F2 TRANSITION OF VOWEL TO VOWEL CONTEXT IN CHILDREN WITH STUTTERING

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APRIL 2018

CERTIFICATE

This is to certify that this dissertation entitled **"F2 transition of vowel to vowel context in children with stuttering"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 16SLP023. 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.

Mysuru
April 2018

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CERTIFICATE

This is to certify that this dissertation entitled "**F2 transition of vowel to vowel context in children with stuttering**" has been prepared under my supervision and guidance. It is also been certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"F2 transition of vowel to vowel context in children with stuttering"** is the result of my own study under the guidance of Dr. Sangeetha Mahesh, Clinical Reader, Department of DCS, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,	Registration No.
April 2018	16SLP023

Dedicated

to my

Family

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CHAPTER I

INTRODUCTION

Van Riper (1982) defined stuttering as a temporal disruption of the simultaneous and successive programming of muscular movements required to produce a speech sound or its link to the next sound. Stuttering is considered a multi-dimensional speech disorder influenced by motor, linguistic, and emotional factors. The exact cause of stuttering is unknown, but it is widely accepted that stuttering is associated with deficiencies in the neural functioning that underlies speech production. For instance, studies have identified timing and functional connectivity issues between speech and language areas of the brain (Chang, Horwitz, Ostuni, Reynolds, & Ludlow, 2011; Salmelin, Schnitzler,Schmitz, & Freund, 2000), indicating possible deficits in speech motor control strategies.

Speech motor control refers to the neuro-muscular organization that mediates the complex and precise movements involved in the production of speech (Kent, 2000). A number of studies have directly and indirectly assessed speech motor control in people who stutter. Direct studies of speech motor control have used a variety of kinematic and isometric force generation tasks to compare stuttering and non-stuttering speakers. For instance, differences have been identified in the relative speed of repetitive movements involving the tongue (McClean & Tasko, 2004), the lips (Howell, Andrew, Bartrip, & Bailey, 2009; Max, Caruso, & Gracco, 2003; Namasivayam & Van Lieshout, 2004; Smith & Goffman, 2004), and the jaw (McClean & Runyan, 2000; Max et al., 2003).These findings have reinforced a long standing belief that, at least in part, the disorder of stuttering is related to a deficit in the ability to coordinate the various components of the speech-motor system (Juste et al., 2012; Van Riper, 1971; Wingate,1969).

A number of theoretical accounts of stuttering have emerged recently that implicate primary deficits in sensorimotor control (Smith, 1999; Van Lieshout, 2004; Alm, 2004; Loucks & deNil, 2006; Civier, Bullock, Max, & Guenther, 2013). Support for this viewpoint comes from a number of sources. First, there is a growing literature demonstrating that children and adults who stutter exhibit speech motor patterns that are different from the non-stuttering population, even during fluent speech (e.g. Smith, 2010; McClean, Tasko, & Runyan, 2004). Second, recent neuro-imaging studies have identified functional and structural differences between children who do and do not stutter (Chang & Zhu, 2013). These differences involve reduced connectivity beneath the motor regions of the face and larynx and in the basal ganglia thalamo-cortical circuitry known to be associated with sequential motor control and sensori-motor learning. Third, significant advancements in contemporary theories/models of speech production allow greater opportunities for testing of specific hypotheses about stuttering. For example, in recent years there have been a handful of published studies which have attempted to provide a mechanistic account of stuttering within the *Directions into Velocities of Articulators (DIVA)* model, a computational model of speech production (Civier & Guenther, 2010; 2013). DIVA is a neural network-based computational model that attempts to account for the acquisition and control of speech production.

The onset of stuttering typically occurs between two and three years of age, a time when there is a rapid expansion in the length and complexity of both speech and language (Yairi & Ambrose, 2005). Incidence and prevalence rates of stuttering are similar across cultures and languages, and there is growing evidence from a variety of sources that genetics play a factor in the etiology of stuttering (Bloodstein & Ratner, 2008). The prevalence of stuttering across the world is nearly 1% of the population and estimates of lifetime incidence rates range from 4% to 11% of the population (Yairi &

Seery, 2011). This discrepancy between prevalence and lifetime incidence highlights the fact that the majority of children who begin to stutter will recover with or without therapy. For the one percent who continue to stutter, it is typically a chronic, lifelong condition. Therefore, understanding the etiology and optimal management of stuttering remains a significant concern for both researchers and clinician alike.

Motor Speech Profile (MSP)

MSP operates similarly in either Multi-Speech or Computerized Speech Lab (CSL). However, there are some differences between how MSP works with CSL hardware or generic audio cards. These operational differences involve the interface to the hardware. Multi- Speech uses generic audio cards while CSL includes professional-level hardware from KayPENTAX. When used with generic audio cards for its operations, the quality of the input and output signal is dependent on the quality of the audio card. Typically, generic cards offer substantially poorer performance when compared to professional-level sound input/output systems such as digital recorders, CSL, and Visi-Pitch. MSP is most commonly used with its built-in protocols to analyze motor speech behaviour in a systematic and automatic procedure. Each protocol provides client prompts and example audio signals where appropriate, records the client input, analyzes the data, and generates graphics and numerical analysis for a report. Many parameters are needed to characterize motor disordered speech. MSP evokes built-in protocols for different tasks (e.g., running speech, sustained phonation, diadochokinesis, etc.) to extract these separate parameters. For example, distorted vowels are often characterized by neutralized second formant positions and abnormal second formant transitions. MSP sets up tasks to measure and assess this behaviour using defined target vocalizations prompts and measurement of client attempts. Similarly, diadochokinetic rate (DDK) and periodicity of DDK have been shown to be closely associated with articulatory motility. MSP asks the client to vocalize a defined target suitable for DDK measurement. MSP complements the speech professional's well-trained ear by systematically and objectively analyzing many speech parameters relevant to motor speech assessment. MSP uses defined tasks and articulatory "exercises" to test for motor speech disorders. Just as heart stress testing is designed to stress the cardiovascular system with standardized tests, MSP protocols use standard tests, which are demanding of a client's motor speech skills. In many cases, this speech "stress" test can reveal motor speech problems before these problems are detectable in normal running speech. In any case, defined speech tasks are required because the client's speech analysis must be compared to normal speakers in order to be useful. Defined speech tasks are required to establish comparable acoustic analysis because normative data requires standard passages. Second Formant Transition is one of the protocols in MSP which assesses the client's ability to accurately, quickly, and rhythmically make target second formant transitions.

Need for the study

Research attempts have been conducted on the F2 transitions in stuttered speech trying to verify different hypotheses. Co articulation and Formant transition rate (FTR), have been directly and indirectly addressed in previous studies of people who stutter. Data regarding formant transition in the dysfluent speech of children and adults indicate that pattern of second formant (F2) transitions is variable. The F2 transitions are sometimes absent or atypical (Howell & Vosue, 1986; Stroma, 1986; Yaruss & Conture, 1993) when they are appropriate they tend to be short in duration (Yaruss & Conture 1993). Recently research has postulated that stuttering is motor disorder that results from brain abnormalities within the central nervous system. Children with stuttering often show broad deficits across a broad range of motor skills: (1) gross motor skills, (2) fine motor skills, (3) visual-spatial motor skills (Andrew, 2012). Based on evidence of numerous irregularities within various motor systems, it has been suggested that other motor domains may be comprised. The results of the past studies on F2 transition vary, but they confirm that: individuals who stutter experience difficulty transitioning from one speech sound to the next; the pattern of second formant transitions in stuttered and non-stuttered speech is different; children with stuttering tend to reveal appreciable variations in F2 transition. This study, in Kannada will focus on Second formant transitions of vowel to vowel context in children with stuttering using Motor Speech Profile (MSP). A common method of acoustically examining vowel formants is within a consonant + vowel (CV) or consonant + vowel + consonant (CVC) syllable context but the MSP uses another method and makes the procedure more practical to implement. Variability exists among speakers for same acoustic targets and within the same regional accent. In Indian context there are limited studies conducted using MSP and also studies conducted using MSP contains small aged and gender matched sample size. Hence the present study is planned to investigate the F2 transition in children with stuttering and in matched normal age and gender population for vowel to vowel context.

Aim

The primary aim of the present study is to investigate the Second formant transition patterns in children with stuttering for vowel to vowel context using Motor Speech Profile.

Objectives of the study

1. To analyse and compare the Second formant transition in children with stuttering and control group.

2. To analyse and compare the Second formant transition across three degrees of stuttering.

CHAPTER II

REVIEW OF LITERATURE

There are a number of previously published studies that have attempted to examine the relationship between stuttering and formant transition patterns in both Western and Indian context focused from early 90's. The literature reviews are discussed as follows.

Acoustic Studies in Children with Stuttering (CWS)

In an effort to evaluate formant transition duration and rate, Zebrowski, Conture, and Cudahy (1985) compared the speech of 11 young CWS with 11 normally fluent counterparts. A large number of acoustic measures were made from subjects' fluent speech including consonant vowel F2 transition duration and rate. Results failed to show any significant differences between the two groups. The authors attempted to explain the lack of significant findings by identifying some inherent challenges associated with their study including the difficulty of obtaining reliable acoustic data for children as well as the small subject sample size.

