F2 TRANSITION OF VOWEL TO VOWEL CONTEXT IN ADULTS WITH STUTTERING

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CERTIFICATE

This is to certify that this dissertation entitled **"F2 transition of vowel to vowel context in adults with stuttering"** is a bonafide work submitted in part fulfilment for degree of Master of Science (Speech-Language Pathology) of the student Registration Number: 15SLP002. 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.

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CERTIFICATE

This is to certify that this dissertation entitled "**F2 transition of vowel to vowel context in adults 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 adults with stuttering"** is the result of my own study under the guidance of Dr. Sangeetha Mahesh, Clinical Lecturer, 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. 15SLP002***

May, 2017

Dedicated

to my

parents.

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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". A number of theoretical accounts of stuttering have emerged recently that implicate primary deficits in Sensorimotor control (Smith, 2000; Van Lieshout, 2004; Alm, 2004; Loucks & DeNil, 2006; Civier, Bullock, Max & Guenther, 2013).

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.

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 et al., 2010; McClean, Tasko & Runyan, 2004). Second, recent neuroimaging 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 sensorimotor 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.

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 protocol 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. The results of the past studies vary, but they confirm that: 1. individuals who stutter experience difficulty transitioning from one speech sound to the next; 2. the pattern of second formant transition in stuttered and nonstuttered speech is different; 3. adults with chronic stuttering tend to reveal appreciable variations in F2 transition.

This study, the first one in Kannada focused on Second formant transitions of vowel to vowel context in adults with stuttering using 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 exist 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 adults with stuttering and in 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 adult 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 adults 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 review are discussed as follows.

Stuttering as a motor programming deficit

Stuttering is a disorder involving breakdowns in the speech motor system. Most theories of the causes of stuttering postulate that many factors are involved in producing these motor breakdowns including genetic, linguistic, and psychosocial contributors. Despite the complex interaction of underlying factors in accounts of the onset and development of stuttering, it is clear that abnormal speech motor output is an essential component of stuttering. According to Van Riper (1982) "during the disfluencies that characterize stuttering, the speech motor system fails to generate and/or send the motor commands to muscles that are necessary for fluent speech to continue. Thus disfluent intervals of speech in children and adul0ts who stutter are clearly associated with breakdowns in the precise spatial and temporal control of movement necessary for fluent speech production". Also striking are findings that people who stutter often differ from controls in terms of the variability, speed, and relative timing of their articulatory movements when producing perceptually fluent speech. These studies provide evidence for persistent motor timing and coordination deficits that are present in the speech motor control systems of people who stutter, even when there are no perceptible stuttering behaviours in their speech.

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 children who stutter (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.

The study conducted by Niemann (1998) investigated second formant transition extent and direction in disfluent speech samples recorded close to stuttering onset in preschool age children. Comparisons were made among subgroups of children known to persist in stuttering, those who recovered from stuttering, and normally fluent control subjects. Twenty-eight subjects, eight persistent stutterers, eight recovered subjects, and twelve normally fluent subjects participated. The initial consonant to vowel transition in the second formant of the repeated portion of the part-word repetition was compared to the transition in the final production. Ten transitions was analyzed for each subject in the stuttering subgroups, and between one and three transitions was analyzed for each control subject. The transitions was judged to be: 1) absent, 2) present/different direction, 3) present/same direction/non-target frequency, or 4) present/same direction/target frequency. A significant main effect was found for the number of absent F2 transitions produced (F=12.15; df=2; p=.0002). Further analysis using a Tukey HSD multiple comparisons post-hoc test showed significant difference in F2 transition, was better in recovered stutterers when compared to controls than persistent stutterers.

