You saw the best there was in me
Lifted me up when I couldn't reach
You gave me faith 'coz you believed
I'm everything I am
Because you loved me

You gave me wings and made me fly
You touched my hand I could touch the sky
I lost my faith, you gave it back to me
You said no star was out of reach
You stood by me and I stood tall
I had your love I had it all
I'm grateful for each day you gave me
Maybe I don't know that much
But I know this much is true
I was blessed because I was loved by you

For all those times you stood by me,
I dedicate this work of mine…….
To "YOU"
"MY FAMILY"
My Wonderful Grandparents, Amazing Parents
& My little Bro & Sis

CERTIFICATE

This is to certify that the dissertation entitled **"Speech Sound Characteristics of Stutterers and Children with Normal Nonfluency"** is a bonafide work done in part fulfillment for the degree of Master Science (Speech Language Pathology) of the student with Register No. L0380005. This has been carried out under the guidance of a faculty of this Institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Prof. M Jayaram
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May 2005

CERTIFICATE

This is to certify that the dissertation titled **"Speech Sound Characteristics of Stutterers and Children with Normal Nonfluency"** has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any diploma or degree.

Guide

Professor M. Jayaram
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May 2005

D E C L A R A T I O N

I hereby declare that this dissertation entitled **"Speech Sound Characteristics of Stutterers and Children with Normal Nonfluency"** is the result of my own study under the guidance of Prof. M. Jayaram, Director, All India Institute of Speech & Hearing, Mysore, and has not been submitted earlier at any other University for any other Diploma or Degree.

Mysore
May 2005 Register No. L0380005.

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You're like a shining star on which I dream
You lead me, guide me, & make me gleam

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worth every dime-
and I'm so glad
that gods blessed me with the best of the clad."

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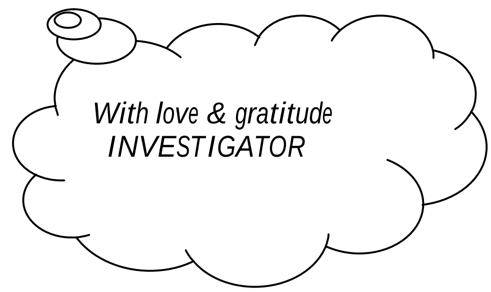

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In The Name

of

Allah …

CHAPTER 1

INTRODUCTION

Fluency disorders are the most researched in the area of speech pathology. Almost all aspects of fluency are researched, yet no conclusions are reached. As far as stuttering is concerned, our journey is both over and just beginning! The last 30 years have been eventful for those interested in stuttering, as stuttering research has gone multidimensional. The laryngeal, respiratory, articulatory, auditory and central neural correlations of stuttering are being explored. The significant findings of this research have indeed helped us to better understand the dynamics of stuttering, but we are still far away from cracking the riddle of stuttering. In fact, speech pathologists cannot even agree on what features should be considered as stuttering. Thus, *stuttering remains an enigma!*

Fluent speech is that whose rate, rhythm and forward flow is free from any hesitations, repetitions, prolongations, interruptions or stoppages. Stuttering is a disorder affecting the fluency of speech. A multitude of definitions have been put forward to characterize stuttering.

- Van Riper (1982) defines “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”. This disruption is characterized by repetitions, hesitations, prolongations and audible pauses.
- Stuttering is defined as the involuntary disruption of a continuing attempt to produce a spoken utterance (Perkins, 1990).

- Culatta & Goldberg (1996) gave the four factor definition: “Stuttering is a (1) a developmental communication disorder beginning in childhood of (2) unknown origin that (3) results in a person viewing the communication process differently from a normal speaker (4) due to experiences with overt or covert factors that disrupt normal communication.”

When a normal speaker repeats syllables or prolongs a sound, the proper transitional formants appear in that syllable or sound and airflow continues (Van Riper, 1971). It is conjectured that this may not be true of the stutterer’s repetitions and prolongations. Agnello (1966) reported that the acoustic and pause characteristics of stuttering disfluencies of stutterers differed from their ‘normal’ speech disfluencies. Some of these acoustic differences were undetectable by the ear and showed up only on the spectrograms. The normal downward shift of the second formant, usually associated with articulatory positioning, was not characteristic of the stuttering moments. The intersyllabic pauses were longer and more variable.

Stromsta (1965) demonstrated that the spectrograms of stuttered speech revealed a lack of the usual falling or rising transactions seen in spectrograms of normal speech. The juncture formants were not present or were different. Normally, in the integration of a syllable, co-articulation occurs. We prepare for the second or third or fourth sound while still uttering the first. The phoneticians refer to this as ‘assimilation’.

According to Van Riper (1971) the stutterer who is saying ‘Mmmmmmm – other’ may not seem to be having any trouble uttering that /m/ but he will tell you that he is, and perhaps he may not be wrong. He may be searching for the /m/, which has the juncture characteristics that are needed for integration of this initial sound with its following vowel. Van Riper (1971) believes that almost universally the schwa vowel can be heard in the stutter's abortive speech attempts. For example, when stutterer repeats the word 'pen', he seldom says /pe pe pe p∂/, instead, he uses the schwa vowel in his repetitions like /pΛ pΛ pe p∂/. Van Riper contemplated on why the schwa vowel was used and not any other vowel. He putforth the following hypothesis:

"It might be that a consonant's set of allophones cluster about a pole or central tendency represented by the utterance of that consonant in syllabic conjunction with the neutral vowel. The substitution of schwa vowel shows that he is searching for the appropriate coarticulatory feature and that stuttering terminates when the correct feature is achieved."

Several studies have put this hypothesis to test. All these studies employed acoustic analysis of the fluent and dysfluent production of speech segments. Some of these studies indicated coarticulatory deficiencies. Guitar (1975) demonstrated inappropriate phonetic transitions and slower than normal rate of articulation in fluent syllables prior to stuttering. This result suggests coarticulatory deficiencies in the speech of stutterers. Klich and May (1982) found differences in formant frequencies between stutterers whom they tested and existing data for nonstutterers who produced fluent vowels in an /hvd/ context suggesting that stutterers restrict their vowel articulation spatially as well as temporally during fluent utterances, thus producing more centralized formant frequencies. They attributed this finding to a strategy employed by stutterers for achieving fluent speech. A note by Blomgren, Roh and

Chen (1998) on vowel centralization in stuttering and nonstuttering individuals reported that in an acoustic analysis of a series of CV tokens, the formant frequency spacing measures showed significantly greater vowel centralization in untreated stutterers compared to those in the speech of treated and nonstuttering individuals.

But, there are several studies which failed to demonstrate consistent coarticulatory deficiencies in the speech of stutterers. For example, Hutchinson and Watkin (1976) reported that only 12% of the stutterings were characterized by abnormal phonetic transition characteristic of coarticulation. Montgomery and Cooke (1976) in a perceptual and acoustic study of carefully selected CV repetitions reported that the listeners perceived schwa vowel in only 25% of CV repetitions. The results of their acoustic analysis indicated that, in CV repetitions, the articulatory breakdown is simply limited to initial consonant.

Howell and Vause (1985), in an acoustic and perceptual analysis of 30 vowels in monosyllabic words beginning with voiceless CV syllables, reported that schwa vowel is not produced, and that generally low amplitude and short duration characterized the vowel. Prosek, Montgomery, Walden and Hawkins (1987) conducted a formant frequency analysis of vowels in stuttered and fluent words produced by adult stutterers and nonstuttering controls in two reading tasks, and reported that stutters do not exhibit significantly greater vowel centralization than nonstutterers.

At best, the research evidence for abnormal transition characteristics in the dysfluent speech of stutterers is equivocal. Furthermore, the evidence seems to be mostly based on speech material derived from highly structured conditions like reading, or repeating monosyllabic words. This merits further attention to an analysis of more natural speech like spontaneous speech.

However, vowel centralization in the dysfluent speech of stutterers is not the major concern of this study. There is dearth of information on the vowel characteristics in the speech of children who stutter. A study by Howell and Williams (1992) looked into syllable repetitions of 24 children (5.0 to 9.1 years) and 8 teenage stutterers (13.11 to 17.1 years) and reported that formant frequencies of vowels in syllable repetitions to be appropriate for intended vowels and further noted that the duration of dysfluent vowels were shorter than those of the fluent vowels in both groups of speakers.

The purpose of this study was to see if the use of 'more centralized' vowels, for which there is some evidence, is also a feature of child stuttering. The question is if adult stutterers employ more centralized vowels in their speech, then is it something they develop through several years of stuttering? Or is it something that is present in early stuttering? It also becomes necessary to answer the question of whether or not centralization of vowels, if found in the speech of child stutterers, is a part of the developmental process of speech that may be apparent in the normal nonfluencies of nonstuttering children.

Statement of the problem

Therefore, the purpose of the study was to investigate whether centralization of vowels occur in the speech disfluencies of stuttering and nonstuttering children and to compare these findings with those from the speech of adult stutterers. The study was also extended, utilizing the data collected for the above purpose, to probe into some of consonant characteristics in consonant vowel (CV) contexts in the stuttering and fluent productions in the speech of adult and child stutterers.

Objectives

The objectives of the study were to

a) investigate the vowel characteristics in the fluent and dysfluent speech of children who stutter and to compare these findings with those from the speech of adult stutterers,

b) compare the vowel characteristics (in part-word repetitions) in the dysfluent speech of confirmed child stutters with those occurring in the dysfluencies of normally non-fluent children to see if neutral vowels are a part of the developmental process of speech, and

c) analyze the consonant characteristics in dysfluent utterances in the speech of child stutterers and compare these with those from the speech of adult stutterers.

Implication

The significance of the result of this study are largely theoretical. However, more enterprising speech pathologists can utilize information on vowel characteristics in the speech of stutterers to modify their therapeutic approach and to develop new therapy techniques. The results of the comparison between child stutterers and normally nonfluent children may throw up a significant confirmatory indicator for differentiating normally nonfluent children from of child stutterers. For example, if centralization of vowels is a feature of child stuttering, but not seen in normal non-fluencies, then it will help to diagnose child stutterers.

CHAPTER 2

REVIEW OF LITERATURE

> *Fifteen million of our fellows throughout the world, one million in our own land, speak with words whose wings are broken. As stutterers, they are one of the very largest contingents of the disadvantaged, and since the first time their predicament was recorded by the ancients, it has been held to be among the more baffling of mankind's many woes. Not until our century did the mystery show any sign of lifting, and only in the laboratories of today are stutterers and their distinctive difficulties coming to be understood.*
>
> *Wendell Johnson (1963)*

Johnson hoped that stuttering may be understood in his time. But years after that stuttering still remains a riddle unsolved**.** According to Van Riper (1982), stuttering has been called a riddle. It is a complicated, multidimensional jig saw puzzle with many pieces still missing. It is also a personal, social and scientific problem with many unknowns.

While many aspects of the stuttering jigsaw still remain an enigma, researchers worldwide are working towards solving the puzzle. Much research has been carried out, to determine the factors that differentiate a stutterer from a nonstutterer, and investigators have also attempted specification of disparities between the fluent and dysfluent utterances of this group of people.

Thus, in the past decade, a number of investigations have compared the acoustic measures of perceptually fluent and dysfluent speech of both stutterers and nonstutterers'. Apart from the fact that most of these studies have been done on the adult population, relating the results of one study to another is difficult because there are a number of methodological differences between the studies. One such difference is the difference in the material used to obtain the durational and spectral measures of speech. Researchers have used material ranging from isolated monosyllables (Disimoni, 1974) to multisyllable nonsense words (Watson & Alfonso, 1982), CVC tokens (Robb & Blomgren, 1997), short phrases (Healey & Adams, 1981) and conversational speech (Yaruss & Contour, 1993).

This chapter reviews research on speech production in stutterers. The review focuses on studies which suggest that there are aberrations in the speech of stutterers, and highlights the various methodologies which have been employed to conclude the same. This chapter also aims at highlighting how research in the field of acoustic (objective) analysis has evolved and how the state of the art technology allows one to understand stutterer's speech behaviors, compare them with normals and verify hypotheses that serve to demarcate stuttering episodes from the fluent ones.

It goes without saying that stuttering is a disorder of early childhood. Available data show that approximately 75% of reported cases of the disorder develop between the second and seventh year of life (Andrews and Harris, 1964). Part-word repetitions are one of the first observable features to be seen in child stutterers (Johnson, 1955). At least three characteristics of repetition sequences have been identified which might help determine which children are likely to persist with stuttering. These are: (1) properties of the temporal structure of repetitions, that is, rate (Van Riper, 1982); (2) change in the proportion of repetitions relative to the prolongations (Contour, 1982; Van Riper, 1982), and (3) the neutrality of the vowel (Van Riper, 1971; 1982). In adult stutterers, the quality of the vowel is more neutral when spoken in a sequence of repetitions than when the same vowel is spoken fluently. A vowel sounds short because it's short and low in intensity, and not because it is articulated incorrectly (Allen, Peters & Williams, 1975; Freeman, Borden & Dorman, 1976; Howell & Vause, 1986; Prosek, Montgomery, Walden and Hawkins, 1987). Van Riper (1971) further suggested that the occurrence of these neutral vowels in the speech of child stutterers indicates that stuttering may persist. Acoustic analysis of vowels in part-word repetitions and when the same vowel is spoken fluently is the method adopted to address this issue.

It has been known for more than 4 decades now that the stutter-free portions of the speech of some adults who stutter may differ perceptually from those of adults who do not stutter (Wendahl and Cole, 1964; Young, 1964, 1984). Both sophisticated and unsophisticated listeners have been able to distinguish stutterers from nonstutterers based on audio recordings of their fluent speech (Runyan and Adams, 1978, 1979). Acoustic studies of the perceptually fluent speech of groups of stuttering and nonstuttering adults have reported more frequent and longer inter- and intraword pauses (Love and Jeffress, 1971), longer voice onset times (Healey and Gutkin, 1984; Hillman and Gilbert and Adams, 1982) and centralized vowels (Howell and Vause, 1986; Klich and May, 1982) to occur in the perceptually fluent speech of stutterers. These acoustic findings appear to parallel the findings from electromyographic (Freeman, 1984) and electroglottographic studies (Contour, 1984) of vocal fold activity, and of kinematic studies of articulator activity (Zimmerman, 1980). In addition, Metz, Samar, and Sacco (1983) reported significant and positive correlation between the frequency of stuttering and the absence of voicing and frication within the intervals following the release of stop consonants in CV and CVC words as well as between stuttering frequency and the length of the intervals between the release of stop and peak air flow (Samar, Metz, & Sacco, 1986).

The extent to which these perceptual and acoustic differences characterize the fluent speech of stuttering adults, and apply to all speech production tasks, is uncertain because follow-up studies have reported contrary findings (e.g., Few and Lingwall, 1972; Gronhvohd, 1977; Watson and Alphonso, 1982). Some failures to replicate may have resulted from the use of different samples, speech tasks, methodologies, measurers, and data analysis procedures. Following an extensive review of this research, however, Bloodstein (1987) concluded that "the weight of the evidence strongly suggests that what observers consider to be the fluent speech of stutterers frequently reveals features on careful study that are not to be found, at least in the same degree, in the speech of nonstutterers when measuring disfluency." An overlap in the data obtained from subjects who do and do not stutter is evident, even when significant group differences are present (Young, 1993).

Substantially fewer studies have compared the fluent utterances of stuttering and nonstuttering children. Except for some recent studies (for example, Ohashi, Kenjo and Ozawa, 1994; Walker, Shine and Hume, 1994; Prakash, 2000), most perceptual and acoustic comparisons have reported few reliable differences in the fluent speech of normal children and children who stutter in contrast to similar studies adults (Colcord and Gregory, 1987; Krikorian and Runyan, 1983; Winkler and Ramig, 1986; Zebrowski, Contour and Cudahy, 1985).

The present study investigates a total of nine parameters in the fluent and dys/disfluent utterances of adults and children with stuttering, and children exhibiting normal nonfluency. The nine parameters include: 1st and 2nd formant frequencies of vowels, formant transition measures, transition duration from consonant to vowel, extent of transition from consonant to vowel, speed of transition, morphology of F_2 contour, vowel duration, closure duration of stop consonants and voice onset time. This chapter reviews findings from studies which have employed acoustic analysis studies to investigate the differences in each of these parameters in the fluent and dysfluent productions of children and adults who do and do not stutter.

RESEARCH ON FORMANT FREQUENCIES IN THE SPEECH OF PERSONS WITH STUTTERING

Over the past 30 years, there has been continued interest in examining the vowel formant frequency characteristics in individuals who stutter (e.g., Howell and Vause, 1986; Klich and May, 1982; Prosek, Montgomery, Walden and Hawkins, 1987; Stromsta, 1965). As formant frequencies provide information on vocal tract geometry, inferences are made on the position of the tongue inside the oral cavity during the production of vowels (Steven and House, 1955). Generally, vowel formants have been examined in the consonant-vowel (CV) or consonant-vowel-consonant (CVC) contexts in these studies. Using a context such as this allows the vowel to be divided into at least two distinct parts: (1) the formant transition which reflects changes in vocal tract shape immediately following or preceding consonant articulation (Kent and Read, 1992), and (2) the steady-state region in formants which is assumed to reflect a fixed vocal tract posture specific to the vowel (Peterson and Barney, 1952).

Klich and May (1982) examined the steady-state F_1 and F_2 values characterizing the fluent CVC production of seven adults who stutter. The authors found that the stutterers' F_1 and F_2 values to be more centralized compared to nonstutterers, which were interpreted to reflect restricted articulatory adjustments by the stutterers to "control" speech fluency. That is, fluent speech could be more easily maintained by producing vowels using a neutral vocal tract posture within the oral cavity.

However, Klich and May's findings were challenged by Prosek, Montgomery, Walden and Hawkins (1987) who critically evaluated several aspects of Klich and May's studies and noted the following: First, no control group was used to obtain comparable measures under similar conditions. Second, comparisons in stuttered as well as fluent contexts were not made. Some measure of formant frequencies in dysfluent speech is needed to conclude as Klich and May did, that stutterers restrict their articulations to be fluent. Third, data concerning the changes in formant frequencies that accompany changes in rate for normal talkers have demonstrated either that there is no change in formant frequencies as rate increases (Gay, 1978) or that less formal speaking styles will result in faster rates and more centralized vowels (Stallhammar, Karlsson, & Fant, 1973; Koopmans-van Beinuem, 1983). Because the fluent speech of stutterers is slower than that of nonstutterers (Prosek & Runyan, 1982, 1983), formant frequencies should be either unaltered or less centralized than the values attained during dysfluent speech. That is, slower rate of stutterers' fluent speech should allow vowel targets to be fully achieved. Klich and May did not control for the vocal tract size of their subjects. As formant frequencies are dependant to a large extent on the overall dimensions of the vocal tract, vocal tract size should have been taken into consideration when comparing vowel spaces. Thus, some normalization needs to be applied to the formant frequencies.