An analysis of acoustic data for fluent and disfluent speech for F2 transitions in 13 CWS was conducted by Yaruss and Conture (1993). The children were divided into two groups based on their likelihood for persistence (based on Stuttering Prediction Index scores). Five acoustic measures were made; duration of F2 transition, onset and offset frequencies of F2 transitions, extent of F2 transition, and rate of frequency change in F2 transition. The results indicated that formant transitions differ between fluent and stuttered productions both within and between groups (low-risk and high-risk for persistence of stuttering). However, since the study did not include a control group, it is not possible to determine if the F2 transition measures of the fluent productions of either group of CWS were different from non-stuttering peers.

Kloth, Janssen, Kraaimaat and Brutten (1995) suggested that both speech-motor and linguistic factors are involved in the etiologic of stuttering. This contention has been supported by findings that tend to indicate that youngsters who stutter have a slower speech rate and are less linguistically skilled than children with non-stuttering. However, no inferences can be drawn from these findings as to the nature or the causation of this disorder. This is because the aforementioned findings might be a result rather than a cause of the disorder. In order to clarify the directionality issue, a multi-year prospective study was undertaken that involved 93 preschool children with a parental history of stuttering. At the initial session, none of the high-risk children sampled was regarded as having a stuttering problem. One year later, 26 children were classified as stutterers. Statistical analyses revealed that prior to the onset of stuttering these children did not differ from the other youngsters studied with respect to either their receptive or expressive language abilities. However, their rate of articulation was significantly faster. The latter finding is taken to mean that the children who developed stuttering were not limited in speech motor ability. Rather, their fluency failures are seen as a result of a relatively high articulation rate. It is noteworthy, in this regard, that the rate of the high-risk children who continued to be viewed as non-stutterers was slower than that previously reported for youngsters of their age. This suggests that the slower rate served as a buffer against fluency breakdown.

Yaruss (1997) examined the relationship between articulatory speaking rate and response time latency in the conversational speech of 12 boys who stutter (mean age = 55.2 months; SD = 8.8 months) who participated in 30-min conversational interactions with their mothers. Discriminant function analyses were conducted on 75 utterances drawn from each child's speech sample to determine if the articulatory speaking rate or response time latency of a specific utterance was related to the likelihood that the child would stutter on that utterance. No significant relationships between these measures of utterance timing and stuttering were found for any of the 12 subjects, and there were no significant relationships between these two measures of utterance timing. Findings do not provide support for many current theories of stuttering and suggest that the role of these measures of utterance timing in predicting the occurrence of stuttering in conversational speech in these theories may need to be re-examined.

A pilot study done by on the incidence and development of early childhood stuttering conducted on the Danish Island of Bornholm by Mansson (2000), where the entire population of children born within a 2-year span was surveyed. The findings indicated that the incidence of stuttering reached the level of 5.19%, that 71.40% of the children stopped stuttering within 2 years after the original survey, and that more children stopped stuttering at a later time. Additional information on the characteristics of the children and early stuttering was presented. The results were compared to recent research in the field. Authors concluded saying that further research activities of this project are in progress.

Chang, Ohde and Conture (2002) assessed anticipatory co articulation and second formant (F2) transition rate (FTR) of speech production in young children who stutter (CWS) and who do not stutter (CWNS). Fourteen CWS and 14 age- and gender-matched CWNS in three age groups (3+, 4+, and 5+year-olds) participated in a picture-naming task that elicited single-word utterances. The initial consonant- vowel (CV) syllables of these utterances, comprising either bilabial [b m] or alveolar [d,n,s,z] consonants and a number of vowels [a,i,u,o,a,i,au], were used for acoustic analysis. To assess co articulation and speech movement velocity, the F2 onset frequency and F2 vowel target frequency (for co articulation) and FTR (for speech movement velocity) were computed for each CV syllable and for each participant. Based on these measures, locus equation statistics of slope, y-intercept, and standard error of estimate as well as the FTR were analyzed. Findings revealed a significant main effect for place of articulation and a significantly larger difference in FTR between the two places of articulation for CWNS than for CWS. Findings suggest that the organization of the FTR production for place of articulation may not be as contrastive or refined in CWS as in CWNS, a subtle difficulty in the speed of speech-language production, which may contribute to the disruption of their speech fluency.

The second formant transitions of 14 children who stutter and 14 fluent, age matched peers were examined by Chang, Ohde, and Conture (2002). Results showed no group differences in the locus equation analysis and failed to show any evidence that formant transition rates were different for Children who stutter (CWS) and normally fluent children. The authors did find that differences in formant transition rates based on place of articulation were not as marked for the CWS as compared to the normally fluent children, which the authors interpreted as evidence for a less refined speech motor organization in CWS.

Subramanian, Yairi and Amir (2003) investigated frequency change and duration of the second formant (F2) transitions in perceptually fluent speech samples recorded close to stuttering onset in preschool age children. Comparison was made among 10 children known to eventually persist in stuttering and 10 normally fluent controls. All were enrolled in the longitudinal stuttering research project at the University of Illinois. Subjects were asked to repeat standard experimental sentences fluently. The same 36 perceptually fluent target segments (syllables embedded in words) from each subjects repeated sentence was analyzed. The syllable was divided into three phonetic categories based on their initial consonants: bilabial, alveolar and velar placement. The frequency change and duration of F2 transitions were analyzed for each of the target CV segments. F2 transition onset and offset frequencies and their interval (duration) was measured for each utterance. Data indicated that near stuttering onset, children whose stuttering eventually persisted demonstrated significantly smaller frequency change than that of the recovered group.

Cerebral lateralization in visual perception was investigated in 9 severe stuttering, 11 mild stuttering and 48 fluent speakers by Szelag , Kolek , Herman & Stasiek (2003). The subjects were asked to identify words presented in the left or right visual field for 20 ms. Children responded by pointing to the exposed test word on a response card which contained four different words. Errors committed in the left and right visual fields were analyzed. The data showed left hemisphere superiority in the processing of words in both the mild stutterers and the fluent speakers, but a right hemisphere advantage in the severe stutterers. The results suggested a close relationship between the severity of stuttering and functional brain organization.

Martinez Jr. (2012) investigated whether motor skills in children who stutter (CWS) were compromised. Participants included 12 CWS and 12 children who do not stutter (CWNS). Participants were recruited from a large urban school district and were administered the Bruininks-Oseretsky Test of Motor Proficiency-Second Edition (Bruininks & Bruininks, 2005; BOT-2). Parents completed a demographic questionnaire. Results indicated that CWS performed poorer on all but one motor area.

Speech motor planning and execution deficits in early childhood stuttering was studied by Walsh, Mettel and Smith (2015). They assessed fundamental characteristics of speech movements in preschool children who stutter and their fluent peers to determine if atypical speech motor characteristics described for adults are early features of the disorder or arise later in the development of chronic stuttering. Oro-facial movement data were recorded from 58 children who stutter and 43 children who do not stutter aged 4;0 to 5;11 (years; months) in a sentence production task. For single speech movements and multiple speech movement sequences, we computed displacement amplitude, velocity, and duration. For the phrase level movement sequence, we computed an index of articulation coordination consistency for repeated productions of the sentence. Results revealed boys who stutter, but not girls, produced speech with reduced amplitudes and velocities of articulatory movement. All children produced speech with similar durations. Boys, particularly the boys who stuttered, had more variable patterns of articulatory coordination compared to girls.

Usler, Smith and Weber (2017) determined if indices of speech motor coordination during the production of sentences varying in sentence length and syntactic complexity were associated with stuttering persistence versus recovery in 5- to 7-year-old children. They compared children with persistent stuttering (CWS-Per) with children who had recovered (CWS-Rec), and children who do not stutter (CWNS). A kinematic measure of articulatory coordination, lip aperture variability (LAVar), and overall movement duration were computed for perceptually fluent sentence productions varying in length and syntactic complexity. CWS-Per exhibited higher LAVar across sentence types compared to CWS-Rec and CWNS. For the participants who successfully completed the experimental paradigm, the demands of increasing sentence length and syntactic complexity did not appear to disproportionately affect the speech motor coordination of CWS-Per compared to their recovered and fluent peers. However, a subset of CWS-Per failed to produce the required number of accurate utterances. Authors concluded that their findings supported the hypothesis that the speech motor coordination of school-age CWS-Per, on average, is less refined and less mature compared to CWS-Rec and CWNS. Childhood recovery from stuttering is characterized, in part, by overcoming an earlier occurring maturational lag in speech motor development.

Acoustic Studies in Adults with Stuttering (AWS)

The spectral properties of stuttered vowels are similar to the following fluent vowel, so it would appear that the stutterers are articulating the vowel appropriately reported by Howell and Vause (1986). Though spectral properties of the stuttered vowels are normal, others are unusual: The stuttered vowels are low in amplitude and short in duration. In two experiments, the effects of amplitude and duration on perception of these vowels are examined. It is shown that, if the amplitude of stuttered vowels is made normal and their duration is lengthened, they sound more like the intended vowels. These experiments lead to the conclusion that low amplitude and short duration are the factors that cause stuttered vowels to sound like schwa.