The study done by Riley and Ingham (2000) examined (a)" the effects of Speech Motor Training (SMT) on selected temporal acoustic durations considered to be related to speech motor programming, in young children (b) to compare the speech motor effects of that treatment with those of a treatment of childhood stuttering that did not directly incorporate speech motor control training (Extended Length of Utterance [ELU]), and (c) to examine the relation of acoustic duration changes to reduction of stuttering". Twelve children who stutter were recorded while repeating syllable sets /pv/ and /tvke/ before and after SMT (*n*=6) or ELU treatment (*n*=6). Children who did not stutter served as matched reference groups. The syllables beginning with /p/ and /t/ were used as tokens for the acoustic measurement. Five measures served as indicators of temporal aspects of speech motor performance: vowel duration, stop gap duration, voice onset time, stop gap/vowel duration ratio, and total token duration. Results indicated that following SMT there was a significant increase in vowel duration and some reduction in stop gap duration that resulted in significantly reduced stop gap/vowel duration ratios. These acoustic effects was consistent across most participants. The ELU treatment reduced stuttering more than the SMT, but was not accompanied by significant effects on the selected temporal acoustic measures.

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.

The study by Brosch, Hage, and Johannsen (2002) examined the acoustic parameters by which children with stuttering can be evaluated in order to predict the further course of their speech disfluency. This study investigated the usefulness of a computer-based speech analysis of fluent utterances. Relationship between acoustic variables, severity, and course of stuttering was sought in a prospective longitudinal study. They analyzed 57 preschool children at 6-month intervals over a period of 4.6

years. The acoustic analyses yielded no clearly distinguishing characteristics. There was, however, one subgroup consisting of children who were still disfluent at study end which showed more variable values at various measurement points for different parameters. They concluded that Speech control seems to be different in children exhibiting chronic stuttering.

Chang, Ohde, and Conture (2002) assessed anticipatory coarticulation 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 coarticulation and speech movement velocity, the F2 onset frequency and F2 vowel target frequency (for coarticulation) 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 study 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 by Subramanian, Yairi, and Amir (2003). Comparisons 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 syllables 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.

The study described coarticulation across voiced stop consonant place of articulation in 10 children younger than 2 years of age by Gibson and Ohde (2007). A total of 1,182 voiced stop CV productions was analyzed using the locus equation metric, which yielded 3 regression lines that described the relation of F2 onset and F2 vowel for /bV/, /dV/, and /gV/ productions. The results revealed significant differential effects for slope and *y*-intercept as a function of stop consonant place of articulation. The ordering of the mean slope values for stop consonant place of articulation was /g/>/b/ and /d/, indicating that /g/ was produced with significantly greater coarticulation than /b/ or /d/. However, the unique vowel allophonic pattern of [g] coarticulation reported in the literature for English-speaking adults was generally not learned by these young children. Group and individual coarticulation trends are described in relation to developmental theories of sound acquisition. Results suggest that early coarticulation patterns are phoneme specific.

The study conducted by Richard, Patricia, Zebrowski, and Moon (2012) focused on phonetically governed changes in the fundamental frequency (F_0) of vowels that immediately precede and follow voiceless stop plosives have been found to follow consistent patterns in adults and children as young as four years of age. In the present study, F_0 onset and offset patterns in 14 children who stutter (CWS) and 14 children who do not stutter (CWNS) were investigated to evaluate differences in speech production. Participants produced utterances containing two VCV sequences. F_0 patterns in the last ten vocal cycles in the preceding vowel (voicing offset) and the first ten vocal cycles in the subsequent vowel (voicing onset) were analyzed. A repeated measures ANOVA revealed no group differences between the CWS and CWNS in either voicing onset or offset gestures. Both groups showed patterns of F_0 onset and offset that were consistent with the mature patterns seen in children and adults in previous studies. These findings suggest that in both CWS and CWNS, a mature pattern of voicing onset and offset is present by age 3;6. This study suggested that there is no difference between CWS and CWNS in the coordination of respiratory and laryngeal systems during voicing onset or offset.

Acoustic Studies in Adults with Stuttering(AWS)

The perceptual and acoustic data was studied on part-word repetitions from the speech of adult stutterers by Allen, Paul, and Cooke (1976). 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 was interpreted 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.