Prosek, Montgomery, Walden and Hawkins (1987) examined formant steady-states in both fluent and dysfluent CVC samples, obtained from a group of 15 adult stutterers from two reading tasks. For each stutterer, the vowels selected for analysis from the adaptation recording were those that involved a syllable repetition on in the first reading, but which were produced fluently in the fifth reading. Vowel normalization scheme was used to account for differences in vocal tract length, among the talkers and this allowed all vowels to be compared more directly, than non-normalized versions. This study took care of the limitations of Klich and May's (1982) investigation, but failed to find formant centralization in either fluent or dysfluent utterances across the subjects. However, the naturalness of the speech produced, in a reading task, like the one employed may be questioned. The data were gathered using isolated words that were well rehearsed before the recording was made. The authors extended the study to examine formant frequencies in connected utterances using oral reading adaptation task, and arrived at the same result : no vowel centralization in either fluent or dysfluent utterances was found. Prosek, Montgomery, Walden and Hawkins (1987), studied and compared the speech of only adult stutterers within the group and with their peers. Both, Klich and May's (1982) and Prosek, Montgomery, Walden and Hawkins (1987) studies questioned the stability of steady-state vowels produced by stutterers.

Robb, Blomgren and Chen (1998), addressed this question. They examined the steady-state portion of F_2 in the fluent production of CVC tokens and examined the absolute Hz difference in F_2 across consecutive glottal periods. Fifteen adult males served as subjects and were grouped into three groups. The results of this study, revealed that the untreated stutterers displayed greatest formant frequency fluctuation (Gerrat, 1983), followed by the control group, with the treated stutterers displaying the most stable F_2. These findings indicate that disordered articulation is manifested not only when transitioning from one speech sound to the next, but also in the steady-state portion of vowels. This further indicates that the fluent speech of stutterers is more different than similar to that of normally fluent individuals. The results and the ensuing interpretation of this study should be viewed with caution. The number of subjects and speech tokens considered for the analysis were small, and thus the statistical power to determining group differences cannot be ensured. Furthermore, the findings of this study are applicable to the speech of only adult speakers.

Rosenthall, Curlee and Yingyong (1998) reported findings from a series of exploratory acoustic analysis which searched for differences in the fluent vowel, diphthong and wordinitial plosive productions of children who do and do not stutter. They examined formant frequencies of vowels and diphthongs as the authors believed that this measure represents possible precursors to the findings that stuttering adults appear to centralize vowels (Howell and Vause, 1986; Klich and May, 1982). The recorded speech samples analyzed were a subset of those used in the perceptual study reported by Colcord and Gregory (1987). The investigators measured only the first and second formants using LP analysis and root-solving procedures because they provide most of the information required for the correct identification of vowels and diphthongs. The results of this study revealed that there was a significant interaction of the vowels analyzed suggesting that the vowel productions of some children who stutter may differ from those of their nonstuttering peers. This study reported another interesting finding: the stuttering children's mean first formant for /æ/ closely approximated the values presented by Baken (1987) and Olive, Greenwood and Coleman (1993) for the mid vowel /є/. This type of acoustic shift indicates a reduction or a centralization of /æ/, according to Shriberg and Kent (1995). In addition, the results revealed that the first and second formant frequency tracings of /ai/ depicted opposing trends in the transitions of these formants among child stutterers. Moreover the mean of the second formants were seen to approximate the frequency of the centralized phonemes in Olive, Greenwood and Coleman (1993) study. The apparent shift towards a centralized vowel by the four child stutterers did not affect the perceptual identification of the vowel as /æ/ as reported. Thus the extent to which the acoustic differences found in the study are a precursor to those which may result in the perception of schwa vowels among stuttering adults cannot be determined.

Howell, Williams and Young (1991) analyzed the acoustic properties of vowels in children's syllable repetitions to establish whether there are differences between children and adults which might be indicative of the early characteristic and progress of the disorder. The subjects were 24 children and 8 teenage stutterers, whose spontaneous speech was recorded during speech therapy sessions. The investigators selected repetitions involving voiced plosive-vowel syllables so as to minimize the influence of context. Thus this study involved the analysis of the vowel in 184 part-word repetitions for the child stutterers and 72 part-word repetitions for the teenagers and the fluent words that followed these repetitions. The formant frequencies were estimated using Linear Predictive Coding. The results of the study revealed that there were no marked differences between the formant frequencies of the fluent and dysfluent vowels of the children or teenagers. This indicates that both the children and the teenagers position the supra-glottal articulators in an equivalent position in order to produce the intended vowel, whether the vowel is spoken fluently or dysfluently. The fact that these authors did not classify their findings according to the various vowels and that they did not analyze the fluent productions of the vowel in different contexts to the one being stuttered makes the interpretation questionable.

RESEARCH ON MEASURES OF F_2 TRANSITION (TRANSITION DURATION, EXTENT OF TRANSITION & SPEED OF TRANSITION) IN THE SPEECH OF PERSONS WITH STUTTERING

The influence of one phoneme on another is termed *coarticulation* (Whalen, 1990). Only recently have sophisticated acoustic measures permitted a fine grain analysis of the articulatory gestures underlying coarticulation. One such measure is the formant transition slope which estimates the vocal tract adjustments accompanying lingual coarticulation (Sussman, Hoemeke & McCaffrey, 1992).

The calculation of a formant transition slope provides information concerning the spatial adjustments specific to the transition which cannot be garnered form a simple rate-of-change (Hz/time) measure. The duration and extent of formant transition is determined (generally in a CV or CVC context) to derive a formant transition slope and then a slope or “trajectory” for the transition is calculated. Assuming coarticulation involves simultaneous changes in both positional and temporal aspects of phoneme production, the resultant slope coefficient can be regarded as an ordinal index of the rate of change in vocal geometry (Weismer, 1991; Weismer & Martin, 1992). Accordingly, a large slope coefficient would reflect considerable positional and temporal movement of the tongue body inside the oral cavity following consonant release (Weismer, 1991).

Formant transitions in the speech of individuals who stutter have been examined, although specific information pertaining to F_2 transition slopes remains to be collected. Stromsta (1986) and others (Harrington, 1987; Howell and Vause, 1986; Yaruss and Conture, 1993) reported that F_2 transitions characterizing the dysfluent speech of adults and children were either atypical or absent. Studies have varied with regard to the analysis methods and speech samples; however, they seem to confirm that the lingual coarticulation accompanying a dysfluency clearly differs from the coarticulation that characterizes normal fluency. Indeed, Wingate (1969) suggested, almost 40 years ago, that stuttering was a phonetic transition defect where "…the difficulty is not manifested in the articulatory postures essential to that sound, but instead in moving one to the successive one(s)".

The findings of a longitudinal study (Stromsta 1965; 1986) indicated that children who stutter and whose speech disfluencies were characterized by "abnormal formant transitions and abnormal terminations of phonation" were more likely to be judged as stuttering 10 years following initial diagnosis than were other children who stuttered, but did not demonstrate "atypical" formant transitions in their speech disfluencies. Stromsta's findings are potentially very important, for if they can be verified, a speech-language pathologist trying to determine whether a child is at risk for continuing to stutter may need to do a little more than to perform an objective acoustic analysis of the child's sound /syllable repetitions (SSRs). However, Stromsta provided relatively little information about his subjects or about the exact nature of the "abnormal" formant transitions he observed. Stromsta's study also exhibits certain methodological concerns that hinder the applicability and/or generalizability of his findings to clinical practice with other children who stutter. Most notably, Stromsta did not report, in a precise, objective manner, the guidelines used for quantitatively assessing formant transitions, such as the duration or types of disfluencies and the number of iterations per sound / syllable repetition (SSR). Instead, Stromsta stated only that samples were "categorized on a forced-choice basis by experienced judges" (Stromsta, 1965). Therefore, it is difficult to determine the basis for Stromsta's distinction between normal and abnormal transitions. Another evident drawback of Stromsta's study was that the judgments of formant transitions were based on narrow band spectrograms, apparently due to his concern that "wide band width analysis is not suitable for displaying the formant structure of speech generated by children" (Stromsta, 1986). However, several researchers (e.g., Baken, 1987; Fant, 1962; Kent, 1976; Lindblom, 1962) suggest using a filter bandwidth greater than the 300 Hz typically used in wide band spectrograms.

Montgomery and Cooke (1976) reported preliminary results of a perceptual and acoustic analysis of a carefully selected set of fourteen part-word repetitions from the speech of adult stutterers. The utterances were taken from conversational speech samples and adaptation sequences. Results indicated that the schwa vowel was perceived in only 25% of the repetitions, far less than previously indicated. Spectrographic analysis showed that although abnormal consonant duration and C-V formant transitions characterized the initial segment of the stuttered word, the remainder of the word is identical to its fluently produced counterpart. The results were interpreted by the authors to mean that for the type of dysfluency selected, the articulatory breakdown is confined to the initial consonant, and it is likely that abnormal formant transitions from initial consonant to vowel, when present, are due to deviant formation of the consonant rather than to faulty transition dynamics. They concluded that the vowel portion of the repetition is normally not the neutral vowel. It often approximates the intended vowel of the word being produced. No extension of the study can be made to explain stuttering in general because the study was conducted using a sample as small as fourteen sound/syllable repetitions from the speech sample of only adult stutterers.

Yaruss and Contour (1993) examined the relationship between second formant (F_2) transitions during SSRs of young children who stutter and their predicted chronicity of stuttering. The investigators recorded 30 minute conversational speech samples from 13 youngsters, who were divided into two groups (high risk group and low risk group). Ten SSRs per child were analyzed spectrographically to identify differences in F_2 transition between the stuttered and fluent portions of the word. Five acoustic measures wereconsidered 1) Duration of F_2 transition; 2) Onset and 3) Offset of F_2 transitions; 4) Extent of F_2 transitions (the congruency of the inflection with the fluent production was also noted); and 5) Rate of frequency change. The results of this study indicated that some aspects of F_2 transitions, specifically, variation in the duration of F_2 transition, in the child's SSR's, may provide a useful gauge of a child's risk for continuing to stutter. The point to be pondered in this analysis is that the authors restricted the analysis to the repeated (stuttered) portions and the fluent (nonstuttered) portion of the word immediately following it, and did not compare it with a word that is completely produced fluently, in another context.

Prakash, Saji and Savithri (1998) studied three stuttering and two normally nonfluent children's SSR's and indicated that children who stutter produce missing or atypical formant transitions. This finding was consistent with findings of Stromsta (1965, 86) and Yaruss and Contour (1993).

An analysis of F_2 transisitons in the speech of stutterers and nonstutterers was examined by Robb and Blomgren (1997). They studied lingual coarticulation by determining the slope of the second formant F_2 transition following consonant release. Five adult male stutterers and five adult male nonstutterers served as subjects in this study and tokens embedded in carrier phrases were used as stimulus material. (CVC tokens in which the last consonant was always an alveolar 't', therefore, (CVt). Acoustic analysis of the CVt tokens was carried out and the results revealed a general pattern of F_2 onset and offset values which were similar across both groups. The F_2 transition onset values were consistently higher for CVt tokens containing /i/, while the onset values associated with /u/ and /a/ tokens varied. In general, results revealed that stutterers were found to display larger slope coefficients in comparison to the nonstutterers. The large coefficients were interpreted to reflect greater dimensional changes in vocal tract behavior compared to those of nonstutterers. These findings were in consonance with Zimmerman's (1980). However, the results and interpretations of this study should be viewed with caution. Although a detailed acoustic analysis was performed, the number of subjects and speech tokens considered in the analysis was too small. In addition, there is a school of thought which believes that it is inappropriate to compare the perceptually fluent speech of stutterers to nonstutterers because of inherent difficulties in fully “removing” the influence of stuttering from the research paradigm (Armson and Kalinowski, 1994). For these reasons, the results may not be representative of the stuttering population as they are of individual stutterers.

There are a few unpublished studies carried out in the Indian contexts which explored F_2 transition measures in stutterers. The first of such studies was by Suchithra (1985). She studied F transition in 2 adult stutterers and 2 normals in 54 VCV nonsense syllables using both narrow band and wide band spectrograms and found that: (i) when the F_2 of the initial vowel was falling in normals, it was steady in the fluent utterances of stutterers; (ii) when the F_2 of the final vowel was steady in normals, it was rising in the fluent utterances of stutterers, and (iii) the F_2 was missing in a number of VCV sequences in the fluent speech of stutterers which was not seen in normals. The results were interpreted to indicate that articulator configurations required for the production of a phoneme in question were not fully achieved by stutterers.

Mohan Murthy (1988) studied the acoustic and laryngeal events during stuttering in a 17-year old male subject with severe stuttering. Using wide band spectrographic analysis a total of 29 dysfluencies obtained pretherapeutically were analyzed and compared with the fluent counterparts obtained after therapy. Results revealed atypical transitions in stuttered events compared to the fluent productions. The stuttered events were found to have faster transition rate in the fluent production of the same.

Revathi (1989) measured the acoustic temporal parameters in 2 children with stuttering and 2 children with normal nonfluency to differentiate between the two groups. Story narration and picture naming were recorded and wide band spectrograms of the fluent utterances were obtained. Transition duration and speed of transition of F_1 and F_2 were measured. The results revealed abnormal F_2 transition in the speech of children with stuttering with faster speed of F_1 and F_2 transition. Conclusions from these two studies on just 2 stutterers and 2 normals cannot be generalized.

Raghunath (1992) analyzed the acoustic dimensions of articulatory dynamics in stutterers. Spontaneous speech samples of four adult male stutterers were audio recorded and perceptually fluent and dysfluent utterances of the same were selected. Using wide band spectrography, five temporal parameters including transition duration and speed of transition were measured. The results indicated lack of F_2 transition; longer transition duration of F_2, inappropriate transitions and related these findings to errors of coarticulation. This study was restricted to analyzing the speech of only adults with stuttering, and more extensive studies are required to confirm these findings.

Prakash (2000) investigated the efficacy of refined acoustic parameters as indicators of stuttering and normal nonfluency. In this study, conversational speech samples from 20 Kannada speaking children (10 children with normal nonfluency and 10 children with stuttering) were audio recorded. SSR's were identified, transcribed and analyzed, using spectrographic analysis, to obtain measures of F_2 transition. The results revealed that children with stuttering exhibited longer transition duration, shorter extent of transition, faster speed of transition and abnormal F_2 transition pattern. The results of this study should be interpreted with caution. Although the study involved elaborate acoustic analysis, the total number of SSR's analyzed was only ten for each group. More extensive studies are required to confirm the findings and draw conclusions.

RESEARCH ON VOWEL DURATION IN THE SPEECH OF PERSONS WITH STUTTERING

A number of investigations have compared temporal acoustic measures like vowel duration and voice onset time of stutterers' and nonstutterers' perceptually fluent and dysfluent speech. In this section of the review, the focus will be to highlight the findings of these studies on vowel duration. Interestingly, differences between the duration of vowels of either fluent/dysfluent utterance of "stutterers" and "nonstutterers" cannot be predicted from these studies because they show divergent results. A few found longer vowel durations in stutterers when compared to the nonstutterers while a few others reported shorter durations. Some studies reported no significant difference between the groups for this measure. Several studies quoted in this section have already been summarized in the previous section and therefore, only the results pertaining to vowel duration have been discussed here.

Disimoni (1974) was one of the first investigators to compare the timing and durational features of stutterers and nonstutterers' speech. He used isolated words and found that consonant and vowel durations of adult stutterers were more variable than were the same measures obtained for a group of nonstutterers. Stutterers had a significantly longer consonant and vowel durations in their repeated and fluent productions.

A few years later, Cooper and Allen (1977) investigated the speech-timing control accuracy of stutterers and nonstutterers using both speech and nonspeech activities. In general, they found that their group of stutterers tended to be less accurate in their timing abilities than was the control group of stutterers in all experimental tasks. The data also showed a wide range of timing abilities among the subjects, with some stutterers performances equal to those of certain nonstutterers. One additional finding from the study of Cooper and Allen is that stutterers released from therapy were more accurate "timers" than were stutterers still receiving therapy. The researchers concluded that stuttering could not be considered a speech-timing disorder in all cases. Rather, stutterers' speech timing difficulties represent "one possible explanation of some stuttering" (Cooper and Allen, 1977).

Prosek and Runyan (1982) studied the duration of vowels that were primarily stressed in a paragraph length utterance produced by 35 stutterers and 35 nonstutterers, and found that the average duration of the vowels that received stress was significantly longer in the group of stutterers than nonstutterers. Because the measurement was restricted to primary-stressed vowels, different results may have been obtained if the durations of all vowel segments had been included.

The speech timing skills of normally fluent, stuttering children and adults were studied by Healey and Adams (1981). The investigators studied four groups of male subjects: normally fluent adults, normally fluent children, stuttering adults and stuttering children. Every subject was asked to produce 10 consecutive fluent repetitions of each of two test sentences, in two conditions: basal rate condition (BRC) and modified rate condition (MRC). Four temporal measures were then obtained using spectrographic analysis. Results of this study revealed that the two groups of children produced speech durational values similar to those of the two adult groups. The results also revealed that between and within-group findings lacked consistency with regard to BRC and MRC. This suggests that the speech task used for this study tapped similar speech timing skills possessed by all four groups. These results are not in accordance with many other studies which report children to have longer vowel durations than adults. The most notable value of this is its demonstration of how a simplified speech task can serve to equalize the otherwise disparate speech timing skills of stutterers and normals. However, the results of this study lead to no conclusion on the exact nature of the speech timing skills in either children or adults. Klich and May (1982) and Zebrowski, Contour and Cudahy (1985) similarly reported no significant differences between vowel duration in the speech of stutterers compared to nonstutterers, and between stutterers and normally nonfluent, respectively.

In a pre-post therapy comparison study, Metz, Contour and Caruso (1979) reported that vowel duration of stutterers were longer following therapy than during pretherapy. Mohan Murthy (1988), in a single case study, reported that the stuttered segments had inappropriate duration of segments when compared to their fluent counterparts analyzed posttherapeutically.

Although vowels appear to be articulated correctly and can be perceived as intended, it is possible that they may sound like schwa in some circumstances. It is important to resolve the issue whether true schwas occur in stuttered speech because it has some practical implications: the way stuttering is explained shapes the way it is treated and helps differentially diagnose stuttering early. Howell and Vause (1985) studied monosyllabic words produced by seven male and one female stutterer. Thirty vowels were acoustically analyzed (the vowel in the dysfluency before the word was spoken fluently and the fluent item were employed for analysis) and the findings revealed that stuttered vowels were shorter in duration and lower in amplitude. In the second part of this experiment, perception of schwas in stuttered speech was studied which indicated that amplitude and duration are important determinants of why stuttered vowels sound like schwa. Howell and Vause (1985) did not mention the exact age of their subjects, but said that they were adults. These investigators have not included children in their study, and data such as this in children would prove important especially in terms of early differential diagnosis between children with stuttering and normal nonfluency.

Mallard and Westbrook (1985) studied the vowel duration of stutterers participating in the precision fluency shaping program and found that extended vowel duration were characteristic of the fluency of stutterers' post therapy.

Pindzola (1987) reported vowel duration to be the same in both normals and stutterers. From his study he speculated that if temporal compensations was the effect which operates to modify the duration of internal segments of the articulation, so that the overall duration of the unit remains relatively constant, then the remaining programs in stutterers was forced by these temporal constraints to move faster throughout the transitional segments, which resulted in temporal differences between the groups.

The study done by Revathi (1989) also included the measurement of vowel duration in stuttering children and their normally nonfluent peers in words and sentences. The results revealed that children with stuttering displayed significantly longer vowel duration in their fluent utterance both at the word level and the sentence levels. Raghunath (1992) reported similar findings.