Prosek, Montgomery, Walden, and Hawkins (1987) measured formant frequencies of 15 adult with stuttering fluent and disfluent vowels and the formant frequencies of stutterers' and non-stutterers' fluent vowels was compared in an F1-F2 vowel space and in a normalized F1-F2 vowel space. The results indicated that differences in formant frequencies observed between the stutterers' and non-stutterers' vowels can be accounted for by differences among the vocal tract dimensions of the talkers. In addition, no difference was found between the formant frequencies of the fluent and disfluent vowels produced by the stutterers. The overall pattern of these results indicates that, contrary to reports Klich and May (1982) stutterers do not exhibit significantly greater vowel centralization than non-stutterers.

Robb and Blomgren (1997) hypothesized that stuttering is associated with difficulties transitioning from sound to sound, and that this difficulty would result in differences in the articulatory and acoustic transitions at consonants-vowel boundaries. The authors examined the changes in second formant (F2) values during fluent production of *CVt* tokens in five AWS and five normally fluent speakers (NFS). F2 values were extracted at vowel onset and at fixed points of 30 and 60 msecs following vowel onset. Each F2 transition was represented as a slope. The AWS exhibited a trend to have larger slope values than the NFS for many of the test conditions. However, a great deal of variation was observed across vowel and consonant context making general conclusions difficult in these small samples.

Blomgren, Robb, and Chen (1998) evaluated vowel space using the same subjects from the previously mentioned research. They tested the hypothesis that Adults with stuttering (AWS) exhibit a reduced vowel space when compared to normally fluent adults. The authors examined F1 and F2 values during the steady-state region of three corner vowels (/i, u, a/) in a *CVt* context in a group of adult males which included five untreated (within the last five years) and five treated AWS, along with five normally fluent speakers (NFS). Only fluent productions were included in the analyses. Results indicated that, across selected measures, there was a trend for the untreated AWS to have a reduced formant space as compared with controls. Additionally, AWS also exhibited longer vowel durations when compared to the control group.

Review was done to determine what neural mechanisms may be dysfunctional in stuttering by Ludlow and Loucks (2003). Three sources of evidence were reviewed. First, studies of dynamic inter-relationships among brain regions during normal speech and in persons who stutter (PWS) suggest that the timing of neural activity in different regions may be abnormal in PWS. Second, the brain lesions associated with acquired stuttering are reviewed. These indicate that in a high percentage of cases, the primary speech and language regions are not affected but lesions involve other structures, such as the basal ganglia, which may modulate the primary speech and language regions. Third, to characterize the motor control disorder in stuttering, similarities and differences from focal dystonias such as spasmodic dysphonia (SD) and Tourette's syndrome (TS) are reviewed. This review indicated that the central control abnormalities in stuttering are not due to disturbance in one particular brain region but rather a system dysfunction that interferes with rapid and dynamic speech processing for production.

Sussman, Byrd, and Guitar (2010) analysed the acoustic structure of voiced stop þ vowel sequences in a group of persons who stutter (PWS). This phonetic unit was chosen because successful production is highly dependent on the differential tweaking of right-to-left anticipatory co-articulation as a function of stop place. Thus, essential elements of both speech motor planning and execution can be parsimoniously assessed. Five adult PWS read three passages 3 times in a randomised order. These passages contained an overabundance of words beginning with initial [bV], [dV] and [gV] sequences. Digital audio and visual recordings were analysed to first identify fluent and stuttered target words, which were then spectrally analysed to yield locus equation (LE) regression plots. The slope of the LE regression function directly indexes the co-articulatory extent of the vowel's influence on the preceding stop consonant. The PWS revealed LE parameters falling within the normal ranges based on previously documented data obtained from fluent speakers. Theoretical considerations of possible underlying factors responsible for stuttering disfluencies are discussed relevant to these findings.

In an effort to determine if stuttering is associated with abnormal anticipatory co-articulation, Sussman, Byrd, and Guitar (2010) derived F2 locus equations for fluent and nonfluent productions of stop+vowel stimuli in a group of eight AWS. Only five subjects were used in the analysis because three of them had too few disfluent productions. No normally fluent controls were used; instead the authors relied on previously published data. F2 frequencies were measured at the onset and the visually determined midpoint of each vowel. The main measures of interest for this study were the coefficients (i.e. slopes and y-intercepts) of the locus equations, which are regression equations that fit the relationship between F2 onset and F2 midpoint. The results of the analyses showed that the stuttered productions had a considerably higher standard error of estimate (a numerical representation of the distribution of the data points around the regression line), when compared to the fluent productions. However, the basic form of the locus equations did not clearly distinguish the stuttering group from previously published work on NFS. It should be noted that, as is the convention for the development of locus equations, the duration between the F2 onset and F2 midpoint was not reported, making it impossible to determine if there was evidence of a reduced rate of F2 transition.

Civiera, Taskob and Guenthera (2010) investigated the hypothesis that stuttering may result in part from impaired readout of feed-forward control of speech, which forces persons who stutter (PWS) to produce speech with a motor strategy that is weighted too much toward auditory feedback control. Over-reliance on feedback control leads to production errors which if they grow large enough, can cause the motor system to “reset” and repeat the current syllable This hypothesis is investigated using computer simulations of a “neurally impaired” version of the DIVA model, a neural network model of speech acquisition and production. The model’s outputs are compared to published acoustic data from PWS’ fluent speech, and to combined acoustic and articulatory movement data collected from the dysfluent speech of one PWS. The simulations mimic the errors observed in the PWS subject’s speech, as well as the repairs of these errors. Additional simulations were able to account for enhancements of fluency gained by slowed/prolonged speech and masking noise. Together these results support the hypothesis that many dysfluencies in stuttering are due to a bias away from feed-forward control and toward feedback control.

The study done by Arnold (2015) tested the hypothesis presented by Civier et al., (2010) by examining formant transition patterns in the fluent speech of stuttering and non-stuttering speakers. It was hypothesized that the feedback control system will appear as a slower rate of formant transitions when compared to normally fluent speakers and he found that the feedback control system was appearing as a slower rate of formant transitions when compared to normally fluent speakers.

Dehqan, Yadegari, Blomgren and Scherer's (2016) compared formant transitions during fluent speech segments of 10 Iranian males who stutter and 10 normally fluent Iranian males. Sixteen different “CVt” tokens were embedded within the phrase “Begu CVt an” and they measured overall F2 transition frequency extents, durations, and derived overall slopes, initial F2 transition slopes at 30 ms and 60 ms, and speaking rate. Results indicated: (1) Mean overall formant frequency extent was significantly greater in 14 of the16 CVt tokens for the group of stuttering speakers. (2) Stuttering speakers exhibited significantly longer overall F2 transitions for all 16 tokens compared to the non-stuttering speakers. (3) The overall F2 slopes were similar between the two groups. (4) The stuttering speakers exhibited significantly greater initial F2 transition slopes (positive or negative) for five of the 16 tokens at 30 ms and six of the 16 tokens at 60 ms. (5) The stuttering group produced a slower syllable rate than the non-stuttering group. Findings support the notion of different speech motor timing strategies in stuttering speakers. Findings are likely to be independent of the language spoken.

Acoustic Studies in Stuttering with respect to Indian Context

Namita and Savithri (2002) conducted a study on the changes in the acoustic feature of the speech of a person with stuttering over a period of time during therapy. The results indicated a reduction in F2 transition duration indicating improved articulatory precision.

Savithri (2002) aimed at evaluating the efficacy of prolongation therapy in establishing fluency by measuring acoustic parameters in the pre post therapy samples of persons who stutter. Five persons who stutter (4 males and 1 female) in the age group of 12 to 25 years participated in the experiment. For spectrographic analyses, words in the pretherapy reading/ speech samples on which stuttering occurred and the same words in the post therapy samples were used. Results indicated that several articulatory, laryngeal and aerodynamic disco-ordinations were found in pretherapy samples when compared with post therapy samples. The data supports the notion that stuttering is a disorder of disco-ordination in articulation, phonation and breathing.

The study done by Prakash (2003) evaluated speech of 10 normal and 10 stuttering children speaking Kannada on refined acoustic measures viz. formant patterns, speed of transitions, F2 transition duration, and F2 transition range as possible indicators for differential diagnosis. Results revealed that stuttering children exhibited longer transition duration, shorter extent and faster speed of transition and abnormal F2 transition patterns.