The measurements were done on formant frequencies and formant transitions associated with the vowels /i/,/a/,/e/and/u/ produced by seven moderate-to-severe Persons with stuttering when they read fluently in a control (normal) condition and under four experimental conditions: masking noise, delayed auditory feedback, rhythmic pacing, and whispering by Klich and May (1982). The first and second formant frequencies in an isolated /hVd/context was more centralized than those reported for nonstutterers. The formant frequencies were centralized even more in reading, but varied little across conditions despite changes in fluency, speaking rates, and vowel duration. Duration and rate of' formant transitions also was essentially the same across conditions. These findings indicated that stutterers' vowel production is morerestricted, spatially and temporally, than nonstutterers.

The speech of 14 person with stuttering were analyzed prior to and at the termination of a 5-week stuttering therapy program by Metz, Samar, and Sacco (1983) to examine the relationship between nine selected acoustic variables i,e VOT (voiceless stop consonants), Voicing (voiceless stop consonant intervocalic intervals), Frication (voiceless stop consonant intervocalic intervals), Silence (voiceless stop consonant intervocalic intervals), VOT (voiced stop consonants), Voicing (voiced stop consonant intervocalic intervals), Frication (voiced stop consonant intervocalic intervals), Silence (voiced stop consonant intervocalic intervals) Vowel duration and stuttering frequency. Group analyses indicated that pre- to post-therapy changes in stuttering frequency was accompanied by mean changes in five of the nine acoustic variables, a finding which is consistent with previous literature. Correlational analyses indicated that only silence in the voiced stop consonant intervocalic interval (IVI) was significantly correlated with stuttering frequency prior to therapy (i.e., lower stuttering frequency values was associated with shorter durations of silence during the IVI). Furthermore, the degree of reduction in silence was positively correlated with the magnitude of reduction in stuttering frequency due to therapy. These findings suggest that silence in the IVI may reflect the operational status of some mechanism which may underlie disfluent speech.

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 differences 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.

Stuttering is to be 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. It is notable that the F2 transitions for the non-stuttering and stuttering groups roughly matches the simulated F2 transitions produced by the DIVA model (Robb & Blomgren, 1997)

Blomgren, Robb, and Chen (1998) evaluated vowel space and hypothesized that Adults with stuttering (AWS) exhibited 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.

The articulatory dynamics were analyzed by Smith and Kleinow (2000) to determine if adults who stutter are generally poorer at speech movement pattern generation and if changing speech rate reflects their stability in the same way that if affects normally fluent controls. The group consisted of 14 adults with stuttering and a matched group of controls produced fluent repetitions of simple phrase at normal, slow, and fast rates. A composite index of spatiotemporal stability(STI), as well as independent measures of timing and spatial variability, revealed that adults who stutter can operate within normal movement parameter ranges under low demand speaking conditions. However, some of the stuttering participants showed evidence of abnormal stability even when repeating a simple utterance at habitual rate. Overall, the results suggested that the kinematic characteristics of the fluent speech of adults who stutter generally overlap that of normally fluent speakers; however, subtle differences in kinematic parameters are interpreted to reveal their susceptibility to speech motor breakdown when performance demands increase.

Evans (2009) examined the effect of linguistic, memory, and social factors on the perceptually fluent speech and affective responses of AWS. A total of 8 AWS and 8 adults who do not stutter (AWNS) participated in this study. Each participant completed three speaking tasks that imposed either a linguistic, memory, or social demand. Autonomic data (heart rate and pulse volume), perceived anxiety, and acoustic data was collected during each speaking task. Acoustic data was analyzed for differences of mean central tendency and intra-speaker variability for phrase duration, word duration, vowel duration, voice onset time, F2 transition duration, F2 transition rate, and F2 transition extent. Acoustic results showed that AWS were not different than AWNS on temporal and spectral measures of central tendency as well as temporal variability. However, AWS were significantly more variable in F2 transition extent than AWNS across all speaking tasks suggested greater variability in posterior to anterior tongue advancement. Results also showed the linguistic task generally contributed to longer and more variable temporal durations when compared to the control. Autonomic results showed AWS were similar to AWNS in their levels of autonomic arousal and perceived anxiety across the speaking tasks. Analyses of individual participants revealed that the greatest increase in autonomic arousal or perceived anxiety during the speaking tasks did not always relate to an increase in temporal or spectral intra-speaker variability. History of stuttering and treatment for stuttering did not predict trends in intra-speaker variability. Interestingly, a negative relationship existed for AWS between heart rate and perceived anxiety during the audience task.