Robb, Blomgren and Chen (1998) studied vowel duration in a group of treated, untreated stuttering (adults) and normal speaking adults using CVt tokens. The findings reported longer duration of vowels in stutterers compared to normal speakers. Among the stutterers, the treated group had longer vowel duration than the untreated stutterers.

Reimann (1976) compared the vowel duration of normal speaking adults and stutterers and reported shorter vowel duration relative to the duration of the whole word in stutterers than nonstutterers. In a study already described previously, Howell and Williams (1991) reported shorter vowel duration in the dysfluent utterances than in vowels produced fluently. This finding was consistent across both the child and teenage stutterers. Prakash (2000) also reported that vowel durations were significantly lower in stuttering children compared to children with normal nonfluency.

RESEARCH ON VOICE ONSET TIME AND CLOSURE DURATION IN THE SPEECH OF PERSONS WITH STUTTERING

In the past decade considerable attention has been focused on the specification of differences in the speech of adult stutterers and nonstutterers. Much of this interest in the laryngeal behaviors of stutterers received its impetus from Wingate's hypothesis regarding the relationship between vocalization and stuttering (Wingate; 1969, 1970). Direct evidence has been provided which suggests that aberrant laryngeal activity is related to stutterers' dysfluencies (Contour, McCall and Brewer, 1977; Freeman and Ushijima, 1978, Shapiro, 1980). Moreover, research has indicated that disruptions in stutterers' laryngeal behaviors characterize their fluent speech. In that regard, stutterers have been reported to exhibit slower voice onset, initiation and termination times (Adam and Hayden, 1976; Agnello 1975; Hillman and Gilbert, 1977). However, like all findings in the field of stuttering, this conclusion cannot be accepted because several other studies have reported contradictory findings (E.g. Metz, Contour and Caruso, 1979). Bloodstein (1981) remarked: *"Inconsistent and Conflicting Findings in the Literature on Stuttering Appear to be a Rule Rather than an Exception"*. This remark still holds good considering all the conflicting evidences reviewed so far.

Elaborating on the studies investigating voice onset times and closure duration, the preliminary study reported by Agnello (1975), seems to be one of the first its kind to be reported in literature. He reported the results of a study on voice onset times and voice termination times in the fluent speech of stutterers and nonstutterers. Agnello analyzed nonsense syllables spoken fluently by stutterers and normal speakers and reported that stutterers had longer voice onset and termination times compared to nonstutterers. Brown (1938) Eisenson and Horowitz (1945) and Wingate (1967) showed that speech of stutterers changed depending upon the type of speech sample produced, for example, isolated versus contextual speech. As a consequence, the finding reported by Agnello (1975) for nonsense syllables may not be applicable, or indicative of VOT measures, in contextual speech.

The VOT data reported by Agnello has been further questioned by Freeman (1975). Freeman (1975) noted discrepancies between voice onset time (VOT) values reported by Agnello for nonsense syllables produced by normal speakers and VOT data reported by Lisker and Abrahamson (1967) for isolated words. The VOT value reported by Agnello for /b/ approximated that reported by Lisker and Abrahamson. However, the VOT value reported by Agnello for /p/ was considerably shorter in duration than the value reported by Lisker and Abrahamson.

Hillman and Gilbert (1977) compared intervocalic voiceless stop consonant segments produced by ten stutterers and ten normal adults, in a reading task. Using wide band spectrography VOT measurements were obtained. The results of this study revealed that (i) stutterers displayed longer VOT values than nonstutterers, (ii) and that VOT values increased in duration as place of articulation moved back in the oral cavity. In this study, the investigators compared between groups and did not attempt to compare the findings within fluently and dysfluently produced utterances of stutterers.

Healey and Gutkin (1984) examined the VOT from target syllables located at the beginning of a carrier phrase as spoken by 10 adult male stutterers and age and gender matched normals. Results showed that VOT's for voiced stops were significantly different between groups. The authors concluded that significantly greater differences emerge between stutterers and nonstutterers when measures of fluency are taken for word-initially syllables. But these authors did not compare the findings across different stimulus material. Thus, a conclusion based on these findings should be taken with care.

Metz, Contour and Caruso (1979) obtained measures of stutterers' and nonstutterers' voice onset times from monosyllables embedded in a carrier phrase. Their results showed that approximately two-thirds of the VOT values were not significantly different between the two groups.

Furthermore, Watson and Alfonso (1982) examined differences between stutterers' and nonstutterers', voice onset times (VOT's) for nonsense syllables consisting of three contiguous VCVC segments. The results of the study indicated no disparities between the two groups.

Zebrowski, Contour and Cudahy (1985) measured nine acoustic variables in a study that has already been summarized in the previous section. These nine parameters included VOT and stop gap duration (Closure duration). Results indicated no significant differences between young stutterers and their normally nonfluent peers for any of the temporal measures for either /b/ or /p/.

It can be seen from the above review that none of the findings with respect to any factor is unequivocal. Given the heterogeneity of the stuttering, this is expected.

The other factor becomes evident from the review: one, that the majority of the studies have analyzed the speech of adult stutterers; two, that the speech materials analyzed have been obtained from very unnatural methods. The implication is that all the factors make the generalization of the result of these studies suspect.

There is some evidence for vowel centralization in the dysfluent speech of stutterers (Van Riper, 1971). As this finding comes from a comparative analysis of the acoustic features of dysfluent utterances and the fluent production of the same, the evidence can be considered valid. However, if this is related to the occurrence or maintenance of stuttering, then it should also be evident in the speech of children who stutter. A comparison of child and adult stutterers would show whether centralization of vowels is a feature that is acquired after years of stuttering. Furthermore, if centralization of vowels is present in the dysfluent speech of stuttering children, then it is of theoretical interest to see if this is a feature of the developmental process of speech. A comparison of the vowel characteristics in the speech of stuttering children with those of normally nonfluent children would throw light on this.

CHAPTER 3

METHOD

Experiments were conducted to analyze the acoustic features of vowels and consonants, in part-word repetitions occurring in the speech of children and adults with stuttering, and normal nonfluencies in the speech of children. The purpose was to see if vowel centralization occurs in the part-word repetitions of CV sequences, in the speech of adult stutterers, and if yes, then whether it is something that is developed through many years of stuttering or does it occur in the speech of child stutterers also. The issue of whether or not centralization of vowels is a part of the developmental aspect of speech was also probed by analyzing the normal nonfluencies of normal children and comparing it with those in the dysfluencies of child stutterers.

Subjects

Three groups of subjects participated in the study. Group A consisted of 6 Kannada speaking stuttering children in the age range of 3-7 years. Group B consisted of 6 Kannada speaking children, matched for age and gender, exhibiting normal nonfluencies. Group C consisted of 6 adult stutterers, both males and females, in the age range of 16-30 years. The adult stutterers had stuttering history of 12 to 26 years as reported by them. Only those children and adults referred by a speech pathologist (who had 10 years of experience) were included in the study.

1. The diagnosis of stuttering was done by speech-language pathologists based on standardized test tools like Stuttering Predictive Instrument (Riley, 1986) in

the case of children (Group A) and Stuttering Severity Instrument (Riley, 1986) for adults (Group C).

2. Children with normal nonfluency were identified by the speech pathologist following extensive interviewing with parents and teachers to find out the nature and degree of disfluencies. The speech pathologist informed that a decision on normal nonfluency in children was arrived at after considering the frequency of stuttering, predominant presence of whole word repetitions, and absence of tension or struggle reactions in speech.
3. None of the subjects had any complaint of hearing impairment, mental retardation language delay, learning disability or any other neurological impairment. This was confirmed by the speech language pathologist with the administration of appropriate checklists.

Material and Recording

Samples of spontaneous speech of a duration of 30 to 40 minutes were obtained from each of the subjects.

The children in group A and B described a series of pictures in which each series made up a different story. Five such picture story charts were used to elicit speech samples. The stories included: “The Thirsty Crow”, “The Fox and the Crow”, “The Lion and the Mouse”, “The Fox and the Grapes” and “Two Friends and the Bear”. All the chosen stories are very commonly told (and enacted) in most preschools and thus are familiar to most children between the ages of 3 and 7. The interviewer mentally noted the occurrence of stuttering on words, and then asked simple questions in such a way that the child was given a chance to come out with such words on which stuttering had occurred previously (the target word) again and again. Children were also encouraged to repeat the target word embedded in a sentence without giving an impression that it is a ‘repeat after me’ exercise. The aim of the whole exercise was to get as many words as possible which have CV context syllables, both fluent and dysfluent.

The adult stutterers in Group C spoke in an interview situation, where they were asked to speak on topics of contemporary relevance and other topics of interest. Here too questions were asked in such a way that the subjects used the target words (dysfluent words) occurring initially in their discourse in different phonetic contexts.

All subjects were comfortably seated in a sound treated room in the speech science laboratory or in a quiet room. The speech samples were audio recorded on a mini disc recorder (Sony digital MZR30). All subjects spoke in Kannada, a Dravidian language, spoken in this part of India.

Judgment of stuttering

The recorded speech samples were played to the experimenter and another speech language pathologist who had more than three years of experience in the area. They identified the dysfluent utterances (part-word repetitions) and the fluent productions of the same units. The speech samples were played as many times as required by the judges till they were sure that all the instances of the stuttered repetitions and the fluent productions of the same units were identified. Stuttering was defined, following Wingate (1964), as any audible or silent repetition of a sound or syllable, or any audible or silent prolongation of a sound. Only those instances of stuttering on which both judges agreed were considered for analysis.

Test-retest reliability

Test-retest reliability of the judgments of the two judges (the experimenter and another speech pathologist) was tested by asking the two judges to judge a portion of the speech (15%) of the subjects in each of these groups. A product moment correlation of 0.98 was obtained between the two sets of judgments. Test-retest reliability was carried out 20 days after the first judgment in each case.

Acoustic Analysis

Only instances of part-word repetitions were considered for further analysis. All relevant units of the stuttered speech (part-word repetitions) and their fluent utterances were transferred to a master tape for further analysis. The recorded material were line fed from the cassette deck onto computer memory, digitized using a 16 bit A/D converter of the CSL (Computerized Speech Lab, Kay Elemetrics) at a sampling rate of 16kHz.

Word pairs in the master tape consisting of fluent and dysfluent utterances and their fluent productions were analyzed separately. Each token had the following sequence, for example:

pΛ - pΛ ……………pen - pen

1 2 3

‘1’ refers to dysfluent utterance, ‘2’ to the eventual fluent utterance of the intended word, and ‘3’ to the same word occurring in as a fluent production in some other context in the speech. The dysfluent utterance could have one repetition (pΛ), or two (pΛ- pΛ) or more. All measures obtained over the dysfluent portions were averaged. Similar measures were obtained on the fluent utterances (‘2’in the above example) and on the same word occurring in some other context (3 in the above example). In all the analysis, average measures of ‘1’ above has been compared with ‘2’ and ‘3, and ‘2’ in turn has been compared with ‘3’ (as given in the above sequence).

Each token was displayed as a broad band spectrogram with a pre-emphasis and a band width of 146 Hz in a ‘Hamming’ window weighting. The spectrogram was displayed in monochrome [black on white] on a grid of 8 × 8 pixels and a linear vertical axis display.

Using the cursors the following measurements were made.

1. First formant frequency - F_1
2. Second formant frequency - F_2
3. Morphology of the changing F_2 contour
4. Vowel duration
5. Extent of transition
6. Transition duration
7. Speed of transition (Extent of transition / Transition duration).

F_1 & F_2 were counter verified by super imposing the LP formants (linear predicted formants) on the spectrogram display.

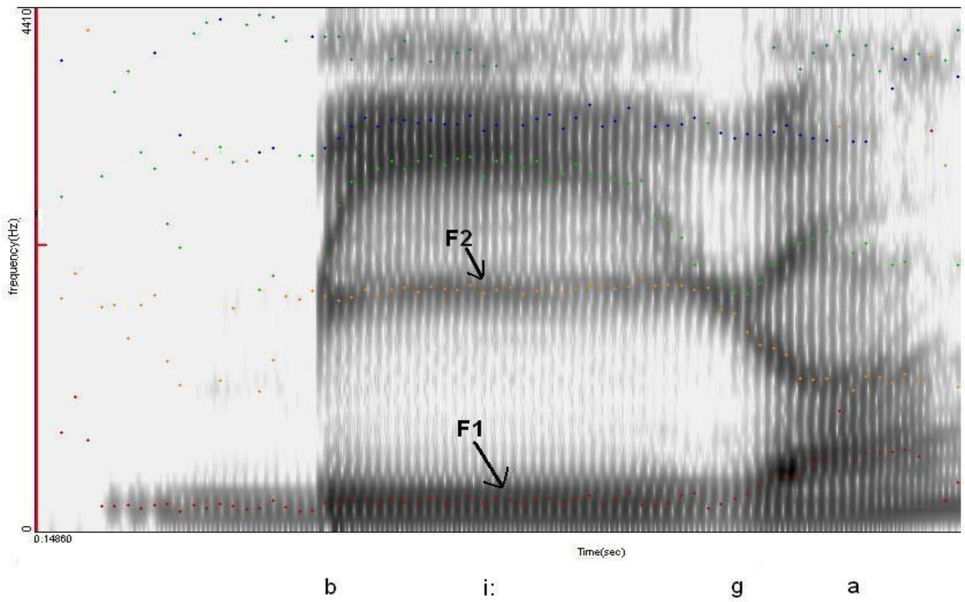


Figure 3.1 Spectrogram of a male adult speaker's fluent production of /bi:ga/, showing the measurement of formant frequencies (F_1 & F_2)

1 & 2. Formant Frequencies (F_1 & F_2) were measured by placing the cursor on the vowel steady state and then superimposing LPC spectra and obtaining the numerical values therefrom. The formants were thus measured as the average of all the F_2 values in the vowel steady state. Figure 3.1 illustrates the measurement of F_1 and F_2.

3. Morphology of F_2 contour was assessed by identifying the sign of F_2 transition and then determining whether the "inflection" (i.e. upward, downward bending of a formant on the frequency axis, Stomsta, 1986) in the stuttered/disfluent portion was similar to that of a comparable fluent transition or was atypical. These atypical patterns were noted. F_2 transition that demonstrated an upward inflection resulted from a negative formant transition, that is < 0 Hz [that is onset of frequency $<$

offset frequency was termed as rising pattern (Stromsta, 1986)}. Downward inflections which resulted from a positive transition, that is > 0 Hz [that is onset frequency > offset frequency] were termed as falling pattern (Stromsta, 1986). When there was no inflection, that is, when the extent of formant transition was 0Hz, then it was termed a flat pattern (Stromsta, 1986) or absent F_2 transition. Some of these are illustrated in Figure 3.2.

A		B		C	
Normal	Rising	Normal	Falling	Normal	Flat

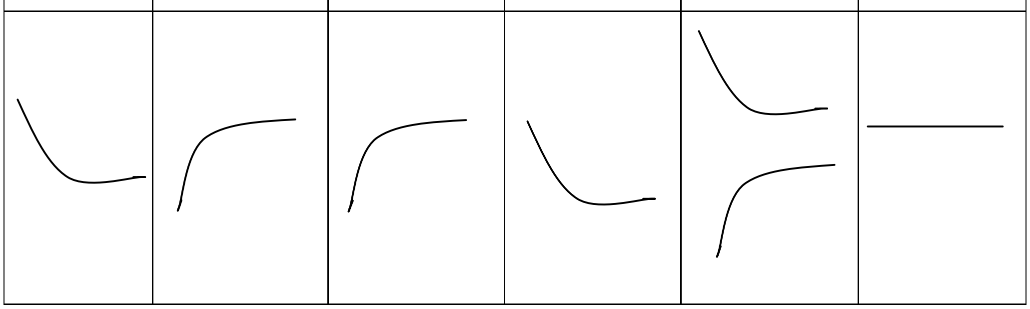


Figure 3.2: Atypical F_2 transition patterns

4. Vowel Duration (VD) was measured as the time duration between the onset and offset of the vowel which was marked by placing two vertical cursors (see Figure 3.3).

5. Extent of F_2 transition (EOT) was estimated by calculating the difference between the offset and onset center frequency of the F_2 transition (Figure 3.3). This is believed to represent the overall movement of the articulators during transition.

6. Transition Duration (TD) of F_2 was measured as the time difference in msec (Figure 3.3) between the onset of F_2 transition to the beginning of the vowel from the end of the previous consonant. The beginning of the steady-state portion of the following vowel was defined as the time when the formant paralleled the time axis (Chaney, 1988; Kent Forner, 1979; Kewley-Port, 1982; Klich & May, 1982; Yaruss & Conture, 1993). This measure of F_2 transition duration is believed to be the duration the articulators take for moving from one position to another.

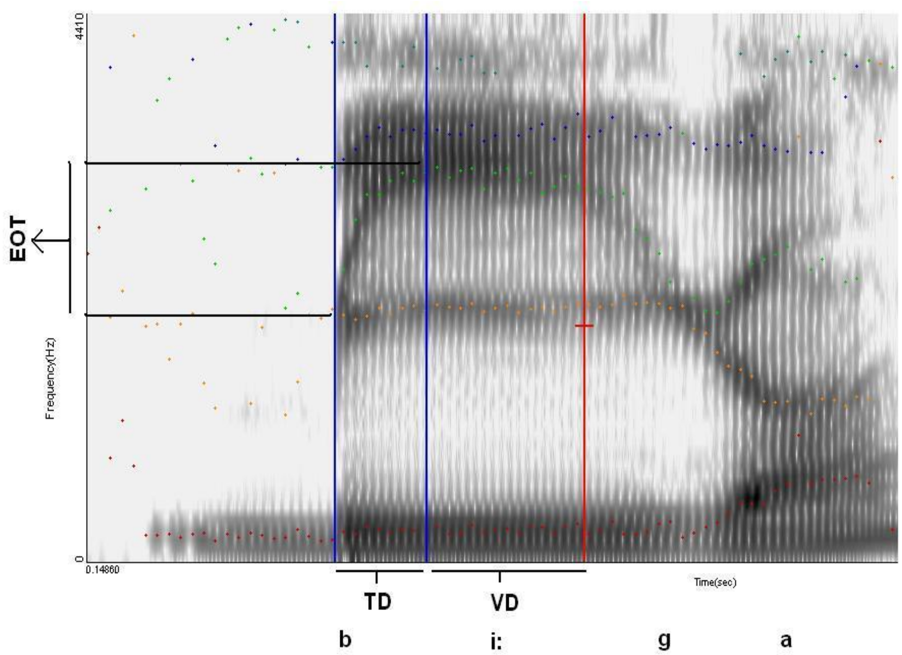


Figure 3.3. Spectrogram of a male adult speaker's fluent production of /bi:ga/. The vertical cursors show the measurement of vowel duration (VD), extent of transition (EOT) and transition duration (TD).

7. Speed of F_2 transition – the speed with which the F_2 changes during transition. It was measured as follows:

Extent of F_2 transition

$$\text{Speed of } F_2 \text{ transition} = \frac{\qquad}{\text{Duration of } F_2 \text{ transition}}$$

This is believed to reflect the speed with which the articulators move from one location to another.