The efficacy of non-programmed prolonged speech technique in persons with stuttering was investigated by Jayaram (2006). A total of 30 Kannada speaking persons with stuttering in the age range of 15-38 years who were stratified into two groups based on their age at the time of treatment (group I- 15 to 24 years, group II- 25 to 38 years) participated in the study. Subjects reading, spontaneous speech / conversation were recorded prior to, after and 6 months after non-programmed prolonged speech therapy. Percent dysfluency, type of dysfluency, rate of reading and mean naturalness score, and temporal and spectral acoustic parameters were measured. Aerodynamic, laryngeal, and articulatory errors were also identified and classified as visualized on wide-band spectrograms. The results showed a significant decrease in percent dysfluency and rate of reading and significant increase in mean naturalness scores from pre-therapy to post-therapy conditions in both age groups. However, percent dysfluency and rate of reading increased and mean naturalness score decreased from post-therapy to 6-month post-therapy conditions. Significant differences between conditions were obtained for vowel duration, F2 transition duration, burst duration and voicing duration. Percent discrepant type of transitions decreased from pre-therapy to post-therapy conditions. Aerodynamic, laryngeal, articulatory and multiple errors were present in all conditions and groups. No consistent effect of age on any of the measures was noticed. The results indicated that non-programmed prolonged speech technique was effective and perceptual measures like percent dysfluency, rate of reading and mean naturalness score and new linear coustic measures like vowel duration, F2 transition duration, burst duration and voicing duration could be used as efficacy measures of non-programmed prolonged speech technique. Also individualized therapy techniques can be devised based on aerodynamic, laryngeal and articulatory errors as visualized on wide band spectrograms.

Savithri, Yeshoda, and Venugopal (2007) study aimed at differentially diagnosing normal non-fluency and stuttering based on perceptual and acoustic parameters. They considered 10 normal and 10 Kannada speaking stuttering children with the age range of

3-12 years and speech was elicited individually using pictures, pictures depicting stories and repetition of words. Using wide band spectrogram, transition duration of F2, extent and speed of F2 transition, onset and off set of F2 and pattern of F2 was extracted. These parameters was compared between the groups and results indicated that shorter transition duration(TD), higher offset of F2 and higher SFT in children with stuttering when compared with normal children. Absent and discrepant transitions was more in children with stuttering compared to normal children.

Amulya (2017) investigated second formant (F2) transitions in 30 adults with stuttering. On examining the F2 transition for the clinical group had significantly poor scores compared to that of control group. The four specific parameters varied between groups and these differences are more important when distinguishing Persons With Stuttering (PWS) from without stuttering. The F2 transition within the clinical group also showed a significant difference between the mild and severe stuttering group when compared to that of mild and moderate stuttering group.

Acoustic studies in stuttering using Motor Speech Profile (MSP)

Wong, Allegro, Tirado, Chadha, and Campisi (2011) obtained objective measurements of motor speech characteristics in normal children, using a computer-based motor speech software program. Participants included 112 subjects (54 females and 58 males) aged 4–18 years. Voice samples were recorded and analyzed using the Motor Speech Profile (MSP) software (KayPENTAX, Lincoln Park, NJ). The MSP produced measures of diadochokinetics, second formant transition, intonation, and syllabic rates. Demographic data, including sex, age, and cigarette smoke exposure were obtained. Normative data for several motor speech characteristics were derived for children ranging from age 4 to 18 years. A number of age-dependent changes were indentified, including an increase in average diadochokinetic rate ($p < 0.001$) and standard syllabic duration (p

< 0.001) with age. There was no identified difference in motor speech characteristics between males and females across the measured age range. Variations in fundamental frequency (Fo) during speech did not change significantly with age for both males and females. These authors developed first pediatric normative database for the MSP program. The MSP is suitable for testing children and can be used to study developmental changes in motor speech. The analysis demonstrated that males and females behave similarly and show the same relationship with age for the motor speech characteristics studied. This normative database will provide essential comparative data for future studies exploring alterations in motor speech that may occur with hearing, voice, and motor disorders and to assess the results of targeted therapies.

The F2 transitions in stutterers and non-stutterers in Bulgarian speakers was investigated by Padareva-Ilieva, Georgieva, and Simonska (2012). To implement this study Motor Speech Profile (MSP) was used. The MSP F2 transition protocol measures the ability of subjects to repeat V+V combinations in a fast and rhythmic manner and generated four parameters – F2magnitude, F2rate, F2regularity, F2average. The purpose was to assess the ability to accurately, quickly, and rhythmically make target second formant transitions. The subjects considered for this study was 4 adults male who stutter (aged – 22, 24, 25, 27 years) enrolled in maintenance therapy, conducted by the second and the third author and 4 non-stuttering controls male (same age) native Bulgarian speakers. For each of the participants audio recordings were obtained for the production of vowel + vowel tokens. The tokens consisted of repeated consequences of front high vowel /i/ + low back vowel /u/ – iu iu iu. The results indicated that F2 magn differ the most. Except one subject the values of F2 magn in stuttering group are consistently low compared to the high values for non-stutterers. Significantly different are the median values of F2 reg but the STD offered in MSP protocol for this parameter is high. So the obvious high F2 reg values for stutterers are not inadmissible and do not show a deviation from the normal regularity. F2 rate and F2 aver differ between two stutterers and their controls but the median values was not significantly different.

Overall, studies that have examined formant transitions in the fluent speech of people who stutter have produced mixed results. In the case of studies that employed the traditional locus equation method, the extent of formant transitions were measured but the durations over which the transitions occurred were not (Sussman et al., 2010; Chang et al., 2002). Although Robb and Blomgren (1997) included information regarding timing of formant transitions, their use of a fixed time-point criterion likely misrepresented the actual rates of formant transitions. Their results showed that formant transition rates of AWS were actually faster than NFS; however, this could be the result of the fixed times points being located beyond the completion of the transition. Howell and Vause (1986) concluded that low amplitude and short duration are the factors that cause stuttered vowels to sound like schwa. Hence the present study is planned to investigate the F2 transition in adults with stuttering and in normal age and gender population for vowel to vowel context.

CHAPTER III

METHOD

3.1 Participants

The present study included two groups;

Group I: The Clinical group consisted of 33 (11 Mild, 13 Moderate and 9 Severe degree of stuttering) Kannada speaking children in the age range of 8-12 years, clinically diagnosed as Stuttering by the Speech- Language Pathologist

Group II: The control group consisted of 32 Kannada speaking children were considered for the study.

3.1.1 Inclusionary criteria for clinical group

All the participants were diagnosed as Mild to Severe degree of stuttering by qualified Speech-Language Pathologist based on SSI-3 (Riley, 1994)**,** they spoke Kannada as their native language, they had normal oro-facial structure and functional mechanism and no complaint of neurological and any other associated problems. Participants were considered prior to attending therapy. However, those who had availed therapy were also considered depending on the availability and were analyzed accordingly. The ethical consent from the participants was taken before considering them for the study.

3.1.2 Inclusionary criteria for control group

Participants had no history of Speech-Language, sensory, motor or cognitive problems and were speaking Kannada as their native language.

3.2 Materials

The test materials included Stuttering severity instrument-3 and Motor Speech Profile

3.2.1 Stuttering severity instrument-3: It is a reliable and valid norm-referenced stuttering assessment that can be used for both clinical and research purpose. It measures stuttering in both children and adults in the three areas of speech behaviour i.e. Frequency, Duration and Physical concomitants.

3.2.2 Motor Speech Profile: The MSP F2 transition protocol measures the ability of subjects to repeat V+V combinations in a fast and rhythmical manner – a different method than the reported previously in the professional literature. It generates four parameters – F2 magnitude (F2magn), F2 rate, F2 regularity (F2reg), F2 average (F2aver).

F2magn (Magnitude of F2 Variations) (Hz) - This is the magnitude of the variations of the second formant during vocalization. If the vocalization has neutralized vowels, reflecting reduced motility of the articulators, the F2 magnitude is reduced.

F2rate (Rate of F2 Variations) (s) - This is the rate of the variations of the second formant during vocalization. This assesses the rate in which the speaker can change to the different positions of the vowels. Reduced motility of the articulators can be reflected as reduced rate of variations.

F2reg (Regularity of F2 Variations) (%) - This is the regularity of the variations of the second formant during vocalization. This assesses the degree in which the speaker can maintain a regular periodic transition between the different positions of the vowels. A regular vocalization show a higher number while an irregular vocalization shows lower regularity.

F2aver (Average of F2 value) (Hz) - This is the average F2 value for the vocalization. This parameter has the least clinical significance because it is not assessing motility. However, it may prove to have some value to show that the articulators are in an unusual position as reflected in a client's average F2 values when compared against the database of normal subjects.

3.3 Procedure

To implement this study Motor Speech Profile (MSP) / CSL, Model 4500; version 2.7.0 / which is digitized at 16 KHz sampling rate and 8-bit quantization was used. The analysis assesses the client's ability to make the second formant transitions in a fast, rhythmic manner without vowel neutralization, thereby assessing articulatory motility. So this study is based on MSP statistics.