Arvey, Sussman, Byrd, and Guitar (2010) analyzed the acoustic structure of voiced stop + 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 coarticulation 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 analyzed to first identify fluent and stuttered target words, which were then spectrally analyzed to yield locus equation

(LE) regression plots. The slope of the LE regression function directly indexes the coarticulatory 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.

Civier, Tasko, and Guenther (2010) investigated the hypothesis that stuttering may result in part from impaired readout of feedforward 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 feedforward control and toward feedback control.

The F2 locus equations for fluent and nonfluent productions of stop+vowel stimuli in a group of eight AWS in order to determine stuttering is associated with anticipatory coarticulation was derived by Sussman, Byrd and Guitar (2011). 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.

The steady—state portion of the first two formants (F1) and (F2) in the production of [CV] sequences, containing vowels [i, a, u], pronounced in two speech rates (normal and fast), by groups of untreated and treated stutterers, and control subjects was analyzed by Hirsch, Bouarourou, Vaxelaire, Monfrais-Pfauwadel, Bechet, Sturm, and Sock (2012) Locus equations have been calculated to observe for potential differences in coarticulatory strategies between the three groups. Data analyses revealed a reduction of vowel space for stutterers at a normal speaking rate. When speech rate increases, no reduction of vowel space is noticeable for the latter group of speakers, contrary to treated stutterers and controls. No significant differences between the three groups have been observed in coarticulatory strategies.

Cai, Beal, Ghosh, Guenther, and Perkell (2014) imposed time-varying perturbations on Auditory Feedback(AF) while PWS and fluent participants uttered a multisyllabic sentence. Two distinct types of perturbations were used to separately probe the control of the spatial and temporal parameters of articulation. While PWS exhibited only 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.

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.

The movement rates of formant frequencies and the extents of articulatory change were spectrographically analyzed in the fluent (VCV) utterances of 20 stutterers and nonstutterers was studied by Pindzola (2015). The velocities of articulator movement throughout the first vowel and velocities into the second, vowel was not significantly different for the two groups. These mean rates of movement, although nonsignificant, was slower in stutterers and slightly more variable, and the extent of articulator movement was comparable. These results do not support the contentions that stutterers use coarticulatory movements that are too rapid or that stutterers have a poorer competence for rapid coordination of speech movements.

Frisch, Maxfield, and Belmont (2016) studied the Coarticulatory data for 46 young adult speakers, 23 who stutter and 23 who do not stutter show coarticulatory patterns in young adults who stutter that are no different from typical young adults. Additionally, the stability of velar-vowel production is analysed in token-to-token variability found in multiple repetitions of the same velar-vowel sequence. Across participants, identical patterns of coarticulation was found between people who do and do not stutter, but decreased stability was found in velar closure production in a significant subset of people who stutter. Other people who stutter appeared no different than typical speakers. Outcomes of this study suggested that articulatory maturation in young adults who stutter is, on average, no different from typical young adults, but that some young adults who stutter could be viewed as having less stably activated articulatory sub-systems.

Dehqan, Yadegari, Blomgren, and Scherer's (2016) study compared formant transitions during fluent speech segments of Farsi (Persian) speaking people who stutter and normally fluent Farsi speakers. Ten Iranian males who stutter and 10 normally fluent Iranian males participated. Sixteen different “CVt” tokens was embedded within the phrase “Begu CVt an”. Measures included overall F2 transition frequency extents, durations, and derived overall slopes, initial F2 transition slopes at 30 ms and 60 ms, and speaking rate. Results suggested that : (1) Mean overall formant frequency extent was significantly greater in 14 of the 16 CVt tokens for the group of stuttering speakers. (2) Stuttering speakers exhibited significantly longer overall F2 transitions for all 16 tokens compared to the nonstuttering 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. During perceptually fluent utterances, the stuttering speakers had greater F2 frequency extents during transitions, took longer to reach vowel steady state, exhibited some evidence of steeper slopes at the beginning of transitions, had overall similar F2 formant slopes, and had slower speaking rates compared to non-stuttering speakers. 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.