In addition, the following measurements were made with respect to consonants (CV repetitions):

1. Voice onset time (VOT) was measured (in msec) from the onset of the oral release of the stop-plosive, to the onset of voicing. This measurement reflects the time taken for initiating voice after oral release and is depicted in Figure 3.4.
2. Closure Duration (CD) was measured from cessation of acoustic energy for the preceding sound ("a" in Figure 3.4) to the onset of acoustic energy associated with the articulatory release burst beginning for the subsequent word initial stop-plosive ("p" in Figure 3.4) of the test word (a vertically oriented concentration or "burst" of energy).

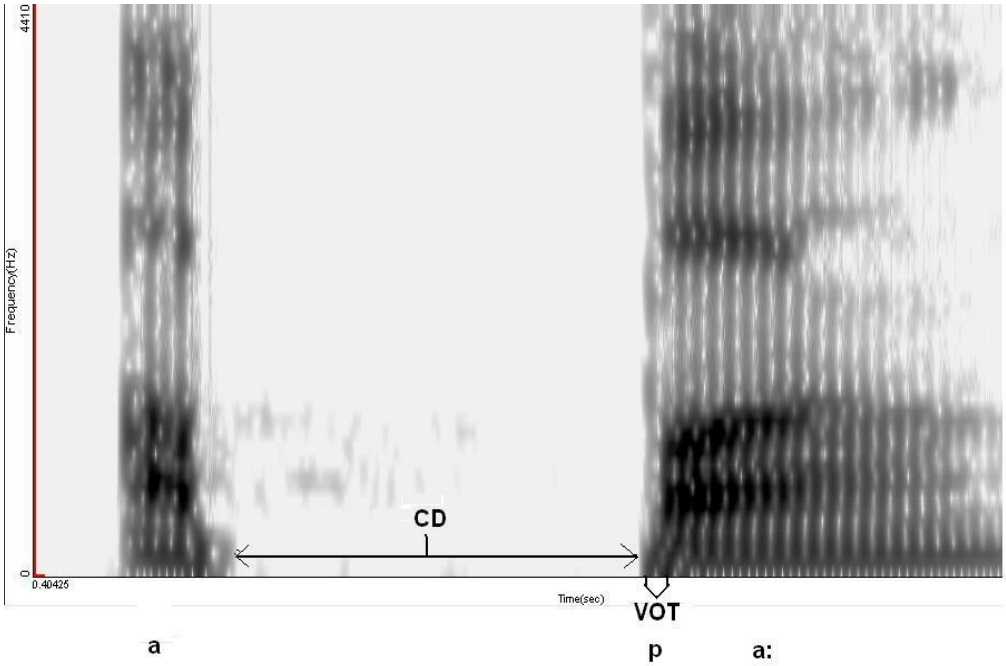


Figure 3.4. Spectrogram of a male adult speaker's fluent production of /a pa:/ showing the measurement of voice onset time (VOT) and closure duration (CD).

CHAPTER 4

RESULTS

The present investigation examined nine different acoustic events (temporal and spectral) in the spontaneous speech of three groups of subjects: six adult stutterers, six child stutterers and six children with normal nonfluency. A total of 180 pairs of fluent and dysfluent utterances were analyzed to compare the three groups of adult stutterers, child stutterers and normally nonfluent children, on several parameters.

The results will be presented in four sections. The first section will compare the average F_1 and F_2 data for each of the vowels analyzed, between the speech conditions - average of the dysfluent segments (AVG); the fluent production in the dysfluent context (FLD) and the fluent production of the same segment in a completely fluent context (FL) - and between groups. The second section will compare the average vowel duration (VD) within and between the groups. Data on measures of F_2 transition - Extent of transition (EOT), Transition duration (TD), Speed of transition (SOT) and morphology of F_2 contour) will then follow in the third section. The fourth section will present the result of two consonantal features, namely, closure duration (CD) and voice onset time (VOT).

Section 1: Formant Frequency Measures

A total of 200 pairs of dysfluent utterances (part-word repetitions) and fluent production of the same units were available for analysis across the three groups in the three speech conditions (AVG, FLD & FL). Each of the tokens was classified according to the vowel contained. However, 20 pairs of fluent and dysfluent utterances containing vowels /e:/, /u:/ and /o:/ were not analyzed because of their small sample number. In effect, 180 samples were analyzed for the three groups of subjects. Table 4.1 shows the average $F_1$and F_2 for dysfluent vowels in the three groups and for the three different speech conditions. ‘N’ in Table 4.1 represents the number of dysfluent (part-word repetitions)/fluent pairs, containing the respective vowel in CV syllable contexts. The F_1 average shown in Table 4.1, for example 495.87 Hz (column 3, 1^{st} row) is the average F_1 value of all the 16 tokens with vowel /a/ in the AVG condition. Other values should be interpreted similarly.

Speech Condi-tions	Vowel	Adult Stutterers			Child Stutterers			Normal Nonflueny		
		F1	F2	N	F1	F2	N	F1	F2	N
AVG	a	495.87 (104.75)	1309.10 (181.65)	16	615.25 (195.53)	1478.37 (281.10)	24	632.99 (130.22)	1489.44 (119.31)	18
	e	504.64 (106.95)	1449.60 (203.37)	11	559.13 (10.50)	1218.70 (218.37)	5	529.17 (59.68)	1348.91 (200.89)	8

	u	394.50 (64.80)	1298.80 (67.18)	7	533.82 (165.53)	1680.14 (114.00)	7	537.36 (70.45)	1543.85 (341.28)	6
	o	365.44 (48.35)	1211.20 (330.65)	3	734.29 (119.27)	1535.25 (96.96)	8	613.44 (46.26)	1485.44 (456.03)	8
	i	450.68 (180.99)	1671.98 (330.65)	8	630.71 (167.22)	1255.86 (665.00)	10	472.56 (95.29)	1865.77 (576.77)	12
	a:	472.29 (115.97)	1169.98 (187.35)	11	794.24 (170.35)	1381.34 (237.90)	10	977.76 (106.82)	1289.77 (130.44)	8
FLD	a	607.80 (122.03)	1507.03 (183.91)	16	749.25 (203.91)	1769.24 (303.18)	24	685.03 (131.73)	1670.44 (180.91)	18

	e	475.74 (42.55)	1851.92 (195.49)	11	641.34 (61.56)	1979.51 (551.21)	5	574.04 (67.29)	1880.96 (320.00)	8
	u	416.56 (57.81)	1151.41 (91.02)	7	462.35 (96.27)	1316.77 (140.21)	7	440.30 (73.06)	1492.41 (318.77)	6
	o	429.14 (49.97)	1018.55 (66.42)	3	545.33 (148.47)	1175.60 (22.32)	8	621.33 (55.29)	1444.30 (450.52)	8
	i	358.53 (33.53)	2154.27 (362.93)	8	447.83 (93.97)	2390.18 (474.49)	10	458.54 (109.38)	2001.13 (456.85)	12
	a:	675.06 (83.11)	1339.62 (107.11)	11	1113.39 (140.26)	1822.92 (145.11)	10	988.68 (193.06)	1855.69 (127.55)	8

FL	a	625.28 (111.29)	1495.30 (228.01)	16	747.12 (164.06)	1852.83 (233.49)	24	676.48 (110.51)	1868..90 (266.54)	18
	e	500.32 (38.28)	1857.24 (165.72)	11	593.81 (25.29)	2554.87 (253.88)	5	552.32 (64.06)	2458.56 (134.64)	8
	u	421.16 (61.08)	1137.30 (130.42)	7	495.48 (88.08)	1262.53 (153.33)	7	460.41 (53.43)	1543.97 (260.97)	6
	o	466.22 (22.78)	1120.49 (130.42)	3	578.93 (112.96)	1174.05 (11.93)	8	589.71 (83.06)	1311.01 (407.53)	8
	i	361.74 (27.80)	2210.49 (228.68)	8	441.85 (61.05)	2718.06 (197.83)	10	477.51 (108.32)	2360. 63 (474,68)	12

	a:	697.15 (71.86)	1439.42 (117.03)	11	1118.08 (245.55)	1824.93 (94.73)	10	1003.10 (86.91)	1870.67 (120.98)	8

Table 4.1 : Mean values of $F_1$and F_2 for the different vowels produced by three groups of subjects – adult stutterers, child stutterers and children with NNF. Standard deviations are shown in parenthesis. N refers to the number of tokens with a given vowel. The values $F_1$and F_2 refer to the average of all the tokens for a given vowel.

In Adult Stutterers : Analysis of variance (ANOVA) with repeated measures was performed. The analysis revealed a significant difference found between the three conditions for F_1 [F (2, 10) = 7.669, p< 0.01]. Bonferroni post-hoc analysis revealed a significant difference between the AVG and FL contexts (p< 0.05), with the difference depending upon the vowels. A similar procedure was carried out for F_2 and the findings revealed a highly significant difference between the conditions for F_2. [F (2,10) = 22.402, p< 0.001] and on post- hoc analysis a significant difference was found to exist between the AVG and FLD contexts as well as the AVG and FL contexts (p< 0.05), with the difference depending upon the vowels.

ANOVA was performed to study the difference, if any, between vowels in each of three different conditions. The results revealed no significant difference between vowels in the AVG condition [(F (5, 52) = 1.826, p= 0.124] for F_1. It means that all the vowels were clustered together. But there was a highly significant difference between the F_1 of vowels in the FLD [F (5, 52) = 21.905, p< 0.001] and FL conditions. [F (5, 52) = 21.905, p< 0.001]. Duncan's post-hoc test, was then used to find out which of the vowels significantly differed from each other for F_1. It was found that in the FLD condition: F_1 of vowel /i/ was significantly different from that of /e/, /a/ and /a: /; F_1 of vowel /u/ was significantly different from /a/ and /a:/ and F_1 of vowel /o/ was significantly different from /a/ and /a:/ and F_1 of vowel /e/ was significantly different form that of /i/, /a/ and /a:/. Figure 4.1 gives a diagrammatic representation of the same. Similarly, as elaborated in Figure 4.2, in the FL condition: F_1 of vowel /i/ was significantly different from that of /o/, /e/, /a/ and /a:/; F_1 of vowel /u/ was significantly different from /e/, /a/ and /a:/; F_1 of vowel /o/ and /e/ was significantly different from /a/ and /a:/. All post-hoc Duncan results were significant at 0.05 level of significance (p< 0.05).

It is evident from Figures 4.1 and 4.2 that the clustering of vowels was more in the FLD condition than in the FL condition. In FL condition, vowels seem to maintain some level of distinctive F_1 values.

Fig 5.2 Grouping of vowels according to F1 in FL condition in adult stutterers.

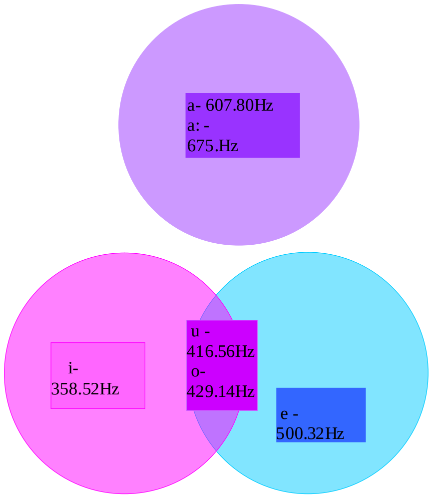


Fig 4.1: Grouping of vowels according to F_1 in FLD condition in adult stutterers

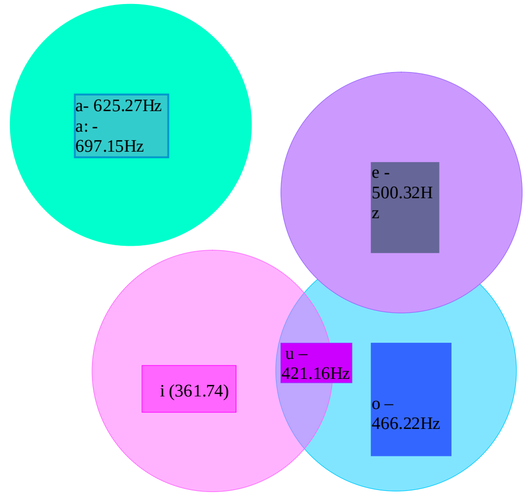


Fig 4.2: Grouping of vowels according to F_1 in FL condition in adult stutterers

It is evident from Figure 4.1 and 4.2 that the clustering of vowels was more in the FLD condition than in FL condition. In FL condition, vowels seem to maintain some level of distinctive F_1 values.

Similar statistics were applied with regard to F_2 which showed highly significant difference between the vowels in the three conditions [In AVG: (F (5, 50) = 6.944, p< 0.001: In FLD: (F (5, 50) = 32.204, p< 0.001): FL (F (5, 50) = 40.154, p< 0.001]. As revealed by Duncan's post-hoc analysis in the AVG condition, there was a significant difference between /a/ and /o/ compared to /e/ and /i/ and /u/ /e/ and /a/ compared to /i/ (p < 0.05). In the FLD condition /o/ was significantly different between /a:/, /a/, /e/ and /i/; /u/ was significantly different to compared to /a/,/e/ and /i/; /a/ was significantly different compared to /e/ and /i/; and vowel /e/ had F_2 values significantly different to that of /i/. In FL condition, there were distinct groups of vowels, when considering F_2. These findings are depicted in Figure 4.3, 4.4 and 4.5

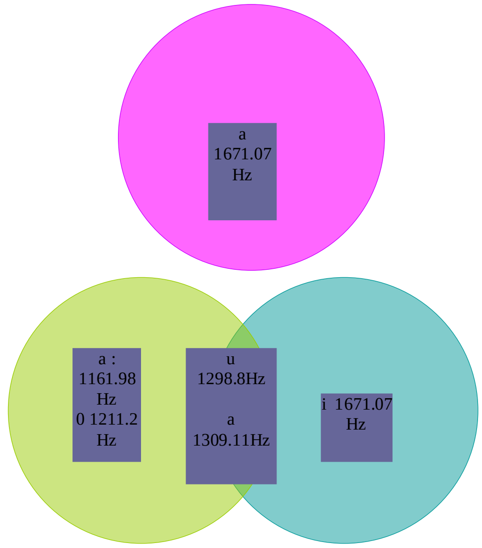


Fig 4.3. : Grouping of vowels on the basis of F_2 in AVG condition in adult stutterers

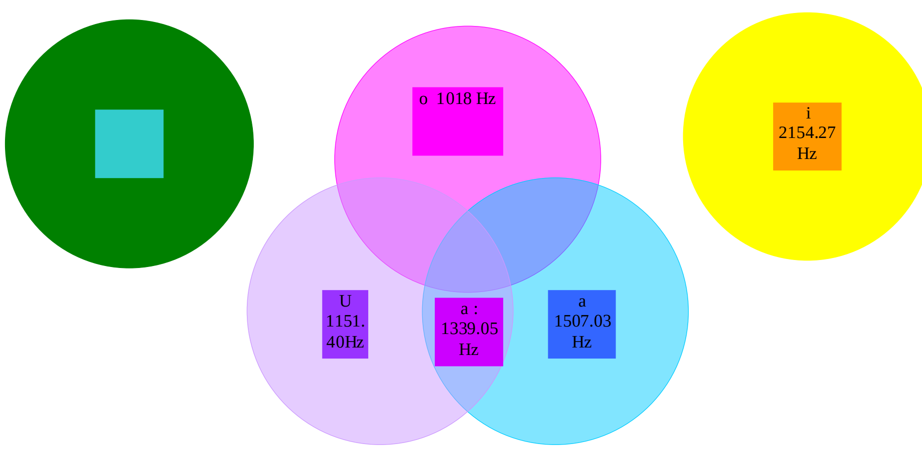


Fig 4.4 : Grouping of vowels on the basis of F_2 in FLD condition in adult stutterers.

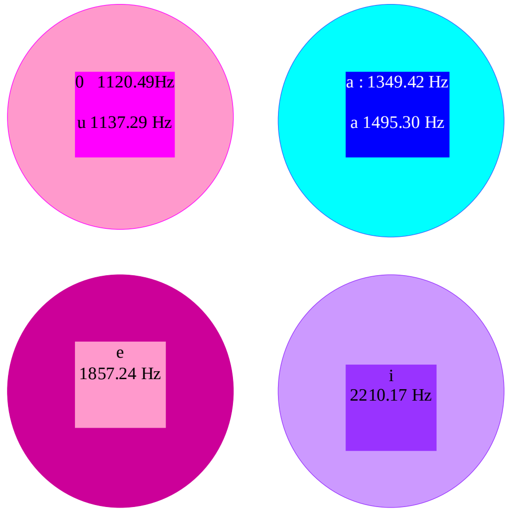


Fig 4.5 : Grouping of vowels on the basis of F_2 in FL condition in adult stutterers.

From Figures 4.3, 4.4 and 4.5, it is evident that in adult stutterers, though there is a significant difference between vowels in the AVG condition, the vowels are more closely clustered (having similar F_2 values) compared to the FLD and F_l condition. In the FL condition, the vowels appear more distinct than in the FLD condition.

In Child Stutterers : Similar statistical procedures like those described for adults were used and the results showed that there was no significant difference between the three conditions for F_1 [F (2,10) = 0.877, p = 0.419]. However, F_2 was significantly different between the conditions [(F (2, 10) = 45.883, p< 0.001)]. Follow-up Bonferroni post- hoc test made evident that there was a significant difference between the three conditions for F_2 (p< 0.05), that is, between AVG & FLD; AVG & FL; FLD & FL.

Association between vowels and conditions was studied using one-way ANOVA which indicated a highly significant difference between vowels in each of the three conditions: AVG [F (5, 58) = 3.031, $p < 0.05$]; FLD [F (5, 58) = 25.619, $p < 0.001$] and FL [F (5, 58) = 39.326, $p < 0.001$]. Duncan's post-hoc test showed that in the average condition, there was a significant difference between F_1 of vowel /u/ and that of /o/ and /a:/ ; and F_1 of vowel /e/ compared to that of /a:/ and F_1 of vowel /a/ compared to /a:/, (($p < 0.05$). In the FLD condition, vowels /i/ and /u/ had values of F_1, which were significantly different from that of /e/, /a/ and /a:/. Similarly vowel /o/ had F_1 which was significantly different from that of /a/ and /a:/. F_1 of vowels /e/ and /a/ were significantly different from that of /a:/. Finally, in the FL condition, significant F_1 differences existed for vowel /i/ compared to vowels /o/, /e/, /a/ and /a:/ ; vowel /u/ compared to vowels /a/ and /a:/ ; vowel /o/ and /e/ compared to /a/ and /a:/ and vowel /a/ compared to vowel /a:/. Figures 4.6, 4.7 and 4.8 illustrate these findings.