3.3.1 Recording procedures**:** Initially the Informed consent was taken from all the participants and were tested individually and they were comfortably seated in a sound treated room. The Dynamic microphone was used for the participants who were kept at a distance of 10cms. They were instructed to say /iu/ /iu/ sequence in the fast, accurate and rhythmical manner. Program provides the illustration of the sequence and the participants were asked to perform the same. Audio recordings were obtained for each subject for the production of vowel + vowel tokens. The tokens consisted of repeated consequences of front high vowel /i/ + low back vowel /u/ – /iu/,/iu/,/iu/. 5 trials of fluent utterances were recorded for each participant and the best 3 trials were considered for the study. The two vowels have very different F2 positions which require the subjects to change the articulatory positions (tongue and lips positions). The recorded samples were saved in the software for further analysis. In general the F2 transition for /i/ is 3081-Hz and /u/ is 1490-Hz (Hillenbrand & Wheeler, 1995).

3.3.2 Steps used for recording the signal using MSP: MSP is most commonly used with its built-in protocols to analyze motor speech behaviour in a systematic and automatic procedure. Each protocol provides client prompts and example audio signals where appropriate, records the client input, analyzes the data, and generates graphics and numerical analysis for a report. There are six protocols (F2magn, F2rate, R2reg, F2avg, F2min and F2max) in the standard Motor Speech Profile program. New Live Input (Second Formant Transition): The data was recorded in Window A, then the second formant transition analysis on the recorded waveform data was performed.

To record data in Window A and analyze: The following steps were used to record the stimulus (figure 3.1).

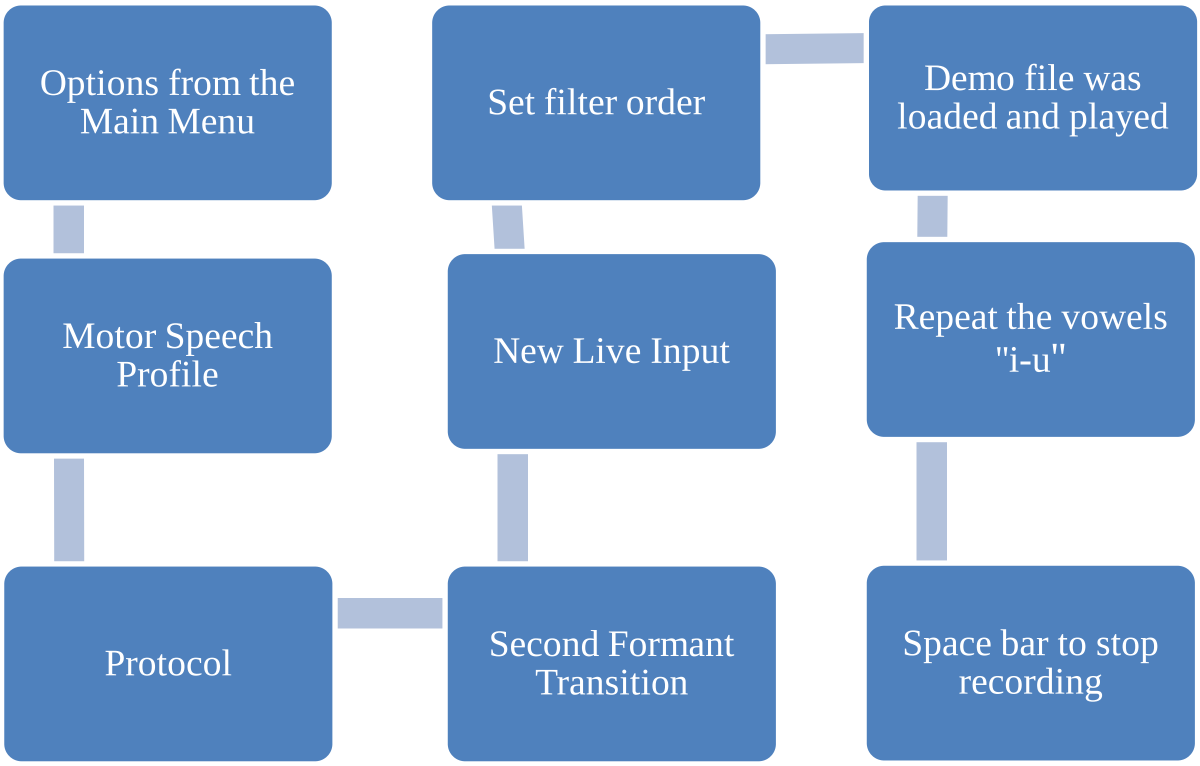

Figure 3.1: Steps to record the signal

3.4 Data Analyses

The parameters are represented in both numerical and graphical formats in the MSP. These variables were compared across normal and clinical groups and within the clinical group across severity of stuttering.

Steps used for data analysis

1. The leading and trailing portions of the waveform data were trimmed, then impulse markers (voiced period marks) were placed in the waveform data and a spectrogram for the data was displayed in Window B. Finally, the formant trace is overlaid on the spectrogram (figure 3.2)

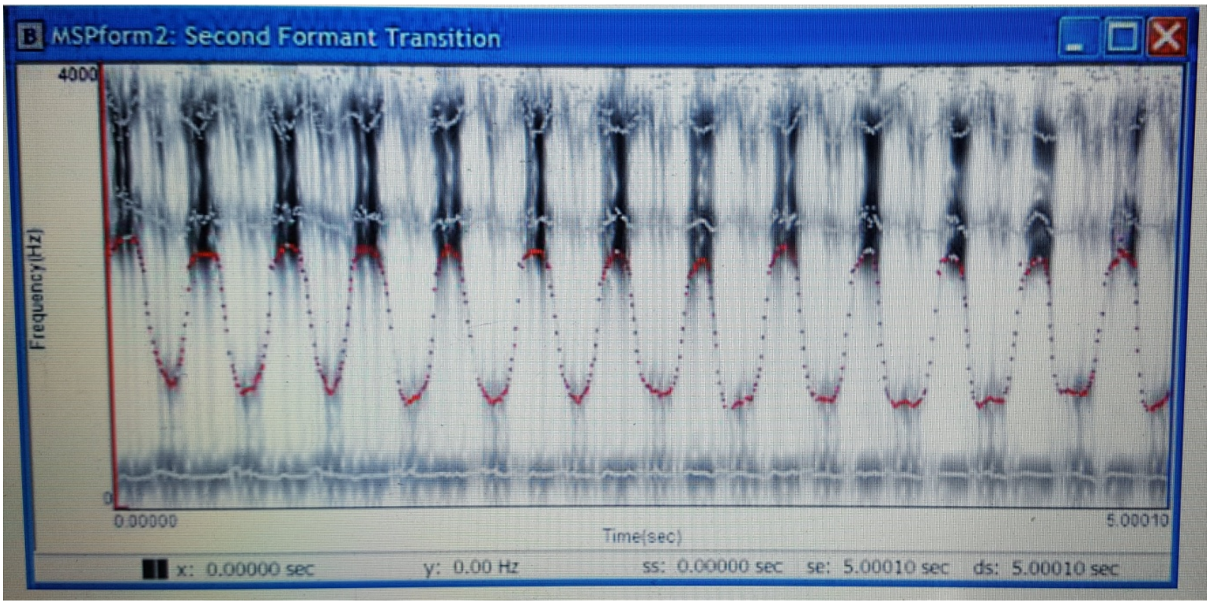

Figure 3.2: Spectrogram of the F2 transition of /i/ and /u/

2. Then Gender Selection box was displayed, requested for selection of the client's gender to determine which MSP average norms and STD to use for comparison with the client's vocalization.

3. The values of the analysis parameters are graphically displayed in the Motor-Speech Graphic Report in Window C and the numerical values was showed in a MSP voice report (figure 3.3)