Jayaram (2006) investigated the efficacy of non-programmed prolonged speech technique in persons with stuttering. 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 newlineacoustic 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.

Imaging studies and articulatory dynamics in Stuttering

Aravind and Pascal (2012) reviewed converging lines of evidence from behavioral, kinematic, and neuroimaging data that point to limitations in speech motor skills in people who stutter (PWS). From their review, they conclude that PWS differ from those who do not in terms of their ability to improve with practice and retain practiced changes in the long term, and that they are less efficient and less flexible in their adaptation to lower (motor) and higher (cognitive–linguistic) order requirements that impact on speech motor functions. These findings in general provide empirical support for the position that PWS may occupy the low end of the speech motor skill continuum as argued in the Speech Motor Skills approach (Van Lieshout, Hulstijn, & Peters, 2004).

Belmont (2015) studied using ultrasound to image onset velar stop consonant articulation in words. By examining tongue body placement, the extent of velar closure variation across vowel contexts provides for the measurement of anticipatory coarticulation while productions within the same vowel context provide measurement of extent of token-to-token variation. Articulate Assistant Advanced 2.0 software was used to semi-automatically generate midsagittal tongue contours at the initial point of maximum velar closure and was used to fit each contour to a curved spline. Patterns of lingual coarticulation and measures of speech motor stability, based on curve-to-curve distance (Zharkova, Hewlett, & Hardcastle, 2011), are investigated to compare the speech of typically fluent speakers to the speech of people who stutter. Anticipatory coarticulation can be interpreted as a quantitative measure indicating the maturity of the speech motor system and its planning abilities. Token-to-token variability is examined from multiple velar vowel productions within the same vowel context, describing the accuracy of control, or stability, of velar closure gestures. Measures for both speaking groups are examined across the lifespan at stages during speech development, maturation, and aging. Results indicate an overall age effect, interpreted as refinement, with increased speech stability and progressively more segmental (less coarticulated) productions across the lifespan. A tendency toward decreased stability and more coarticulated speech was found for younger people who stutter, but this difference was small and absent among older adults. Outcomes of this study suggest the articulatory maturation trajectories of people who stutter may be delayed, but overall maturation of the speech mechanism is evident by older adulthood for typically fluent speakers and those who stutter.

Oh (2015) the study consist of PWS (n=18) and persons with fluent speech (PFS) (n=17) was taught phonotactically illegal (e.g. gbesb) and phonotactically legal (e.g. blerk) speech motor sequences over two practice sessions. Functional magnetic resonance imaging (fMRI) was used to investigate brain regions underlying the production of learned illegal syllables and novel illegal syllables. With practice, subjects produced syllables more accurately, which is indicative of motor sequence learning. Their findings suggested a speech motor performance deficit in PWS. Furthermore, these findings indicate speech motor sequence learning relies on a speech motor sequence learning network.

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 differences 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 nonstutterers 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 nonstuttering 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 differs the most. Except one subject the values of F2 magn in stuttering group are consistently low compared to the high values for nonstutterers. 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 30 (10 Mild, 10 Moderate and 10 Severe degree of stuttering) Kannada speaking individuals in the age range of 18-35 years, clinically diagnosed as Stuttering by the Speech- Language Pathologist

Group II: The control group consisted of 30 Kannada speaking individuals with age and gender matched were considered for the study.

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.

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

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.

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 16KHz sampling rate and 12 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.

***Recording procedures*:** Initially the Informed consent were 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 which was 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 2162Hz-Male and 2468Hz-Female (Sreedevi, 2003) and /u/ is 850Hz-Male and 950Hz-Female (Peterson & Barney, 1955)

Steps used for recording the signal using MSP: MSP is most commonly used with its built-in protocols to analyze motor speech behavior 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 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 (figure1).