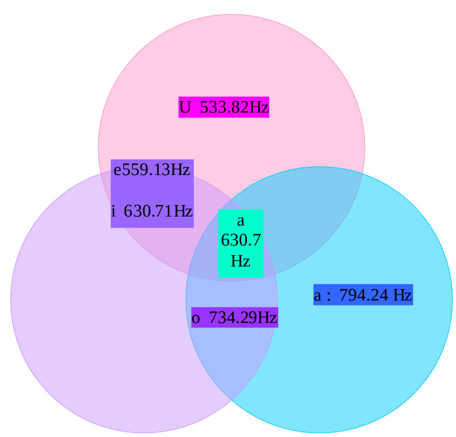


Fig 4.6 : Grouping of vowels on the basis of F_1 in AVG condition in child stutterers

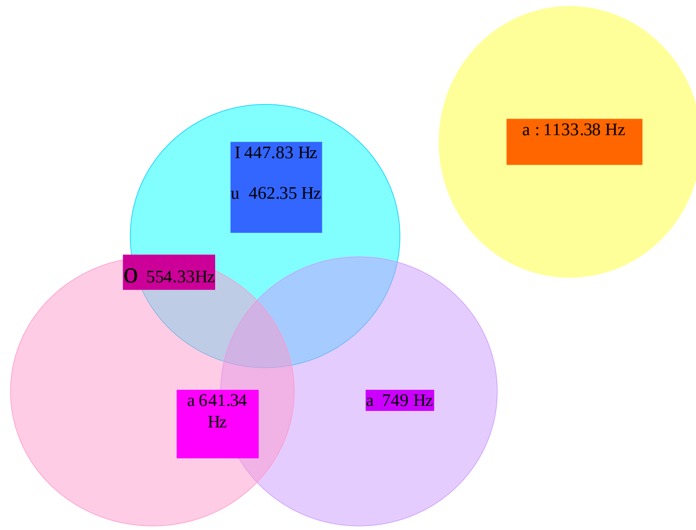


Fig 4.7 : Grouping of vowels on the basis of F_1in FLD condition in child stutterers.

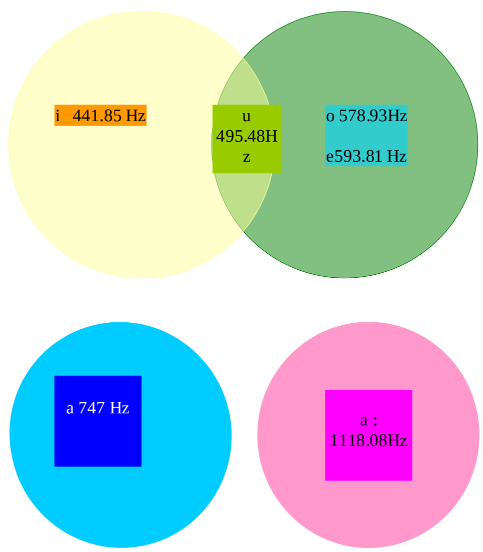


Fig 4.8 : Grouping of vowels on the basis of F_1 in FL condition in child stutterers.

From Figures 4.6, 4.7 and 4.8, it is evident that in child stutterers, though there is a significant difference between vowels in the AVG condition, the vowels are more closely clustered (having similar F_1 values) compared to the FLD and FL condition. In the FL condition the vowels appear more distinct than in the FLD condition.

Similar statistical procedures were carried out for analyzing F_2, and here too there was a significant association between vowels and all three speech conditions: AVG [$F(5,58) = 1.973$, $p < 0.05$)]; FLD [$F(5,58) = 17.109$, $p < 0.001$] and FL [$F(5,58) = 88.963$, $p < 0.001$]. In the AVG condition, the only significant difference in F_2 was between vowels /e/ and /i/ compared to that of /u/. In the FLD condition, vowels /o/ and /u/ had F_2 values significantly different from /a/, /a:/, /e/, /i/ and vowels /a/, /a:/ and /e/ had F_2 values significantly different form that of /i/. In the FL condition, vowels /u/ and /o/ had F_2 values significantly different to that of /a/, /a:/ /e/ and /i/; and vowels /a/ and /a:/ had values significantly different to /e/ and /i/ ($p < 0.05$). Figures 4.9, 4.10 and 4.11 depicts these findings.

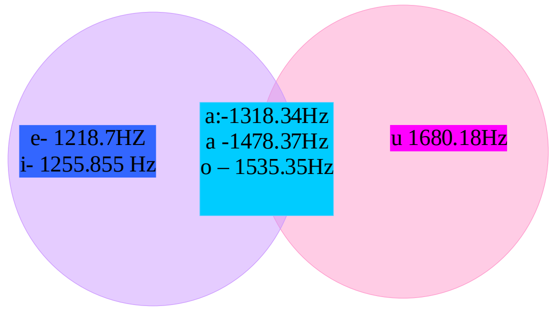


Fig 4.9 : Grouping of vowels on the basis of F_2 in AVG condition in child stutterers.

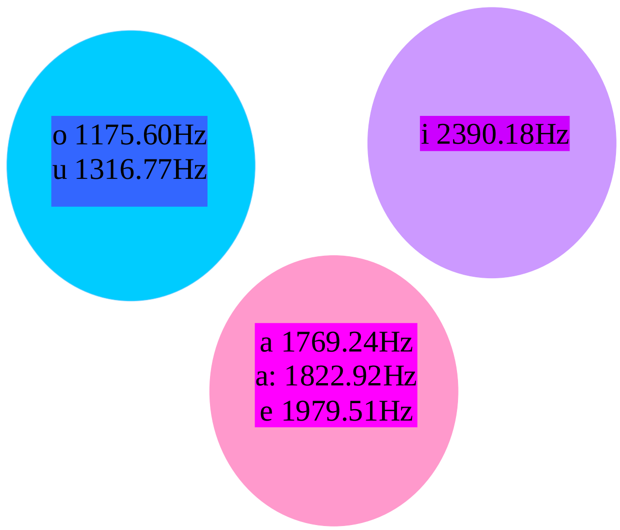


Fig 4.10 : Grouping of vowels on the basis of F_2 in FLD condition in child stutterers.

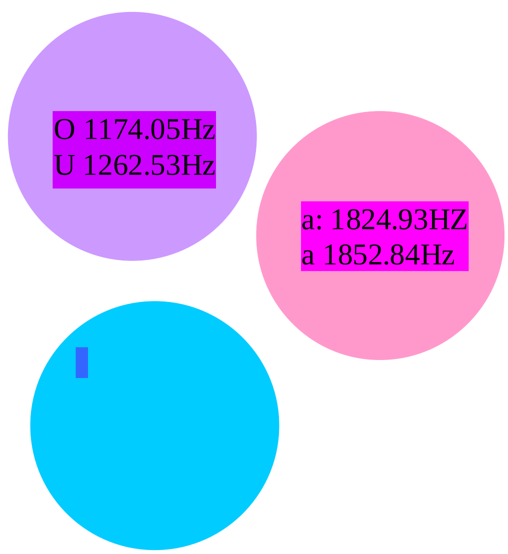


Fig 4.11 : Grouping of vowels on the basis of F_2 in FL condition in child stutterers.

From Figures 4.9, 4.10 and 4.11, it is evident that in child stutterers, the vowels are closely clustered (having similar F_2 values) compared to the FLD and FL condition. In the FL condition the vowels appear more distinct than in the FLD condition

In Children with Normal Nonflueny : Using similar statistical procedures like those described for adult and child stutterers, it was found that there was no significant difference between the three fluency conditions for either F_1 [F (2,10) = 0.006, p =0.994] or F_2 [F (2,10) = 2.620, p = 0.77]..

Difference between vowels, if any, in different conditions was studied for this group using one-way ANOVA. Results, indicated a highly significant difference between vowels in each of the three conditions in F1 :AVG [F (5,57) = 28.713, p< 0.001]; FLD [F (5,57) = 30.403, p< 0.001] and FL [F (5,58) = 37.697, p< 0.001] as well as for F2: AVG [F (5,54) = 70.779, p< 0.001)]; FLD [(F (5,58) = 101.447, p< 0.001] and FL [F (5,58) = 135.840, p< 0.001]. Follow up Duncan's post-hoc test showed that in the AVG condition, there was a significant difference between F_1 of vowel /i/ and that of /o/ /a/ and /a:/ ; and F_1 of vowel /e/ compared to that of /a/ and /a:/ ; /u/ compared to /a/ and F_1 of vowel /o/ and /a/ compared to /i/ and /a:/, (p< 0.05). In the FLD condition vowels /i/ and /u/ had values of F_1, which were significantly different from that of /e/, /o/, /a/ and /a:/. Similarly, vowel /e/ had F_1 which were significantly different from that of /i/, /u/, /a/ and /a:/. /o/ had F1 values different form /u/, /i/ and /a:/. And the F_1 of vowel /a:/ was significantly different from that of all other vowels including /a/. Finally in the FL condition significant F_1 differences existed for vowel /i/ and /u/ compared to vowels /o/, /a/ and /a:/ ; vowel /e/ compared to vowels /a/ and /a:/ ; vowel /o/ compared to vowel /a:/ and vowel /a:/ compared to all other vowels including /a/. The results are illustrated in the Figures 4.12, 4.13 and 4.14.

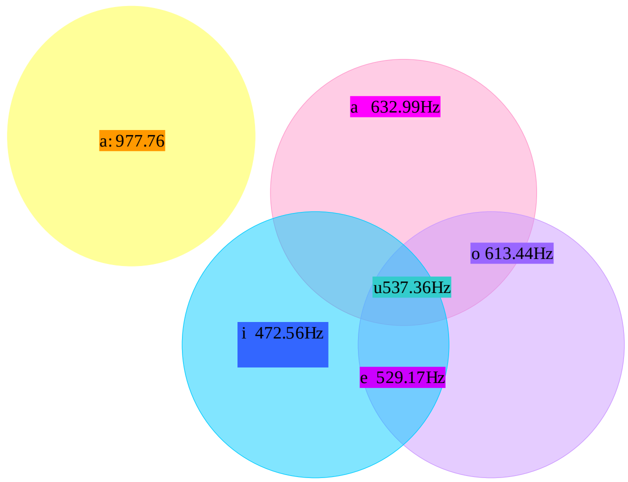


Fig 4.12 : Grouping of vowels on the basis of F_1 in AVG condition in children with normal nonfluency.

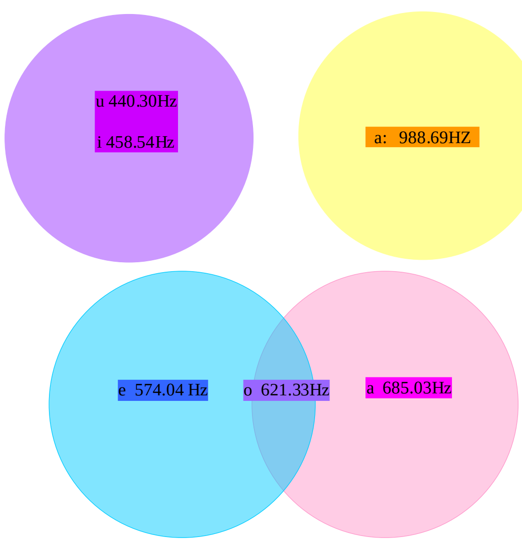


Fig 4.13: Grouping of vowels on the basis of F_1 in FLD condition in children with normal nonfluency.

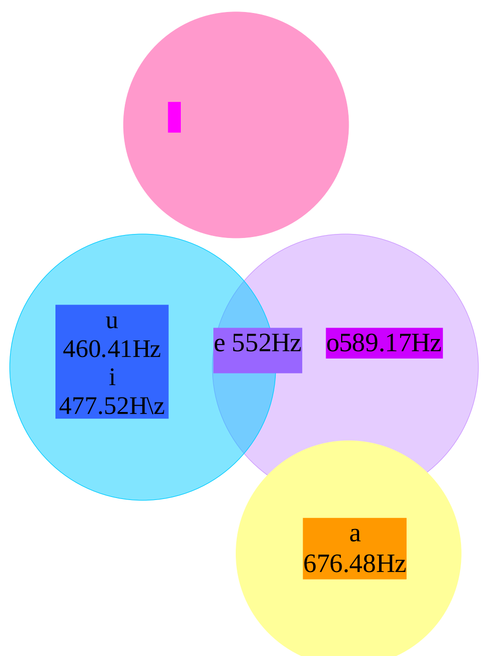


Fig 4.14: Grouping of vowels on the basis of F_1 in FL condition in children with normal nonfluency.

For F_2 in the AVG, FLD and FL conditions, there existed a significant difference in F_2 between vowels /e/ /a/ and /a:/ compared to that of /u/, /o/ and /i/ and vowel /i/ compared to all other vowels including /u/ and /o/ as revealed by post-hoc Duncan's tests ($p < 0.05$). The results are illustrated in Figures 4.15, 4.16 and 4.17.

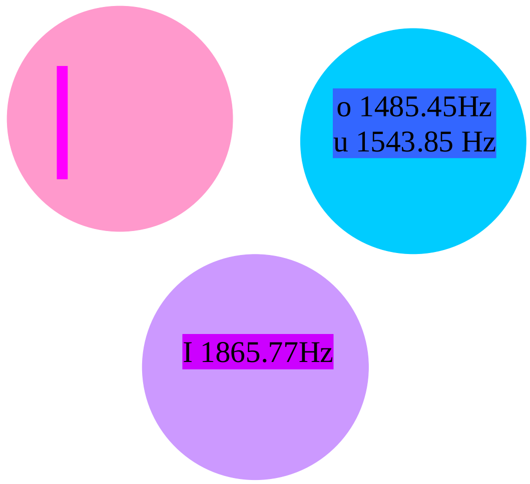


Fig 4.15 : Grouping of vowels on the basis of F_2 in AVG condition in children with normal nonfluency

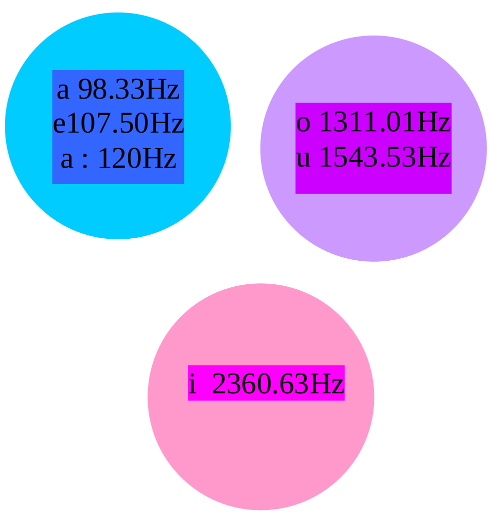


Fig 4.16 : Grouping of vowels on the basis of F_2 in FLD condition in children with normal nonfluency.

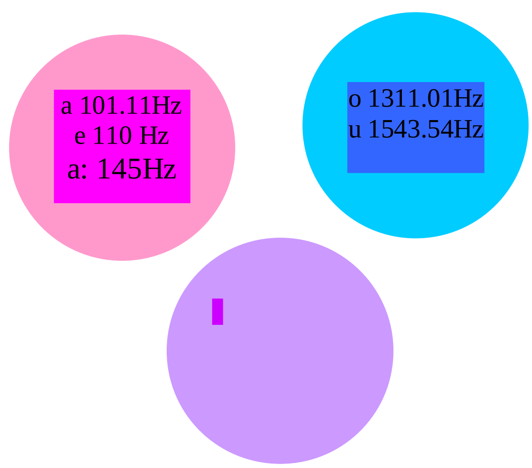


Fig 4.17 : Grouping of vowels on the basis of F_2 in FL condition in children with normal nonfluency.

From the Figures 4.15, 4.16 and 4.17, it is evident, that in children with normal nonfluency, the vowels are distinct (having different F_2 values).

Between Subject - Group Differences

One-way analysis of variance (ANOVA) was performed to determine differences in performance between the groups. Results revealed a significantly different F_1 between the three groups in all the three conditions [In AVG: ($F(2,182) = 22.27$, $p < 0.001$) ; in FLD: ($F(2,182) = 10.666$, $p < 0.001$); in FL ($F(2,182) = 9.631$, $p < 0.001$)]. Duncan's post-hoc test revealed a significant difference ($p < 0.05$) between the group of adult stutterers child stutterers and children with normal nonfluency, with the adult stutterers having a lower F_1 compared to the two groups of children. This was the case in all three speech conditions.

Similarly, there was a highly significant difference between the three subject groups in all three speech conditions for F_2 [In AVG: ($F(2,177) = 25.136$, $p < 0.001$); in FLD: ($F(2,177) = 41.945$, $p < 0.001$) and in FL ($F(2,177) = 36.871$, $p < 0.001$)]. Follow up post-hoc Duncan test was performed which showed that in the AVG and FLD conditions children with NNF had F_2 values significantly different from that of child and adult stutterers. In the FL condition, all three groups had F_2 values that were significantly different from each other ($p < 0.05$). The results are depicted graphically in Figure 4.18.

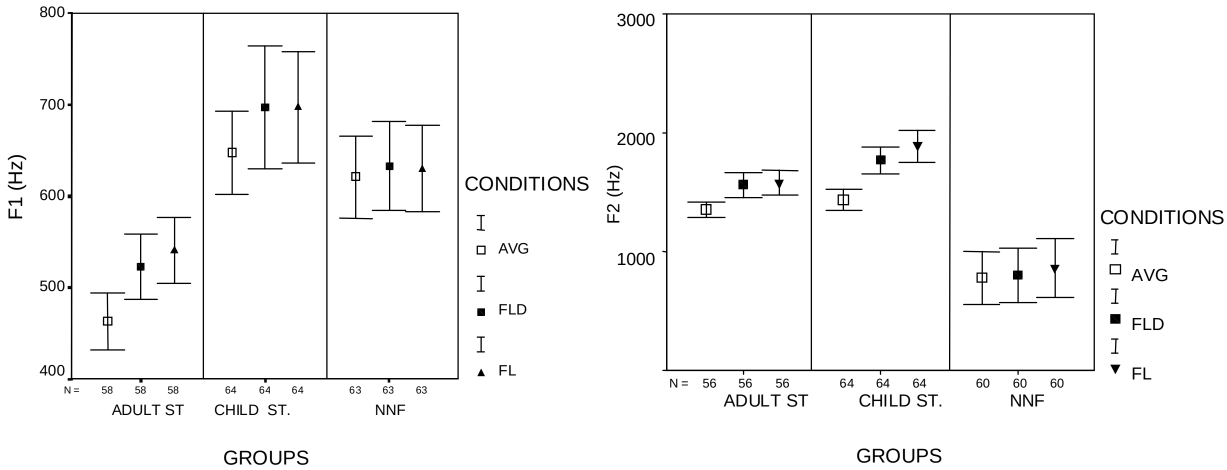


Figure 4.18 : Group differences in F_1 and F_2 in the three fluency conditions

Section 2: Vowel Duration

A total of 200 pairs of dysfluent and fluent utterances were analyzed for the three groups in the three fluency conditions (AVG, FLD & FL). Each of the tokens was classified according to the vowel contained. 18 pairs of fluent and dysfluent utterances containing vowels /e:/, /u:/, and /o:/ were eliminated from the study due to the small sample size. In effect, 182 samples were analyzed for the three groups of subjects. The results were calculated by collapsing the vowel durations for each token produced by each participant in each of the three fluency conditions. Table 4.2 shows the average vowel duration for different vowels in the three groups for the three different speech conditions. The VD shown in Table 4.2, for example 53.03 msec (column 3, 1st row) is the average F_1 value of all the 15 items with vowel /a/ in the average condition. Other vowels should be interpreted similarly.