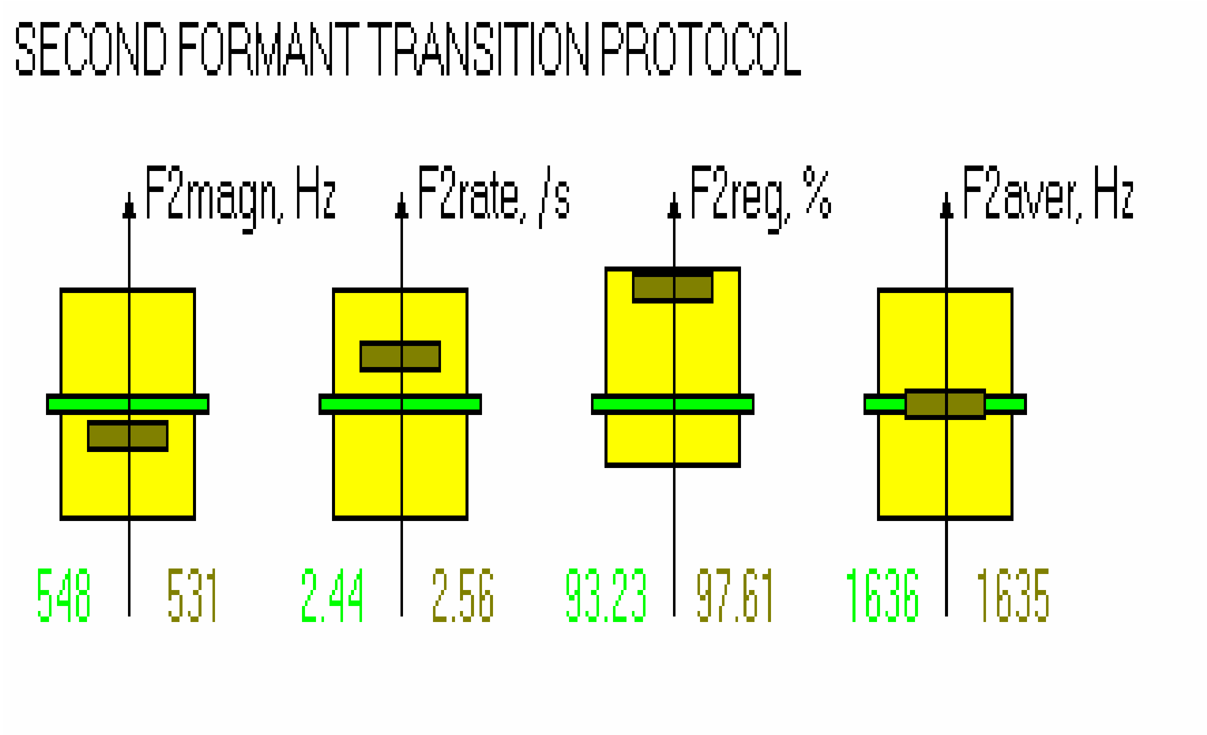

Figure 3.3: Graphical representation of the F2 transition parameters

In the figure 3.3, Square Yellow box indicates the normative range for the values, Green bar indicates the Mean value and the Grey bar indicates the participant values.

3.5 Research design used: Standard group comparison.

3.6 Test re-tests reliability:

The analysis was repeated on 10% of the participants within one week of initial testing. Cronbach's Alpha test was used to check the test re-test reliability for control and clinical group. Reliability was found for control group (0.95) and experimental group (0.90) respectively. The value suggested good reliability for both the groups.

3.7 Statistical analysis

The data was obtained for each parameter from both groups and were tabulated and analyzed using the SPSS (version 20) software. The data obtained was further subjected to following statistical procedures.

- Descriptive statistics was carried out for both clinical group and control group to obtain the mean, median and standard deviation.
- Normality was checked for both the groups using Shapiro-Wilks test.
- One-Way MANOVA test was employed to find out the significant difference between the control groups and clinical groups.
- Kruskal Wallis test was employed as there was difference in the sample size of the three group's i.e. mild, moderate and severe group. The results are presented and discussed in the following chapter.

CHAPTER IV

RESULTS AND DISCUSSION

The present study aimed to investigate the second formant transition in control group and clinical group and across three degrees of stuttering. Total 65 participants were included in the study divided into four groups (Control group, Mild, Moderate and Severe stuttering). The motor speech profile was used to obtain the second format transition for each participant and the values of second formant transitions were noted. The values of each parameter in each group were tabulated and the data obtained from all the groups was analysed using the SPSS software version 20. The following statistical procedures were used:

a. Normality was checked for both the groups using Shapiro-Wilks test.
b. Descriptive statistics was carried out for each group to obtain the mean, median and standard deviation. Since the data have the normal distribution the parametric test was used.
c. Parametric test- One-Way MANOVA test was employed to find the significant difference between the control and clinical group for all the four parameters.
d. Kruskal Wallis test was employed as there was difference in the sample size of the three groups i.e., mild, moderate and severe.

Shapiro-Wilks test of normality was done and except magnitude other parameters were not normal. Seven outliers including two moderate, three controls and two severe were identified and removed. Again the normality was tested and it was found to be normal after removal of outliers.

The results obtained for each group has been presented and discussed in this chapter under different sections:

4.1 Comparison of two group's i.e. Second formant transition in children with stuttering and control group.

4.2 Comparison of Second formant transition across three degrees of stuttering.

4.1 Comparison of Second formant transition in children with stuttering and control group: The performance of the two groups on all the four parameters was analysed. The data was subjected to descriptive statistical methods to obtain Mean, Median and Standard Deviation. Table 4.1 depicts overall results of descriptive statistics for different groups.

Table 4.1

Results of descriptive statistics for the two groups

Parameters	Group					
	Control (N=32)			Stuttering (N=33)		
	Mean	Std. Deviation	Median	Mean	Std. Deviation	Median
F2 magnitude	881.62	46.57	892.50	648.48	221.53	687.00
F2 rate	1.72	.070	1.73	1.64	0.17	1.66
F2 regularity	84.46	8.07	84.91	74.31	13.75	75.20
F2 average	2643.28	76.64	2667.00	2516.90	177.94	2515.00

On comparison of the overall median values the control group was having higher values than that of clinical group in all the parameters, while the standard deviation values were greater in clinical group for all the parameters suggesting inter-subject variability.

To check if this difference was statistically significant, Parametric One-Way MANOVA test was administered. The results of One-Way MANOVA test revealed a statistically significant difference the overall values of the two groups and also difference in all the parameters between both the groups. Comparisons of the overall performance of the two groups are graphically represented in figure 4.1. In the figure 4.1 the overall performance on all four parameters of F2 transition were better in control group when compared to that of clinical group.

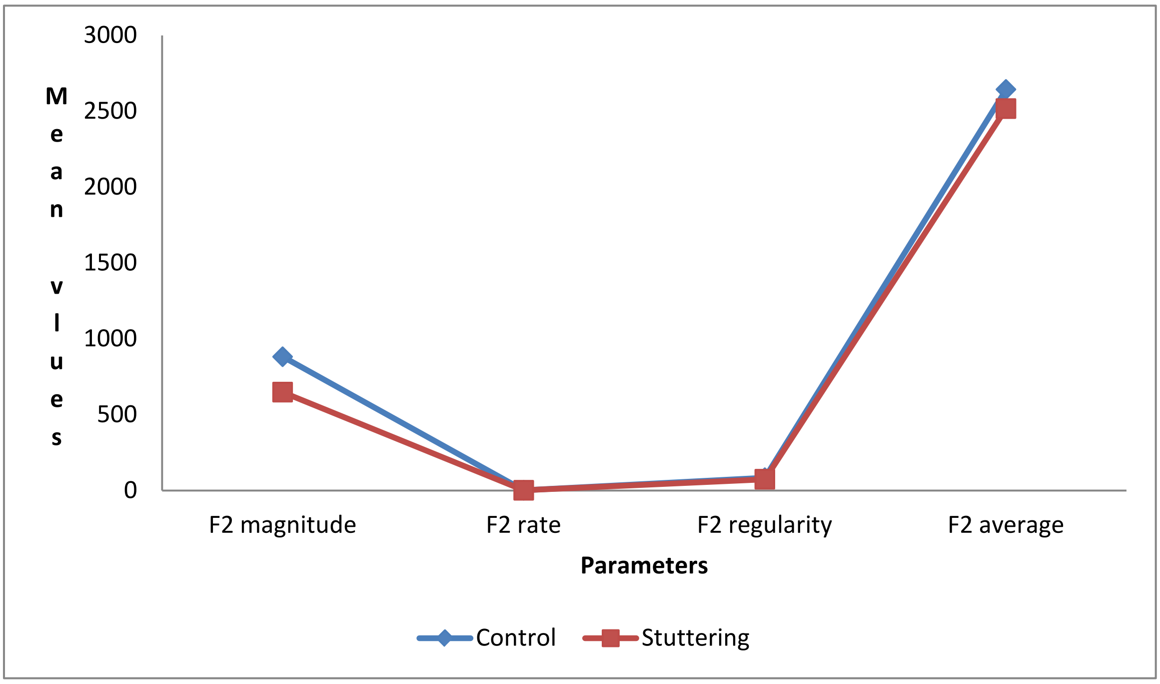

Figure 4.1: Overall Performance of F2 transition of the two groups (Control group and stuttering group)

Table 4.2 represents the comparison of groups (control group and clinical group) using One-Way MANOVA. Each parameters were significantly different in control group when compared to that of clinical group ($p<0.05$). All the values of F2 transition was significantly lower in clinical group when compared to that of control group.

Table 4.2

Results of One-Way MANOVA for two groups

Parameters	F	Sig.	Partial Eta Squared
F2 magnitude	33.96	0.00*	.35
F2 rate	4.77	.03*	.07
F2 regularity	13.06	.00*	.17
F2 average	13.67	.00*	.17

*Note: *p ≤ 0.05*

The results of the One-Way MANOVA test suggest lower values for all the four parameters of F2 transition in clinical group compared to control group.

Lower F2 magnitude value indicates that children with stuttering (CWS) vocalization had neutralized vowels, reflecting reduced motility of the articulators.

Lower F2 rate value indicate that children with stuttering had reduced motility of the articulators can be reflected as reduced rate of variations.

Lower F2 regularity value indicate that children with stuttering had irregular vocalization which showed lower regularity

Lower F2 average value indicates that children with stuttering had lower average F2 value for the vocalization.