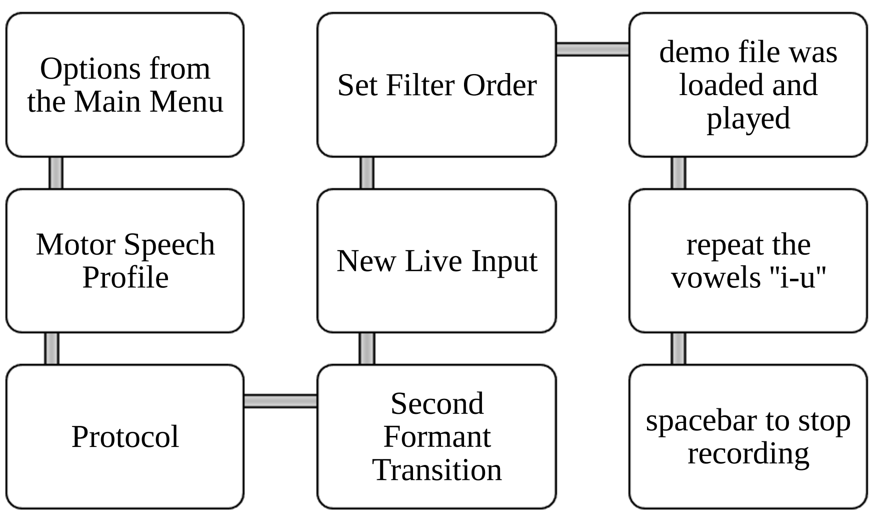

Figure 1: Steps to record the signal

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 2)

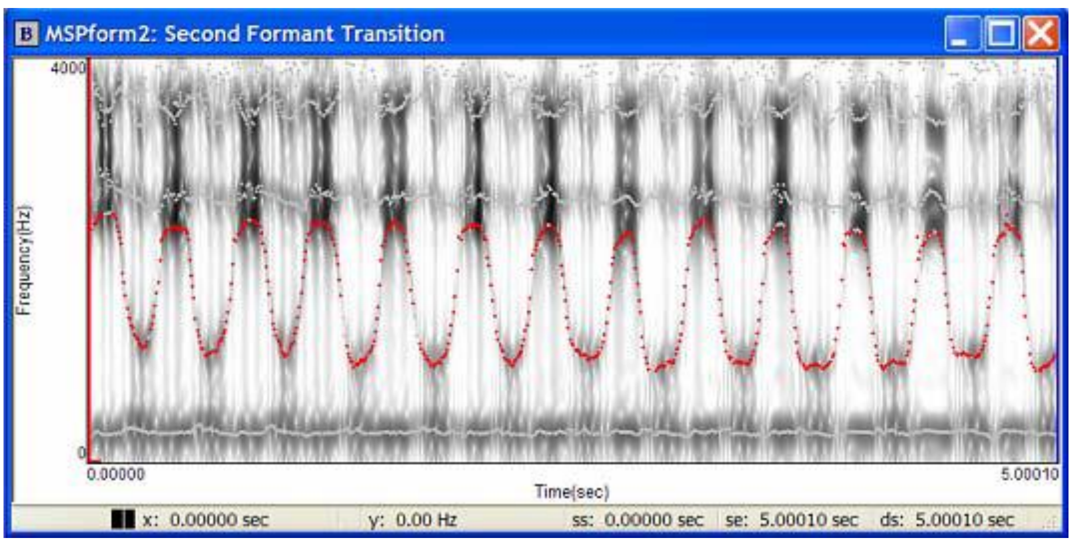

Figure 2: Spectrogram of the F2 transition of /i/ and /u/

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, then it was clicked **OK**.