Speech Condition	Vowels	Adult Stutterers		Child Stutterers		Normal Nonfluency	
		VD	N	VD	N	VD	N
AVG	a	53.03 (24.51)	15	187.29 (98.72)	24	94.17 (23.28)	18
	e	48.27 (12.68)	11	82.00 (8.37)	5	87.50 (13.89)	8
	u	69.42 (11.42)	7	111.43 (47.05)	7	113.33 (16.33)	6
	o	59.50 (24.53)	5	136.87 (53.85)	8	108.75 (45.49)	8
	i	53.33 (19.36)	9	66.50 (39.72)	10	99.17 (35.22)	12
	a :	61.53 (20.52)	13	85.50 (26.71)	10	107.50 (42.26)	8
FLD	a	70.13 (45.79)	15	124.17 (52.25)	24	92.78 (18.09)	18
	e	78.72 (15.29)	11	96.00 (11.40)	5	108.75 (26.42)	8
	u	84.29	7	110.00	7	93.33	6

		(19.88)		(42.82)		(17.51)	
	o	116.00 (32.09)	5	108.75 (35.63)	8	107.50 (36.94)	8
	i	84.44 (41.26)	9	87.00 (41.38)	10	88.33 (26.23)	12
	a :	97.31 (34.25)	13	140.00 (51.17)	10	152.50 (60.89)	8
FL	a	77.67 (44.22)	15	121.67 (49.31)	24	96.11 (19.75)	18
	e	82.73 (15.55)	11	110.00 (14.14)	5	108.75 (25.32)	8
	u	102.86 (38.61)	7	97.14 (28.12)	7	869.67 (15.06)	6
	o	126.00 (23.02)	5	135.00 (70.10)	8	96.25 (34.62)	8
	i	83.33 (40.31)	9	102.00 (51.39)	10	78.33 (19.46)	12
	a :	125.62 (52.52)	13	185.00 (73.22)	10	157.5 (32.56)	8

Table 4.2 : Mean values of Vowel Duration (VD) for the different vowels produced by the three groups of subjects - adult stutterers, child stutterers and children with normal nonfluency. Standard deviations are shown in parenthesis. N refers to number of token with a given vowel. Mean values (F_1 & F_2) refer to the average of all the tokens for a given vowel.

In Adult Stutterers : ANOVA with repeated measures showed that VD was significantly different between the three speech conditions [$F(2, 9)=43.735$, $p<0.001$]. Follow-up post-hoc Bonferroni test revealed that VD was significantly different between AVG and FD and FL conditions. VD was significantly different between FLD and F_l conditions.

One-way ANOVA was performed to study the difference, if any, between vowels in the three different speech conditions. The results revealed no significant difference between vowels in the AVG [$F (5, 54) = 1.275$, $p = 2.88$] and FLD condition [$F (5, 54) = 1.725$, $p = 1.44$], but there was a significant difference between the VD of vowels in the FL condition [$F (5, 54) = 2.969$, $p<0.05$]. Follow up Duncan's post-hoc test, was then used to find out which of the vowels significantly differed from each other with respect to VD. It was found that VD of vowel /a/ was significantly different from that of /a:/ and /o/ ($p< 0.05$).

In Child Stutteres : ANOVA with repeated measures showed no significant difference between the three speech conditions for vowel duration [$F (1, 7)=1.245$, $p=0.282$].

One-way ANOVA was then performed to find out the difference, if any, between vowels in the different conditions. Results revealed a significant difference in VD between the different vowels in the AVG [$F(5, 58) = 6.378$, $p<0.001$] and FL [$F(5, 58) = 3.369$, $p<0.05$] conditions, but not in the FLD condition [$F(5, 58) = 1.456$, $p= 0.218$]. As shown by the results of Duncan's post-hoc analysis, VD of vowels /i/, /e/, /a:/ and /u/ were significantly different from that of /a/ ($p< 0.05$), in the AVG and FL conditions.

In Children With Normal Nonfluency : ANOVA with repeated measures revealed no significant difference between the three speech conditions [$F(2,10) = 0.623$, $p = 0.538$].

One-way ANOVA performed to study the variation among vowels with each speech condition and it revealed no significant difference in VD among the vowels in the AVG condition [$F(5, 54) = 0.822$, $p = 0.539$], but a significant difference was found in the vowels in the FLD condition [($F(5, 54) = 4.903$) ($p<0.05$)] and a highly significant difference in the FL condition [$F(5, 54) = 12.685$, $p<0.001$]. Follow-up Duncan's post-hoc analysis revealed a significant difference between the VD of vowel /a:/ compared to that of the other vowels (/a/, /i/, /u/, /o/ and /e/). In the FL condition, the VD of vowel /i/ was significantly different from that of /i/ compared to that of /e/, and VD of vowel /a:/ was significantly different from all other vowels ($p<0.05$).

Between Subject - Group Differences

One-way analysis of variance (ANOVA) was performed to determine differences in performance between the three subject groups. Results revealed a highly significant difference between the three groups in each of the three speech conditions [In AVG: $F(2,181) = 29.609$, $p < 0.001$); in FLD: ($F(2,181) = 7.941$, $p < 0.001$) and in FL condition ($F(2,181) = 7.369$, $p < 0.001$)]. Duncan's post-hoc test revealed that VD was significantly different ($p < 0.05$) between the three subject groups in the AVG condition, with the adult stutterers having a shorter VD compared to the two groups of children, and the children with NNF in turn having lower VD compared to child stutterers. In the FLD, condition results revealed a significant difference in vowel duration ($p < 0.05$) between adult stutterers and the other two groups, with the adult stutterers having shorter VDs compared to the two groups of children. In the FL condition child stutterers had significantly longer VDs compared to those of adult stutterers and children with normal nonfluency. This is illustrated in the Figure 4.19.

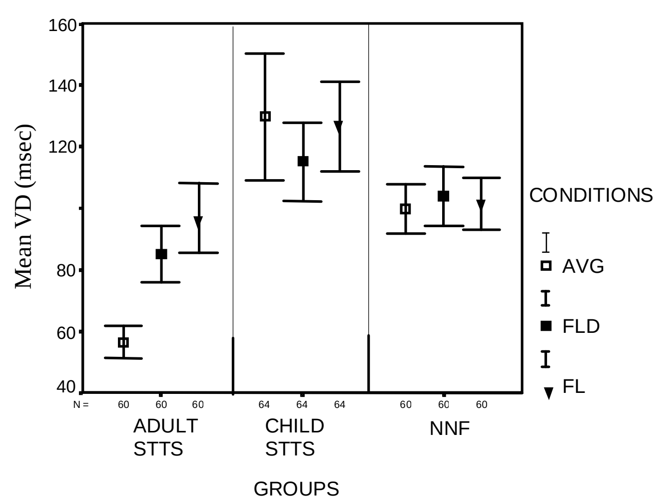


Figure 4.19: Group differences in VD in the three conditions

Section 3 : Measures of F_2 transition (extent of transition-eot, transition duration- td, speed of transition -sot & morphology of f_2 contour)

A total of 185 utterances were analyzed. These were then classified as measurable and nonmeasurable. 20 out of these 185 utterances were nonmeasurable. The nonmeasurable or missing transitions were those that could not be identified through visual examination of the spectrogram, either because of limitations of the instrument or recording techniques.

Morphology of F_2 contour

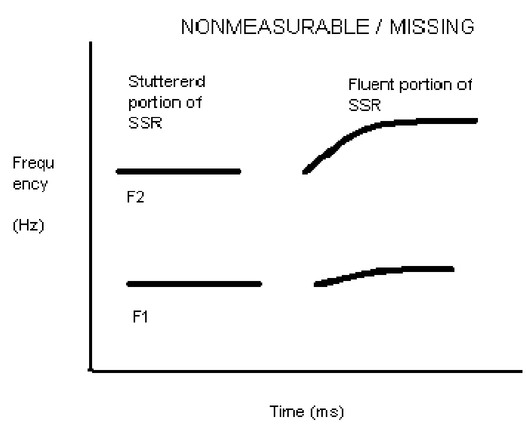
In reporting the results of morphology, percentage of discrepant transitions were calculated for each of the speech conditions. In the EOT data, the statistical significance of these observations have been elaborated, using appropriate statistical tests as will be described. Table 4.3 shows the result of within group – between speech conditions comparison.

Group	Speech Condition	% of Discrepant Observations
Adult Stutterers	AVG & FLD	33
	AVG & FL	40
	FLD & FLUENT	11
Child Stutterers	AVG & FLD	28
	AVG & FL	35
	FLD & FLUENT	17
Normal Nonfluency	AVG & FLD	17
	AVG & FL	22
	FLD & FL	10

Table 4.3 : Percentage of discrepant dysfluencies between speech conditions produced by the three groups of subjects.

As can be seen from the table, maximum discrepant transitions are observed between AVG and FL speech contexts (adult stutterers- 40%, child stutteres-35% and NNF-22%), followed by the AVG and FLD contexts (adult stutterers- 33%, child stutteres-28% and NNF-17%) and FLD and FL contexts. Comparison between subject groups shows that adult stutterers exhibit the maximum percentage of discrepant transitions followed by child stutterers, and children with NNF in all the three speech conditions.

Extent of F_2 Transition (EOT) : The 165 measurable utterances were then classified according to the direction of movement of the F_2 transition, and these were again grouped according to their occurrence in the three conditions, e.g.: RFF (Rising, Falling, Falling). It means that EOT was –ve (raising) in AVG, +ve (falling) in FLD and FL conditions. In this manner, 16 different configurations were identified. But, only three of these F_2 transitions (FFF-measurable and nondiscrepant, RRR-measurable and nondiscrepant and FRR/ RFF-measurable and discrepant) were subjected to statistical analysis, since only these combinations had adequate number of samples for meaningful statistical analysis. Figure 4.20 shows the idealized spectrograms of the three types of F_2 transitions. In effect, out of the total of 165 measurable utterances analyzed to obtain EOT data, only 137 were statistically analyzed.



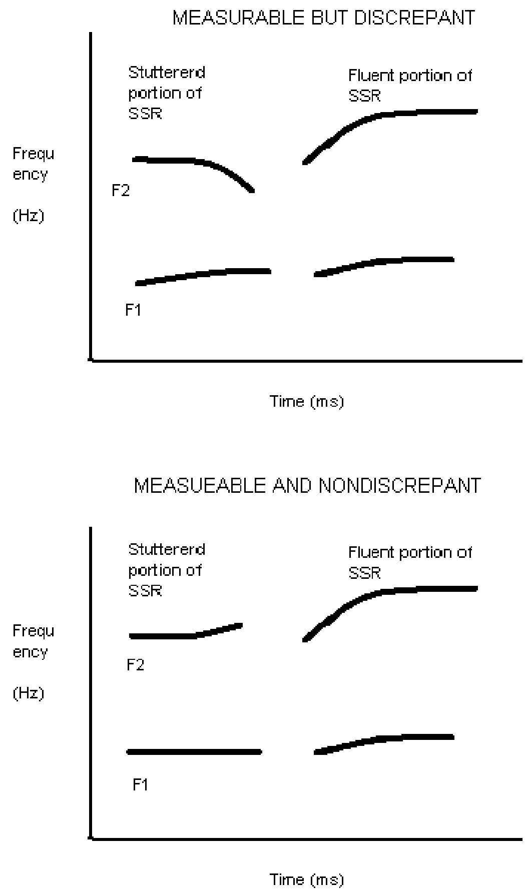


Figure 4.20 : Examples of types of F2 transitions during stutterered portions of SSR's

Table 4.4 shows the average EOT's for the 165 measurable utterances, in the three conditions and for the three groups.

F_2 Transition Groups	Speech Condition	Adult Stutterers		Child Stutterers		Normal Nonfluency	
		EOT(Hz)	N	EOT(Hz)	N	EOT(Hz)	N
RRR	AVG	-267.15 (242.53)	13	-291.30 (274.27)	25	-325.73 (150.24)	26

	FLD	-352.07 (200.41)	13	-342.20 (189.43)	25	-376.98.57 (221.57)	26
	FL	-251.62 (85.83)	13	-306.20 (212.96)	25	-388.91 (221.69)	26
FFF	AVG	405.62 (331.25)	21	312.18 (147.81)	11	533.20 (506.49)	14
	FL	295.43 (210.85)	21	603.60 (464.89)	11	521.23 (435.05)	14
	FLD	247.26 (177.96)	21	557.60 (400.03)	11	488.42 (232.71)	14
FRR/RFF	AVG	132.80 (303.87)	15	141.82 (332.38)	15	280.60 (305.65)	5
	FLD	-123.05 (286.98)	15	-238.52 (454.26)	15	-266.46 (170.36)	5
	FL	-80.69 (368.74)	15	-190.91 (373.86)	15	-397.20 (217.58)	5

Table 4.4 : Mean values of Extent of transition (EOT) for the different vowels produced by the three groups of subjects - adult stutterers, child stutterers and children with normal nonfluency. Standard deviations are shown in parenthesis. N refers to number of tokens with

a given group of transition. Mean values (EOT) refer to the average of all the tokens for a category of F_2 transition.

In adults, analysis of variance with repeated measures showed no significant difference in EOT for the “measurable and nondiscrepant” F_2 transitions: the RRR group [(F (2, 24) = 1.808) (p = 1.86)], but in the other group of “measurable and nondiscrepant” F_2 transitions: the FFF group, there was a significant difference between the conditions, which as revealed by Bonferroni post hoc test was between the AVG and FL conditions (p < 0.05). But, in the “measurable but discrepant” sequence (FRR/RFF) F_2 transitions, were not significantly different between the speech conditions in adults [(F (2, 25) = 2.38) (p = 0.111)]. In child stutterers, there was no significant difference between the speech conditions for any of the groups of F_2 transitions: “measurable and nondiscrepant”- RRR [(F (2, 48) = 0.652) (p = 0.526)]; FFF [(F (2, 20) = 3.026) (p = 0.071)] and “measurable but discrepant” FFR/RRF [(F (2, 28) = 3.727) (p = 0.068)]. In NNF, there was no significant difference in the “measurable and nondiscrepant” RRR [(F (2, 50) = 1.605) (p = 0.211)] and FFF [(F (2, 25) = 3.760) (p = 0.168)] category. Due to the small sample size (N=5), nonparametric Friedman’s test was used to statistically analyze the “measurable but discrepant” (FRR/RFF) F_2 transition categories and the results revealed that there was a significant difference between the speech conditions, and further statistics revealed that this difference was statistically significant between AVG and FLD/FL conditions (p < 0.05).

Between Subject - Group Differences

One-way ANOVA was performed to find out whether there existed a significant difference in EOT between the three groups. As illustrated in Figure 4.21, for the RRR F_2 transitions, there was no significant difference in EOT between the subject groups in AVG [F (2, 61) = 0.329, p = 0.721], FLD condition [F (2,61) = 0.191, p = 0.827)] and FL conditions [F(2,61) = 2.335, p = 0.105)]. As illustrated in Figure 4.22, for the FFF F_2 transitions, there was no significant difference between the subject for the AVG condition [(F (2, 43) = 1.165) (p = 0.322)], but a significant difference was seen between the groups for the FLD [F (2, 43) = 3.221, $p < 0.05$] and FL conditions [F (2, 43) = 6.337, $p < 0.05$)]. A Duncan's post-hoc showed a significant difference between adult stutterers and the group of child stutterers, for the FLD condition, with the child stutterers having a greater EOT than adults. In the FL condition, a significant difference in EOT was found between adult stutterers and the other two groups. For the 'measurable but nondiscrepant' F_2 transitions, there was no significant difference between the subject groups in for any of the three fluency conditions, as is evident in Figure 4.23 {AVG [F (2, 32) = 0.441, p = 0.647)]; FLD [F (2, 32) = 0.506, p = 0.608] ; FLD [F (2, 32) = 1.157, p = 0.235]}.

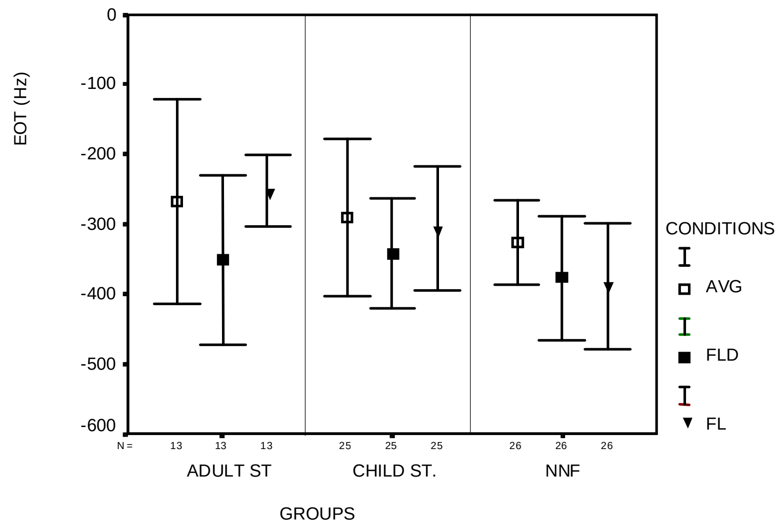


Figure 4.21: Group difference in EOT in the RRR category for the three conditions

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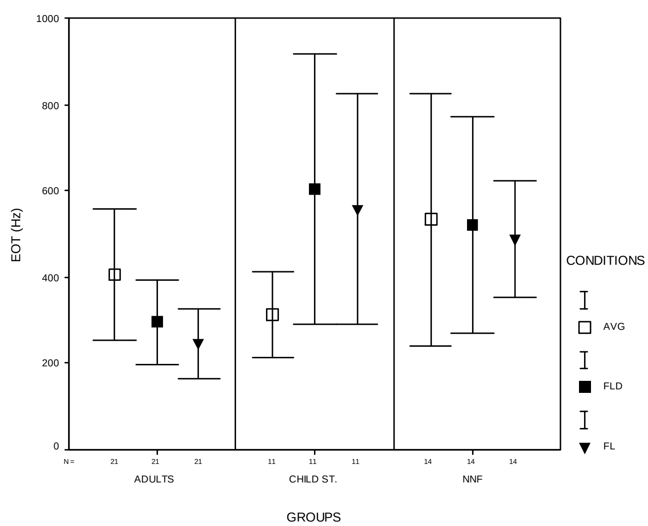

Figure 4.22: Group difference in EOT in the FFF category for the three conditions

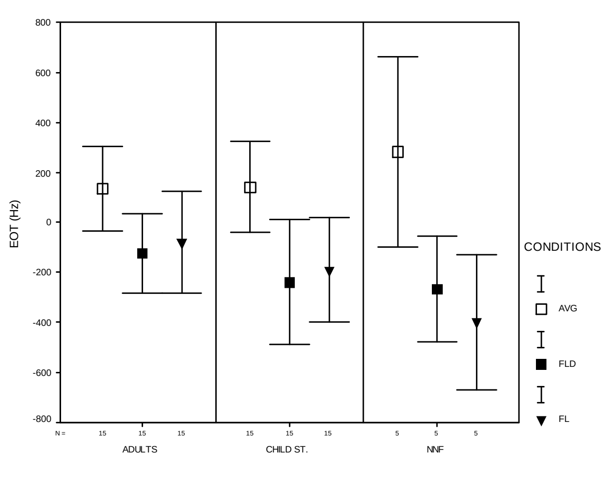

Figure 4.23: Group difference in EOT in the FRR/RFF category for the three conditions

speech condition are listed in Table 4.5.