The researchers argue that the formant frequencies were centralized even more in reading, but varied little across conditions despite changes in fluency, speaking rates, and vowel duration. However, in the present study only spontaneous production of /i-u/ was considered. Duration and rate of' formant transitions also was essentially the same across conditions (Klich & May, 1982). These findings indicated that stutterers' vowel production is more restricted, spatially and temporally, than non-stutterers.

Some experiments also lead the conclusion that low amplitude and short duration are the factors that cause stuttered vowels to sound like schwa (Howell & Vause, 1986). These findings was also highlighted in children with stuttering (CWS) population which was compared with children with no stuttering (CWNS) that the organization of the formant transition rate production for place of articulation may not be as contrastive or refined in CWS as in CWNS, a subtle difficulty in the speed of speech-language production, which may contribute to the disruption of their speech fluency (Chang, Ohde, & Conture, 2002).

There are also other arguments based on auditory feedback in Person with stuttering (PWS) that they exhibit subtle anomalies in the AF-based spatial control, their AF-based fine-tuning of articulatory timing was substantially weaker than normal, especially in early parts of the responses, indicating slowness in the auditory–motor integration for temporal control (Cai et al., 2014).

Coarticulation study on PWS also proves that they have a poorer competence for rapid coordination of speech movements when compared with control group (Pindzola, 2015). In other study they found that speech motor performance deficit in stutters which interpreted as speech motor sequence learning relies on a speech motor sequence learning network (Oh, 2015). In support to previous studies, present study proves that the F2 transition is different in clinical group when compared to control group.

From the present study it has been found that variability is significantly high for clinical group than that of control group. On comparison of clinical and control group statistical analysis revealed variability in each trials for every individual suggesting motoric variability or motoric instability in children with stuttering. Variability is one of the hallmarks of stuttering in children and adults who stutter. Because many factors play a role in this variability (Andrews et al., 1993; Bloodstein, 1995, & Starkweather, 1987), it would seem difficult, if not impossible, to develop a complete list of factors that influence the production of speech disfluencies. In general, however, variability in stuttering during conversational speech or as simple as producing /iu/ in fast and rhythmic manner is at least partially dependent upon the speaking task, (i.e., the activity in which the speaker is engaged, such as answering questions or describing pictures) and the speaking situation (i.e., the environment in which the speaker is speaking, including factors such as the conversational partner and setting).

Variability: Stuttering is variable: the frequency of a speaker's disfluencies, as well as their intensity and duration, vary markedly from situation to situation and from day to day (Bloodstein & Bernstein Ratner, 2008; Costello & Ingham, 1984; Yaruss, 1997a). People who stutter may find variability discouraging because they do not always know when a moment of stuttering will occur. They are given false hope when they experience moments of increased fluency and are disheartened when they are more disfluent (Bobrick, 2011; Carlisle, 1986; Corcoran & Stewart, 1998; Jezer, 1997). Observers see people who stutter speaking fluently in one moment or situation and stuttering in the next. This may give the impression that speakers only need to "try harder," "slow down," or "stop being nervous" in order to speak fluently. As individuals who stutter routinely report, this is not the reality of the situation (Bobrick, 2011; Carlisle, 1986; Corcoran & Stewart, 1998; Jezer, 1997). Clinicians are also affected by variability because they do not know if their measurements of a speaker's stuttering behaviors are representative of the speaker's overall experience with the disorder. The stuttering behaviors observed in the clinic are not representative of the client's fluency in general (Ingham, 1975, 1980; Ingham & Lewis, 1978; Johnson, Karrass, Conture, & Walden, 2009). Moreover, when treating a person who stutters, clinicians cannot be certain whether any observed change in stuttering frequency is due to their treatment or to the variability of the speaker's stuttering (Bloodstein & Bernstein Ratner, 2008).

The situation in which a person is communicating can also affect their fluency. Differences in the frequency of disfluencies across situations are seen in both nonstuttering children (Silverman, 1971; Wexler,1982) and children who stutter (Ingham & Riley, 1998; Martin, Kuhl, & Haroldson, 1972). Children who stutter show significantly greater variability between different speaking situations than within a single speaking situation (Yaruss, 1997a). Additionally, reading aloud has been shown to produce less stuttering than spontaneously generated speech (Young,1980). Frequency of stuttering varies with emotion and stress (Blood, Wertz, Blood, Bennett, & Simpson, 1997; Vanryckeghem, Hylebos, Brutten, & Peleman, 2001) Stuttering has also been shown to vary over time: children can demonstrate large changes in stuttering frequency from one clinic visit to the next (Gutierrez & Caruso, 1995; Throneburg & Yairi, 2001). Thus, situational, emotional, linguistic, and paralinguistic factors all contribute to the variable nature of stuttering behaviours.

The study on Development of Functional Synergies for Speech Motor Coordination in Childhood and Adolescence by Smith and Zelaznik (2004) supports variability. In this study, the development of the stable functional synergies (consistent patterns of activation of muscle collectives) was examined. Motion of the upper lip, lower lip, and jaw was recorded during sentence production in 180 children and adults (aged 4–22 years). Two indices of oral motor coordination were computed, which reflect the degree of trial-to-trial consistency in inter-effector relationships and thus the stability of the underlying functional synergies. Major findings were: (a) The time course of development for speech motor coordination is protracted, (b) speech motor control processes were not adult like until after age 14 years for both females and males, (c) boys (until age 5 years) show a slower maturational course of speech motor development, and (d) late childhood (the 7- to 12-year period) is characterized by a plateau in the development of these coordinative synergies for speech production. They posit that multiple factors are likely to contribute to the protracted development of oral motor coordination for speech, including maturation of components of the motor system itself and maturation of the brain subsystems for language processing.

Chang Ohde and Conture (2002) also examined the anticipatory coarticulation and second formant (F2) transition rate (FTR) of speech production in young children who stutter (CWS) and who do not stutter (CWNS). Findings revealed a significant main effect for place of articulation and a significantly larger difference in FTR between the two places of articulation for CWNS than for CWS. Findings suggest that the organization of the FTR production for place of articulation may not be as contrastive or refined in CWS as in CWNS, a subtle difficulty in the speed of speech-language production, which may contribute to the disruption of their speech fluency.

Some of the auditory processing studies also argued that auditory processing abnormality proposed to be the underlying deficit in a subset of stutterers (Ibraheem & Quriba, 2014). In another study authors suggest that both laryngeal activation and auditory feedback is necessary in the production of normally articulate speech, and that the absence of these may account for the significant changes between the voiced and mouthed conditions in different degrees of stuttering (Barber, 2015).

4.2 Comparison of Second formant transition across three degrees of stuttering:

The performance of the clinical group across degrees of severity on all the four parameters was analysed. The data was subjected to descriptive statistical methods to obtain Mean, Median and Standard Deviation. Table 4.3 depicts overall results of descriptive statistics for clinical groups (mild, moderate and severe group).

Table 4.3

Results of descriptive statistics for the clinical groups

Parameters	Groups	Mean	Std. Deviation	Median
	Mild	667.09	254.07	750.00
F2 magnitude	Moderate	565.76	184.86	552.00
	Severe	745.22	205.52	852.00
	Mild	1.62	.17	1.66
F2 rate	Moderate	1.70	.13	1.73
	Severe	1.59	.23	1.57
	Mild	78.31	16.13	79.10
F2 regularity	Moderate	67.48	12.55	68.14
	Severe	79.29	8.29	79.57
	Mild	2497.90	206.58	2482.00
F2 average	Moderate	2586.69	142.56	2596.00
	Severe	2439.33	166.28	2393.00

On comparison of within three degrees of stuttering the analysis of F2magn revealed the mean values in an ascending order related to moderate degree of severity followed by mild and severe degree. Finding implies that neutralized vowels, reflecting reduced motility of the articulators, that is affected in an increase manner in case of severe stuttering compared to mild and moderate degree of stuttering

Mean values of F2rate is lower for severe degree of stuttering followed by mild and moderate degree of stuttering. Finding implies reduced motility of the articulators which can be reflected as reduced rate of variations.

Mean values of F2reg is lower in moderate degree followed by mild and severe degree of stuttering. Finding suggests irregular vocalization reflecting as lower regularity.

On comparison of three degrees of severity F2avg is lower in severe degree followed by mild and moderate degree of stuttering. Findings indicate severe degree had lower average F2 value for the vocalization followed by mild and moderate degrees of stuttering. Comparisons of the performance of the stuttering group across degrees of severity are graphically represented in figure 4.2.