Speech Condition	Adult Stutterers		Child Stutterers		Normal Nonfluency	
	TD(ms)	N	TD(ms)	N	TD(ms)	N
AVG	57.50 (36.53)	56	74.21 (35.09)	57	59.20 (17.91)	56
FLD	61.57 (40.84)	56	73.33 (25.72)	57	64.91 (29.35)	57
FL	59.20 (17.91)	56	56.43 (19.95)	56	55.36 (17.10)	56

Table 4.5 : Mean values of Transition Duration (TD) for the different vowels produced by the three groups of subjects - adult stutterers, child stutterers and children with normal nonfluency. Standard deviations are shown in parenthesis. N refers to number of token in each category. Mean values (TD) refers to the average of all the tokens in a given speech condition.

ANOVA with repeated measures showed no significant difference between the three speech conditions in any of the three subject groups with respect to TD [(F (2, 110) = 1.348) (p = 0.264)].

Between Subject - Group Differences

One-way ANOVA was performed to find out whether there existed a significant difference in TD between the three subject groups. In the AVG condition, no significant difference was found between the three groups [F (2, 166) = 4.973) (p = 0.008)]. However, FLD and FL conditions were significantly different between the three subject groups {FLD [F (2, 166) = 4.682, p < 0.05], FL [F (2, 166) = 2.350, p < 0.05]}. A follow-up post-hoc Duncan's test revealed that adults with stuttering and children with NNF had lower TDs compared to children with stuttering in the AVG and FLD speech conditions (p < 0.05). This is clearly evident in the Figure 4.24.

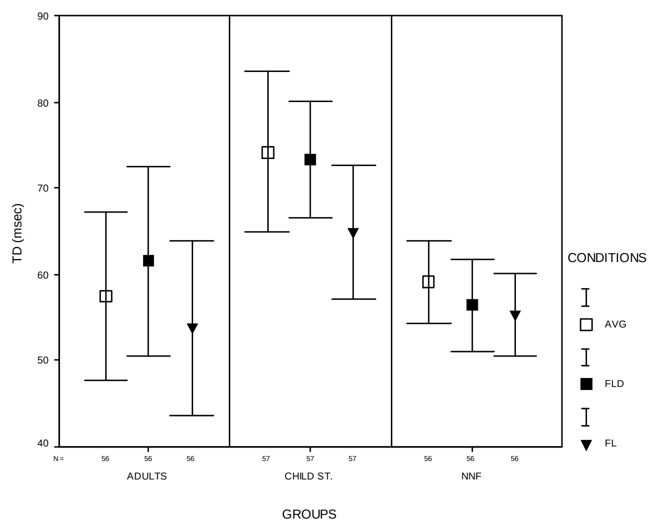

Figure 4.24 : Group difference in TD in the three conditions

Speed of Transition (SOT) : The average SOT values for each of the tokens are listed in Table 4.6.

Speech Condition	Adult Stutterers		Child Stutterers		Normal Nonfluency	
	SOT (Hz/msec)	N	SOT (Hz/msec)	N	SOT (Hz/msec)	N
AVG	6.49 (6.73)	56	4.45 (4.19)	56	6.84 (5.93)	56
FLD	6.54 (5.50)	56	6.41 (4.93)	56	7.23 (5.95)	56
FL	6.60 (6.63)	52	6.64 (4.53)	52	7.04 (4.26)	52

Table 4.6 : Mean values of Speed of Transition (SOT) for the different vowels produced by the three groups of subjects - adult stutterers, child stutterers and children with normal nonfluency. Standard deviations are shown in parenthesis. N refers to number of token in each category. Mean values (SOT) refers to the average of all the tokens in a given speech condition.

ANOVA with repeated measures was used to analyze SOTs of the measurable F_2 transitions. There was no significant difference between the three speech conditions in adult stutterers [$F (2, 110) = 0.006$, $p = 0.994$] and in children with normal nonfluency [$F (2, 102) = 0.851$, $p = 0.851$] with respect to SOT. However, the difference was significant between the speech conditions in child stutterers [$F (2, 110) = 6.026, p < 0.05$].

A follow up post-hoc Bonferroni test revealed that the in child stutterers the difference in SOTs was significantly different between AVG and the other two speech conditions (FLD and FL).

Between Subject - Group Differences

One- way ANOVA showed no significant difference between the groups for any of the three speech conditions: AVG [$F (2, 161) = 2.821, p = 0.063$], FLD [$F (2, 161) = 0.346, p = 0.708$] and FL conditions [$F (2, 161) = 0.117, p = 0.890$]. This is clearly represented in the Figure 4.25.

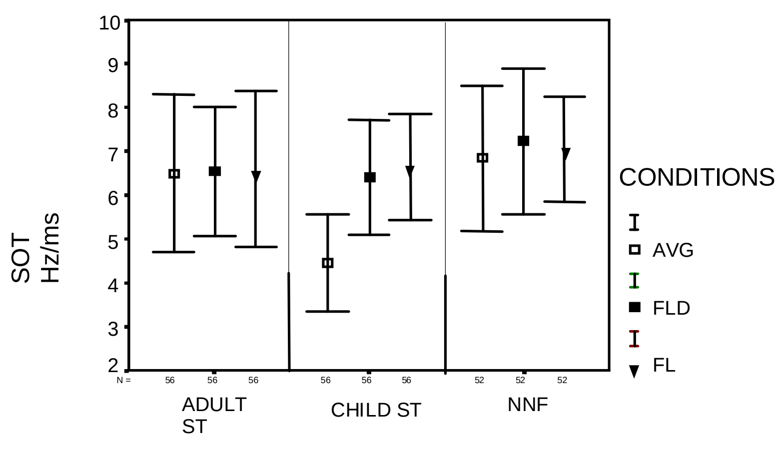

Figure 4.25: Group differences in SOT in the three conditions

Section 4: Consonant Features: Closure Duration (CD) and Voice Onset Time (VOT)

The average CD and VOT values for each of the 62 pairs of fluent and dysfluent tokens analyzed are listed in Table 4.7.

Speech Condition	Adult Stutterers			Child Stutterers			Normal Nonfluency		
	CD (ms)	VOT (ms)	N	CD (ms)	VOT (ms)	N	CD (ms)	VOT (ms)	N
AVG	338.00 (421.08)	40.53 (44.26)	20	185.62 (114.15)	-65.31* (256.68)	32	243.33 (191.11)	-7.33* (69.64)	15
FLD	199.96 (244.04)	41.55 (51.76)	20	296.56 (182.82)	-5.31* (215.74)	32	214.00 (100.98)	-6.00* (58.77)	15
FL	390.78 (452.78)	34.20 (48.55)	20	287.97 (217.14)	10.31 (178.70)	32	208.00 (146.98)	-3.33* (56.53)	15

Table 4.7: Mean and standard deviation (SD) of Closure duration (CD) and Voice onset times (VOT) produced by the three subject groups (adult stutterers, child stutterers and children with NNF)

(*-ve sign indicates a lead VOT)

Closure Duration (CD) : ANOVA with repeated measures showed that CD was significantly different between the three speech conditions in adult Stutterers [F (2, 44)

= 4.092, $p < 0.05$] and in child stutterers [F (2, 62) = 6.178, $p < 0.05$], but not in children with NNF [F (2, 28) = .470, p = 0.630].

A Bonferroni post-hoc test showed that the CD's were significantly different between FLD and FL conditions in adult stutterers, while in the child stutterers, the difference between AVG and FLD conditions were significantly different.

Voice Onset Time (VOT) : Analysis of variance (ANOVA) revealed no significant difference between the three speech conditions in any of the three groups: adult stutterers [F (2, 38) = 0.227, p = 0.798], child stutterers [F (1, 38) = 2.670, p = 0.104] and children with NNF [F (1, 15) = 0.066, p = 0.814].

Between Subject - Group Differences

One-way ANOVA revealed that there was no significant difference in CD {AVG [F (2, 67) = 2.164, p = 0.123] and in FLD [F (2, 67) = 1.968, p = 0.148], FL [F (2, 67) = 1.707, p = 0.189]} and VOT {AVG [F (2, 64) = 2.106, p = 0.130] and in FLD [F (2, 64) = 0.645, p = 0.528], FL [F (2, 64) = 0.388, p = 0.680]} among the three groups in any of the three conditions: This is illustrated in Figure 4.26 and 4.27.

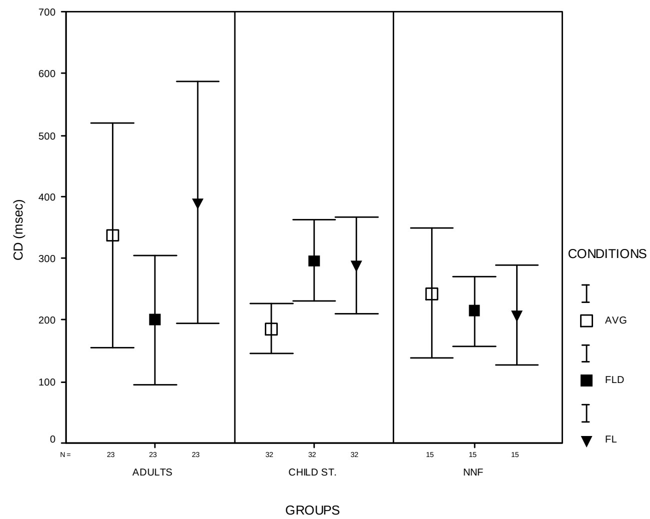

Figure 4.26: Group performance in CD across the three conditions

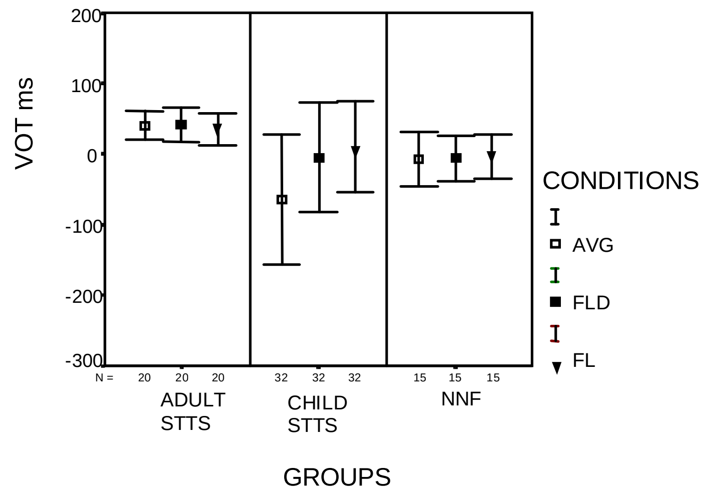

Figure 4.27: Group performance in VOT across the three conditions

CHAPTER 5

DISCUSSION

This study revealed several interesting results: The findings on formant frequency measures (F_1 and F_2) in the speech of the three groups of subjects revealed a clear centralization of vowels in the speech of adult and child stutterers, but not in the speech of children with NNF. A rule of thumb in relating F_1 is that it varies with tongue height while F_2 varies with tongue advancement (with variation in the anterior-posterior position of the tongue). Figure 5.1 illustrates this acoustic-articulatory relation.

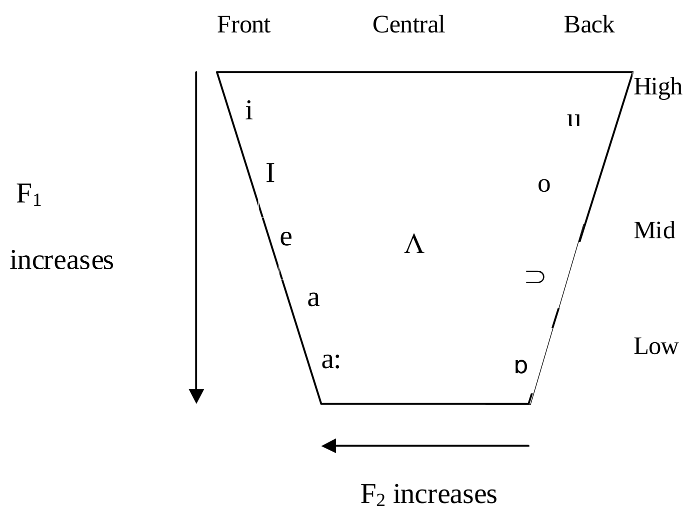

Figure 5.1: Vowel quadrilateral adopted from Handbook of International Phonetic Association (1999) and modified for the purpose of the study to illustrate the acoustic-articulatory relation of vowels used in the study.

It is clearly evident from Figures 5.2(a) to (f) that there is a clear centralization of vowels in the AVG condition in contrast to FLD and FL conditions. In the Figures 5.2 (d) to (f), average F_2 values show that centralization is evident for all vowels and in both adult and child stutterers. There is no centralization observed for vowel /u/ and /o/ except for F1 in the speech of adult stutterers.

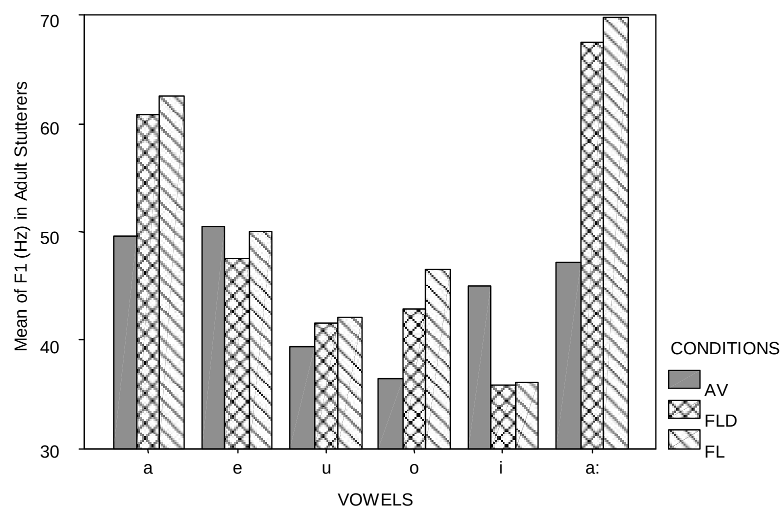

Fig. 5.2 (a): F_1 of vowels produced in the three speech conditions by the adult stutterers

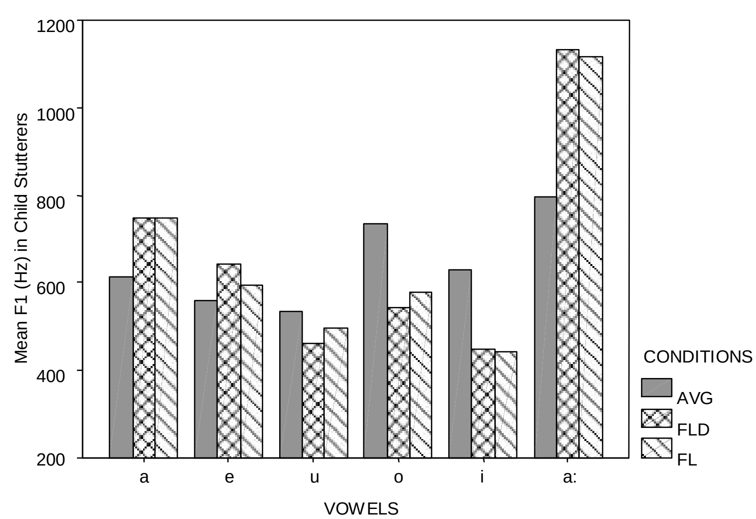

Fig. 5.2 (b) : F_1 of the vowels produced in the three speech conditions by child stutterers.

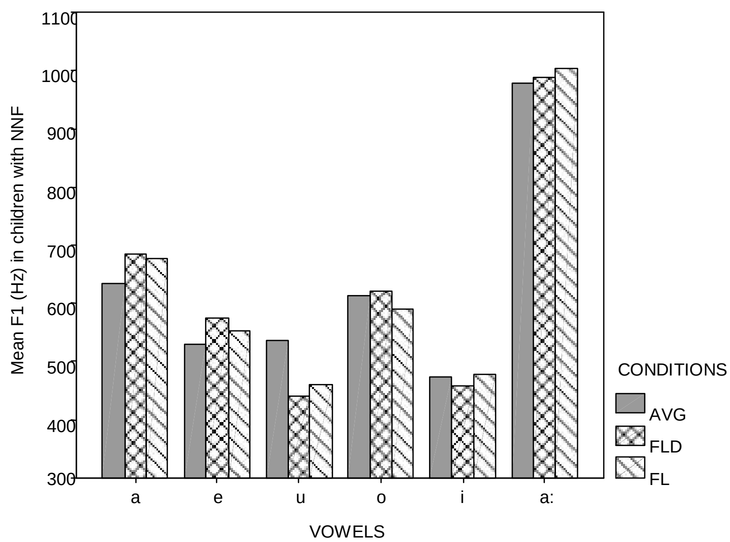

Fig. 5.2 (c) : F_1 of the vowels produced in the three speech conditions by children with normal nonfluency.

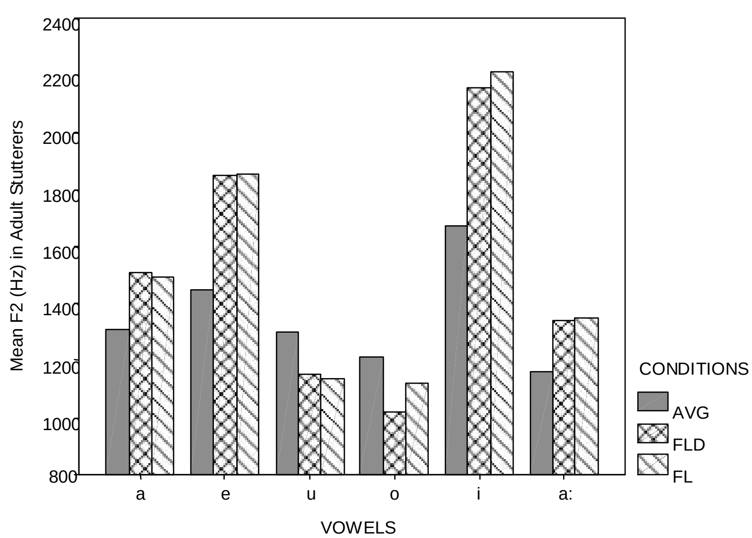

Fig. 5.2 (d) : F_2 of the vowels produced in the three speech conditions by adult stutterers.

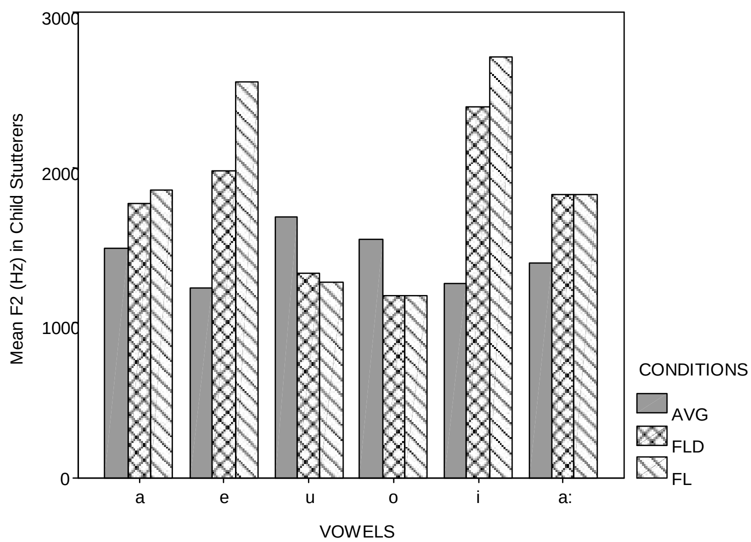

Fig. 5.2 (e) : F_2 of the vowels produced in the three speech conditions by child stutterers.