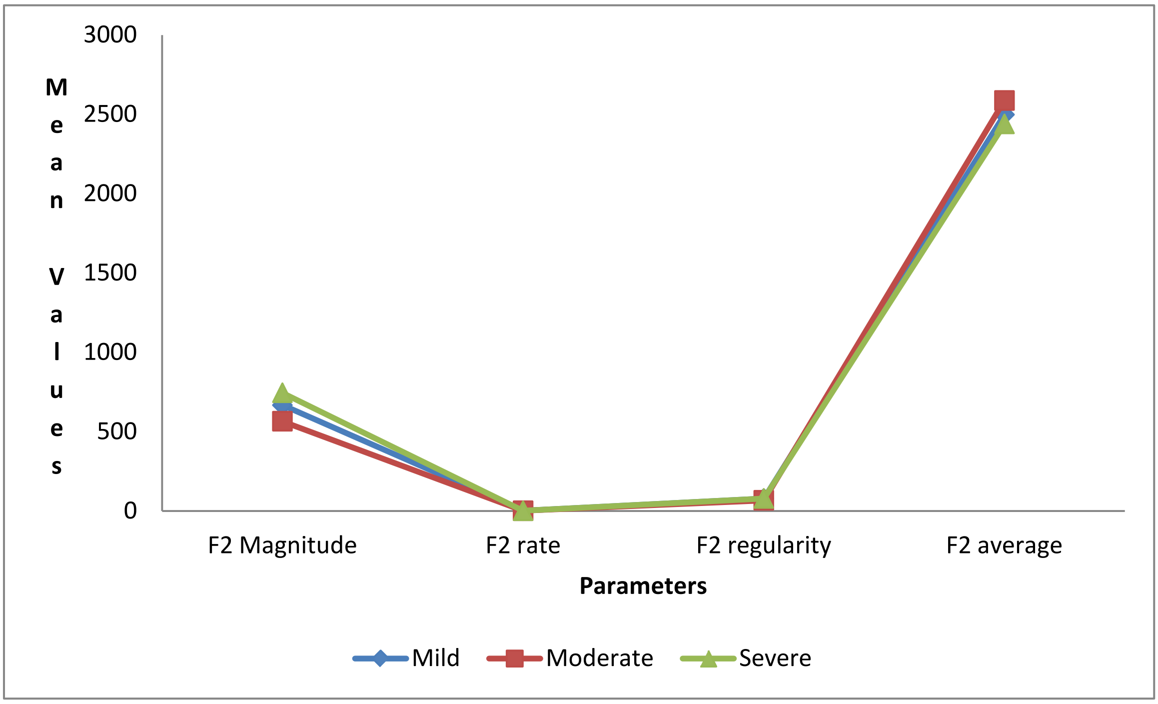

Figure 4.2: Overall Performance of the Stuttering group across degrees of severity

The performance of the three degrees of stuttering groups on all the four parameters were analysed using Kruskal-Wallis test. Results suggested no significant difference while comparing within the clinical group. The values are depicted in table 4.4.

Table 4.4

Results of Kruskal-Wallis test for clinical group

Parameters	**Chi-Square (χ^2)**	**p value**
F2magn	0.94	1.00
F2reg	6.10	1.00
F2rate	0.00	1.00
F2aver	1.78	1.00

Note: $p \geq 0.05$

Kruskal-Wallis test revealed no significant difference while comparing clinical groups across the three degrees of severity. Considering the second objective of the present study as to compare second formant transition across three degrees of stuttering, no significant difference was found across degrees of severity.

This is contradictory to the present study; where F2 transition of vowel to vowel context in adults with stuttering was studied (Amulya & Mahesh, 2017). The finding was obtained with respect to speech rates in severity of stuttering. The group with mild and moderate stuttering presented higher and similar speech rates, differing statistically from the group with severe stuttering. Therefore the analysis indicated that the higher the severity of stuttering, the lower the speech rate and this difference seems to be related to difficulties in motor programming, affecting mainly the rhythm and the timing of discourse (Arcuri, Schiefer, & Chiari, 2009). This variability in results could be because of subject-criteria.

Some of the auditory processing studies also argued that auditory processing abnormality proposed to be the underlying deficit in a subset of stutterers (Ibraheem & Quriba, 2014). In another study authors suggest that both laryngeal activation and auditory feedback is necessary in the production of normally articulate speech, and that the absence of these may account for the significant changes between the voiced and mouthed conditions in different degrees of stuttering (Barber, 2015).

To conclude, the analysis of the present study revealed the following results.

1. All the four parameters of F2 transition was significantly lower in clinical group when compared to that of control group.
2. All the four parameters of F2 transition did not show significant difference across severity of stuttering.

Findings suggest that CWS vocalization tend to be neutralized, reflecting reduced motility of the articulators, irregular and more variations in the vocalizations. CWS vowel production is more restricted, spatially and temporally, than CWNS. The empirical support for the position that person with stuttering may occupy the low end of the speech motor skill continuum as argued in the Speech Motor Skills approach. Additionally CWS tends to exhibit poorer competence for rapid coordination of speech movements when compared with control group.

CHAPTER V

SUMMARY AND CONCLUSION

The present study aimed to investigate the second formant transition in control group and clinical group and across three degrees of stuttering. 65 participants were included in the study divided into four groups (control group, mild, moderate and severe stuttering). The motor speech profile was used for each participant and the values of second formant transitions were noted. The values of each parameter i.e.F2magn, F2rate, F2reg and F2aver in each group were tabulated and the data obtained from all the groups were analysed using the SPSS software version 20. The data was subjected to descriptive statistics and based on the normality criteria, parametric tests as well non-parametric tests were employed.

On examining the F2 transition the clinical group had significantly poor scores compared to that of control group. The four specific parameters varied between groups. The F2 transition within the clinical group did not show a significant difference between the different degrees of stuttering.

All the parameters show significant difference in control group and stuttering group. F2magn in stuttering group were significantly low compared to the high values for CWNS, reflecting reduced motility of the articulators. F2 rate value were significantly lower in stuttering when compared to control group indicated reduced motility of the articulators which can be reflected as reduced rate of variations. F2 regularity was significantly lower in clinical group compared to control group. F2 average value was significantly lower in stuttering group when compared to the high values for CWNS.

On examining the F2 transition within the clinical group no significant difference was found across three degrees of stuttering. F2magn revealed the lower mean values when compared to mild and severe degree of stuttering but statistically no significance was obtained. Finding implies that neutralized vowels, reflecting reduced motility of the articulators in an increase manner in case of severe stuttering compared to mild and moderate degree of stuttering. Mean values of F2rate is lower for severe degree of stuttering compared to mild and moderate degree of stuttering though, not significant. Finding implies reduced motility of the articulators which can be reflected as reduced rate of variations. F2reg was lower in moderate degree followed by mild and severe degree of stuttering. F2avg was lower in severe degree followed by mild and moderate degree of stuttering.

This study tested the ability of the children who stutter to maintain a periodic, constant level of V+V vocalization, with very different second formant target positions, repeated at a fast rate, and to show that F2 transition is a useful acoustic parameter with a high correlation to perception of intelligibility of a vocalization. Most significantly the F2 transition protocol assesses the degree of neutralization of the vowels. Therefore the magnitude of the F2 variations should directly correlate with articulatory motility and global intelligibility. As a whole, the CWS group in this research demonstrated reduced F2magn as a result of neutralization of the vowels. These findings indicated that CWS's vowel production is more restricted, spatially and temporally, than CWNS and empirical support for the position that person with stuttering may occupy the low end of the speech motor skill continuum as argued in the Speech Motor Skills approach and also poorer competence for rapid coordination of speech movements when compared with control group.

A common method of acoustically examining vowel formants is within a consonant + vowel (CV) or consonant + vowel + consonant (CVC) syllable context. As it was mentioned already MSP uses another method and makes the procedure more practical to implement. Using this method the present preliminary study proved previous results (Robb & Blomgren, 1997; Padareva et al., 2012), that F2 transition differs for PWS and PWNS in vowel to vowel context in CWS who were native Kannada speakers.

Thus, it can be concluded that F2 transition in Children with stuttering (CWS) is different when compared to that of Children with no stuttering (CWNS) whereas within the Stuttering group there was no significant differences across degree of severity. Hence, the Motor Speech Profile, F2 transition protocol assesses the degree of neutralization of the vowels, therefore the magnitude of the F2 variations should directly correlate with articulatory motility and global intelligibility, and this can be used as an additional tool for the assessment and intervention for the children with stuttering.

Implications of the study

1. The results of the present study has lead to better understanding the nature of F2 transition with respect to vowel-vowel pattern in children with stuttering and typically developing children.

2. The results of the present study has also lead to better understanding the nature of F2 transition with respect to vowel-vowel pattern across three degrees of severity in Children with stuttering (CWS).
3. The study provided the information regarding the motor stability in CWS.
4. The results of present study add to literature/theory on "Stuttering as a motor deficit". It's important to note that children with stuttering exhibits poor articulatory motility in the context of vowel-vowel combination.

5. From the results of the present findings lead us in better understanding about variability as a hallmark in stuttering.

Limitations of the study

1. In the present study only children with stuttering were considered.
2. Present study included Limited sample size.
3. The study considered only single vowel context /i-u/. However, spontaneous speech includes the several combinations of /v-v/,/v-c/,c-v/,/c-c/ contexts.

Future directions

1. F2 transition can be conducted on greater sample size.
2. F2 transition can be studied on wider age range including children, adolescents and adults.
3. F2 transition can be measured as how they are different between the gender.
4. F2 transition can be studied using the dysfluent utterances and fluent utterances of the same client to note the affected parameters.

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