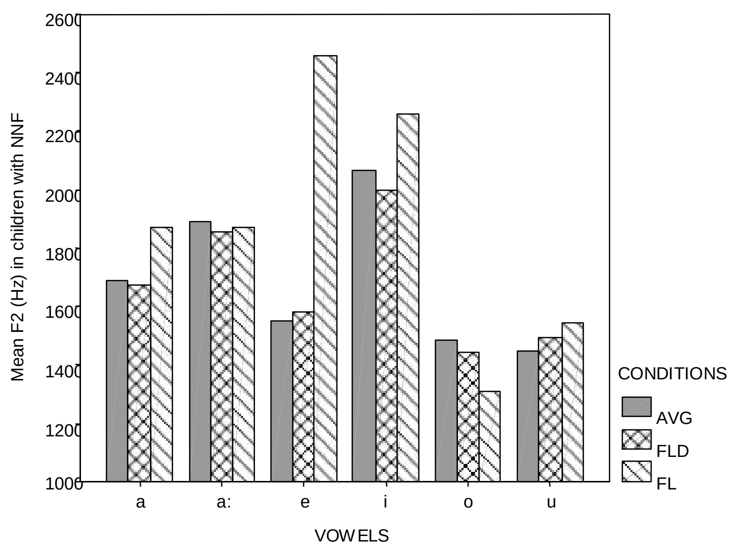

Fig. 5.2 (f) : F_2 of the vowels produced in the three speech conditions by children with normal nonfluency (NNF)

This may be because of two reasons: the sample size (number of CV tokens) analyzed for these two vowels was too small compared to other vowels to expect any consistent result. Front vowels and F_2 are known to be a particular combination in which stutterers and non-stutterers are different (Prosek, Montgomery, Walden and Hawkins, 1987). These findings are in agreement with those of Klich and May (1982), but Klich and May studied only adult stutterers and did not employ a control group. Similar results were reported by Blomgren, Robb and Chen (1998), but they too studied only adult stutterers. Rosenthal, Curlee and Yingyong (1998) also reported similar results on vowel centralization that is present only in the speech of child stutterers, but not in the speech of non-stuttering children, but this evidence comes from an analysis of only a small number of samples and phonemes. A large number of part-word repetitions were analyzed in this study for F_1 and F_2 characteristics, thus making the results valid. These findings add to the mounting evidence that vowels produced by stutterers (both children and adults) are more centralized compared to that of normally nonfluent children, indicating that stutterers restrict their vowel articulations spatially during dysfluent utterances. Therefore, presence or absence of vowel centralization can be considered a factor which differentiates child stutterers from children with normal nonfluency. The findings of the present study also suggest that once vowel centralization sets in child stutterers, it persists into adulthood. Contradicting evidence to the findings exist (Prosek, Montgomery, Walden and Hawkins, 1987; Howell and Williams, 1998). However, Prosek et. al reported only on the speech of adult stutterers while Howell and Williams (1998) did not have a control group for comparison.

The present study further revealed that, in the speech of adult stutterers vowels were shorter in dysfluent utterances, compared to the same vowels uttered fluently in a totally fluent context. Reimann (1976) also reported similar findings though only in the speech of adults. The results of the present study on vowel duration are different from those reported by Disimoni (1974), Hillman et al (1977), Metz et al (1979), and Prosek et al. (1979) who all reported longer vowel duration in the speech of stutterers compared to that in the speech of nonstutterers. Perhaps, the nature of vowel and their realization is different in the languages that these studies were concerned with.

In addition to this, the present investigation revealed that in child stutterers and children with normal nonfluency, there was no significant difference in duration of vowels between the stutterered (or normally nonfluent) vowels and those produced fluently. This result is depicted in Figure 5.3 (a) to (c). A majority of the studies on vowel duration have compared stutterers with normally fluent children and not between dysfluent and fluent utterances produced by the same child. Studies have also been carried out that conducted pretherapy - posttherapy comparisons. Metz, Contour and Caruso (1979) and Murthy (1988) have reported that vowel durations were shorter prior to therapy compared to vowels produced after therapy.

This study also revealed that adult stutterers had significantly shorter vowel durations compared to the two groups of children in all the three fluency conditions. Contradicting evidence for this finding has been reported by Healey and Adams (1981) who reported that two groups of children (children with stuttering and normal nonfluency) produced speech durational values similar to adults with and without stuttering. Methodological variations, specifically in data collection and analysis procedures, can account for this difference in the results of the present study compared to that reported in Healey and Adams (1981). In the fluent condition, however, children with normal nonfluency produced vowel durations similar to that of adults whereas children with stuttering displayed significantly longer durations compared to the other two groups. This may indicate that children with normal nonfluency can control their durational components of speech like vowel duration as good as adults in fluent conditions, while children with stuttering fail to do so even in fluent utterances.

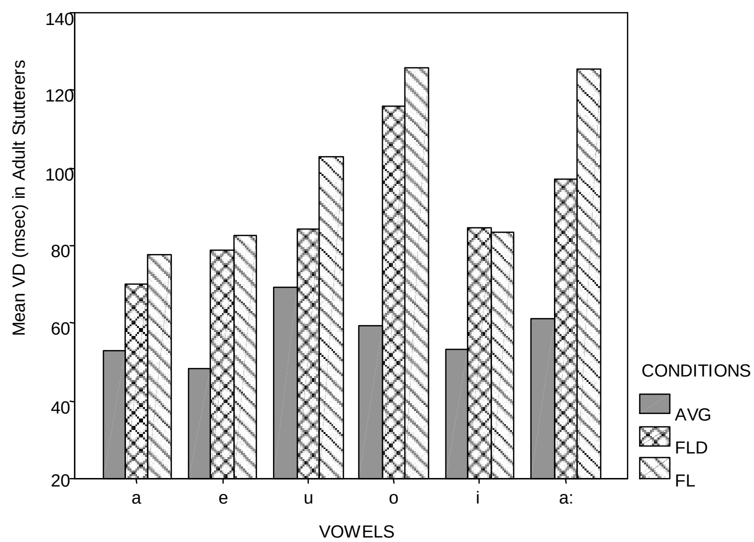

Fig. 5.3a : Mean VD of the vowels produced in the three speech conditions by adult stutterers.

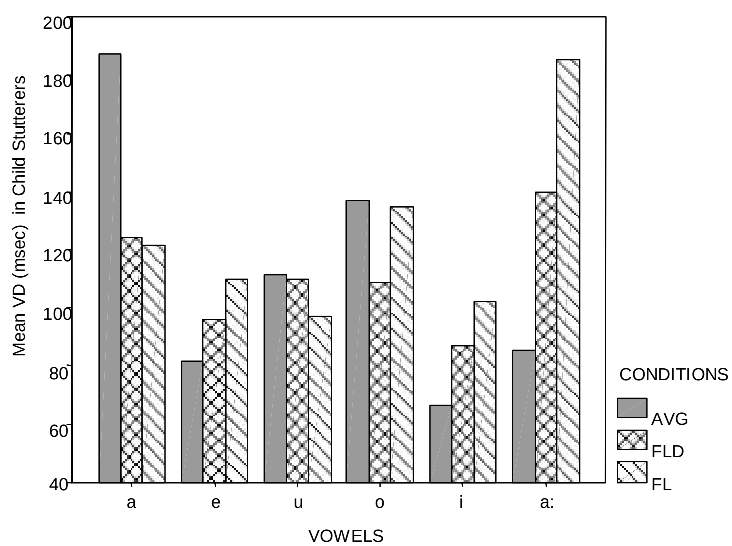

Fig. 5.3 b : Mean VD of vowels produced in the three speech conditions by child stutterers

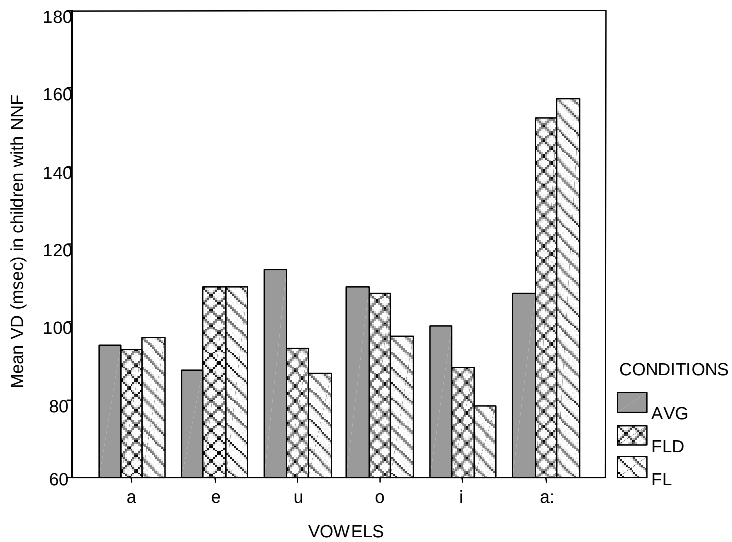

Fig. 5.3c : Mean VD of vowels produced in the three speech conditions by children with normal nonfluency (NNF)

The next set of interesting findings of this study pertain to those relating to the formant transition measures. The nonmeasurable transitions were seen to a maximum extent in the speech of adults and children with stuttering in the dysfluent conditions in comparison to the disfluent utterances of children with NNF. This finding is supported by results reported by Yaruss and Contour (1993), Prakash et al (1998) and Prakash (2000). In addition to this, a more subjective set of observations on the pairs of spectrographic analysis was made. These observations revealed that a discrepancy existed between AVG compared to FLD and FL conditions, and even between the FLD and FL conditions, indicating that the production of a fluent word following a stuttered event, was generally not free of stuttering. Supporting evidence for the same is available in Montgomery and Cooke (1976). The occurrence of such discrepancies was seen to a greater extent in the speech of adult stutterers followed by child stutterers and children with NNF. This means that this abnormality becomes progressively more pronounced as a child stutterer develops into an adult.

In all the three subject groups, there was no difference in transition duration between the dysfluent and fluent utterances. This indicates that the time taken for movement from one articulator to the next in the production of the first syllable of the sequence remains constant regardless of whether the utterance is produced fluently or dysfluently. This finding is in agreement with the findings of Zebrowski, Contour and Cudahy (1985). But several contradicting findings have also been reported. Several studies have reported shorter vowel durations in stutterers compared to normals (Revathi, 1989; Raghunath, 1992, Prakash et al 1998 and Yaruss and Contour). These differences may be attributed to methodological variations which include subjects, method, language studied, or the differences in the statistical procedures employed. More importantly, most of these studies have compared stutterers with normals. The within-group comparison in this study indicated significant lengthening of F_2 transition duration by child stutterers in comparison to adult stutterers and children with NNF in the AVG and FLD (dysfluent context). This result can also be a diagnoistic indicator for differentiating children with stuttering from their normally nonfluent peers.

The results revealed that there was no significant difference in the extent of transition in the “measurable and nondiscrepant” -RRR transitions, but there was a significant difference in the FFF transitions. In addition, “measurable but discrepant” (RFF, FRR) transitions in the dysfluent utterances (AVG) had a lower extent of transition or were in opposite directions compared to the fluent utterances. This indicates that during instances of dysfluent behavior, a sound, either the consonant or the vowel is produced with an abnormal articulatory posture and articulatory "path" that does not lead to the next gesture. Between group comparisons revealed that in "measurable and nondiscrepant" transitions (FFF) in fluent speech, adults showed significantly shorter extent of F_2 transitions compared to the two groups of children. The difference between child stutterers and normally nonfluent children was not statistically significant, however.

The speed of transition was not statistically different between the adult stutterers for any of the speech conditions. But, the speed of transition during the dysfluent portion (AVG condition) of speech is significantly slower compared to the speed during the fluent production of the same in child stutterers whether it was in a totally fluent context (FL) or the fluent portion following dysfluency (FLD). Robb and Blomgren (1997) reported that the fluent portions of stutterers speech was characterized by larger slope coefficients / faster speed of transition indicating greater or quicker changes in vocal-tract behavior compared to those of nonstutterers. Though the results of the present study do not add to this evidence, a possible explanation for the findings may be that when individuals cannot change the dimensions of vocal tract-behavior quickly enough to achieve the next target, the result is dysfluent utterance.

Features of consonants

The adult stutterers and child stutterers, on the hand, and child stutterers and normally nonfluent children, on the other hand, were not significantly different with respect to VOT and consonant duration. This means that the VOTs and consonant durations are the same in dysfluent and fluent utterances of child and adult stutterers. Although there are no comparable studies which have focused on VOT and consonant duration in the dysfluent and fluent utterances of the same in stutterers, there is some evidence from comparisons of stutterers with normals (Metz, Contour and Caruso (1979), Watson and Alfonso (1982) and Zebrowski, Contour and Cudahy (1985).

Vowels : The Central Characters

The significance of these findings to understanding stuttering is this: it is the vowels, which are the focal points in stuttering. Production of consonants is not seriously affected. The individual who repeats /p^… p^…pen/ or prolongs /p………en/ perhaps has no difficulty in achieving the consonant, but it is in moving from the consonant to the next articulatory configuration that he/she encounters a problem.

An interpretation like this may not be warranted coming as it is from an analysis of a small number of tokens of part-word repetitions in this study. However, evidence was presented in the earlier section of this chapter that both adult and child stutterers centralize their vowels (in CV part-word repetitions) in dysfluent utterances, but not in fluent utterances. Therefore, the focus of our study in stuttering should be vowels and not consonants.

There is mounting evidence to show that stutterers centralize their vowels (at least in part-word repetitions on CV sequences) and the results of this study add further evidence to this observation. It means that stutterers restrict their vowel articulation spatially in their dysfluent utterances. Such a restriction was not seen in their fluent utterances. It appears that only when stutterers overcome vowel centralization, a fluent production of the same is possible. It would be interesting to study the factors which enable the stutterers to overcome vowel centralization or what compensatory strategies they practice in overcoming vowel centralization. In other words, a study of why vowel centralization occurs only sometimes and not all times, and why they lead (if at all !) to repetitions need to be investigated.

Several cardinal features have been identified to differentiate children with stuttering from children with normal nonfluency. Some of these features are: presence of a greater number of part-word repetitions in child stutterers, presence of schwa vowel in syllable repetitions, silent or audible sound prolongations occurring in initial or final syllables of words, silent pauses within words, apparent tension during repetitions, multiple iterations, and phoneme consistency are seen to occur in the speech of only child stutterers and not in the speech of children with normal nonfluency.

This study has suggested that vowel centralization occurs in the dysfluent utterances in the speech of child stutterers, but not in the speech utterances of normally nonfluent children. Therefore, vowel centralization may be used as a predictor of stuttering in children with normal nonfluency. However, longitudinal studies are warranted to explore this possibility.

Another result from this study which can be used as an indicator for differentiating child stutterers from normally nonfluent children is the lengthening of F_2 transition in the dysfluent utterance of child stutterers. However, it must be remembered that there were only group differences (child stutterers had significantly longer F_2 transition duration compared to adult stutterers and normally nonfluent children) with regard to F_2 transition duration, and that, this may or may not be associated with stuttering. In other words, longer F_2 transition duration was seen in both dysfluent utterances and the fluent utterances of the same. The potential of F_2 transition duration as a diagnostic indicator of stuttering in children needs to be explored.

CHAPTER 6

SUMMARY & CONCLUSIONS

A decade and half since the time Van Riper (1990) made his concluding remarks on stuttering, and hoped that sooner than later the cause and cure for stuttering will be found so that his vow to the birch sapling will be fulfilled, stuttering still remains a puzzle in more ways than one. The present study was aimed at investigating if the feature of vowel centralization is seen in adult stutterers and if so, is it something they develop through several years of stuttering? Or is it something that is present in early stuttering? And if found in child stutterers, then is it a part of the developmental process apparent in children with normal nonfluency also? The study was also extended, utilizing the data collected for the above purpose, to probe into some of the consonant characteristics in consonant-vowel (CV) contexts of the stuttered and fluent productions in the speech of adult and child stutterers.

The study involved acoustic analysis of CV part-word repetitions in three groups of subjects: adult stutterers, child stutterers and children with normal nonfluency. The dysfluent utterance of CV tokens, their eventual fluent production, and fluent production of the same token in some other context were subjected to analysis. The adults were aged 16-30 years, while child stutterers and normally non-fluent children, were aged 3-7 years. Specifically, nine parameters were analyzed using a software based program (SSL): formant frequencies (F_1 & F_2), vowel duration, transition duration, extent of transition, speed of transition, morphology of F_2 contour, voice onset time and closure duration.

Each of these parameters was evaluated as a function of fluency condition (dysfluent utterance, eventual fluent utterance and fluent production in some other context of speech), and subject group (adult stutterers, child stutterers and children with NNF). The results revealed the following:

i) F_1 and F_2 patterns showed centralization in the dysfluent utterances compared to that in the fluent production of the same utterance. This was true of both adult and child stutterers, but not of children with NNF.

ii) Adult stutterers demonstrated shorter vowel duration in their dysfluent productions compared to the fluent utterances. This was not seen in the speech of child stutterers or of children with normal nonfluency.

iii) Abnormal and non-measurable transitions were seen to occur to a greater extent in the speech of adults and children with stuttering in the dysfluent conditions in comparison to the dysfluent portions produced by children with NNF.

iv) F_2 transition duration was significantly longer in the speech of child stutterers in comparison to adult stutterers and children with NNF.

v) Dysfluent utterances had lower extent of transition, or the tranisitions in opposite directions compared to the fluent utterances in the speech of adults and child stutterers. Adult stutterers, as a group, had significantly shorter extent of F_2 transitions compared to the two groups of children.

vi) Child stutterers had significantly slower speed of transitions in their dysfluent utterances compared to fluent utterances of the same. Again, this was not seen in either adult stutterers or children with NNF. However, the three subject groups were not significantly different with respect to speed of transition in any of the speech conditions.

vii) No statistically significant difference was found in voice onset time and closure duration between the three conditions for any of the three groups of subjects, or between the groups for any of the three conditions.

It appears that vowel centralization is purely a phenomenon of stuttering and it is present in child stutterers and persists into adulthood. Additionally, the deviations found in F_1 / F_2 transitions reflect the aberrant movements in the articulatory systems. However, deriving conclusions based on these findings should be done with caution, since this was not a longitudinal study, and the analysis was limited to sound/syllable repetitions. It is also not clear whether these abnormalities also characterize other types of dysfluent behaviors, say prolongations. Acoustic measures however, have proved to be useful in differentiating children with stuttering from their normally nonfluent peers. It is suggested vowel centralization can be used as an indicator for diagnosis of stuttering in children; and to differentiate them from children with normal nonfluency.

The findings of the present study throw some useful indicators for future research. For example,

- Kinematic studies can be done to confirm the exact nature of articulator displacements in stutterers compared to normals, both in terms of dysfluent utterances and their fluent productions.
- Dysfluent behaviors other than sound/syllable repetitions, particularly prolongations should be investigated on similar lines.

Vowel centralization was observed in the dysfluent utterances of adult and child stutterers, but not in the speech of normally nonfluent children. A study of what factors precipitate development of vowel centralization so that some of the normally nonfluent children go on to develop stuttering might help solve the riddle of stuttering.

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