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)

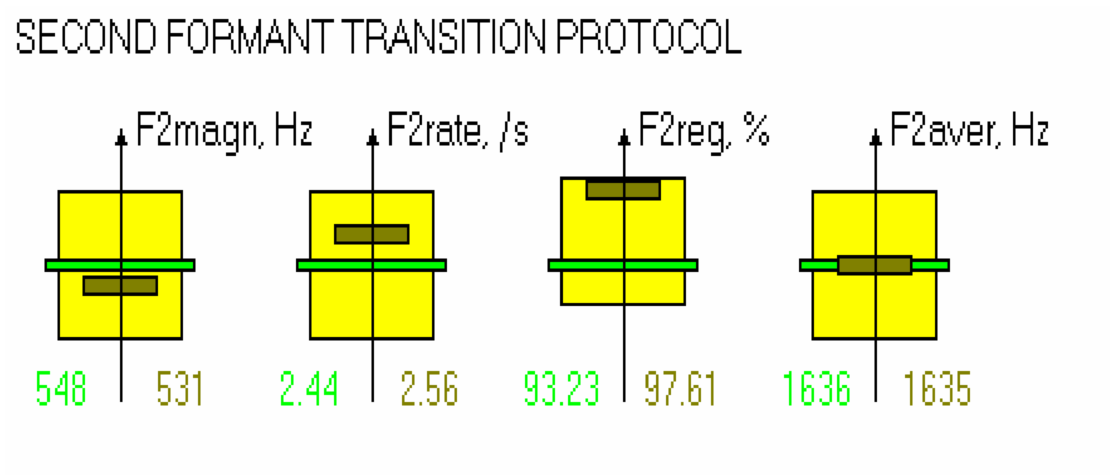

Figure 3:Graphical representation of the F2 transition parameters

In the figure 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-test reliability: The recording procedure 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 in control and clinical group. Reliability found for control group was 0.992, experimental group: 0.999, mild stuttering: 0.988, moderate stuttering: 0.974 and severe stuttering: 0.991. Since, the value is <6, it can be considered as good reliability.

3.7 Statistical analysis

The data obtained for each parameter from both groups were tabulated and analyzed using the SPSS (version 21) software. The data obtained was further subjected to different statistical procedures.

- Descriptive statistics was carried out on the clinical and control group to obtain the mean, median and standard deviation.
- Mann Whitney U test was employed to find out the significant difference between the control groups and clinical groups.
- Kruskal Wallis test was employed to find out the significant difference across the clinical groups. Further Mann Whitney U test was employed for comparing pair-wise severity differences. 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. 60 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 parameters in each group were tabulated and the data obtained from all the groups was analysed using the SPSS software version 21. The following statistical procedures were used:

a. Descriptive statistics was carried out for each group to obtain the mean, median and standard deviation. Since the data do not have the normal distribution the Non-parametric test was used.

b. Non-parametric tests- Mann Whitney U test was employed to find the significant difference between the control and clinical group for all four parameters

c. Kruskal Wallis test was employed to find the significant difference, if any, within each type of clinical groups, as significant difference i.e. $p<0.05$ was noted further Mann Whitney U test was employed for comparing pair wise severity differences.

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

4.1 Comparison of two groups i.e. Second formant transisition in adults with stuttering and control group

4.2 Comparison of Second formant transition across three degrees of stuttering

4.1 ***Comparison of two groups i.e. Second formant transisition in adults with stuttering and control group*** **:** The performance of the two groups on all the four parameters were analysed. The data was subjected to descriptive statistical methods to obtain Mean, Median and Standard Deviation. Table 1 depicts overall results of descriptive statistics for different groups.

Table 1: ***Results of descriptive statistics for the groups***

	Parameters	**Mean**	**Median**	**SD**
Control group (N=30)	F2magn	597.507	595.90	39.70
	F2reg	95.9623	96.73	2.00
	F2rate	2.5800	2.60	.212
	F2aver	1676.75	1674.40	78.93
Clinical group (N=30)	F2magn	534.043	494.40	62.56
	F2reg	89.5175	84.75	6.37
	F2rate	2.3623	2.23	.223
	F2aver	1585.66	1496.9	45.88

Note: F2magn=F2 magnitude; F2reg=F2 regularity; F2aver=F2 average

On comparison of the overall mean values the control group was having higher values when compared to that of clinical group. Additionally, the standard deviation values were greater in clinical group for F2magn and F2reg suggesting variability.

To check if this difference was statistically significant, non-Parametric Mann-Witney U test was administered. The results of Mann-Witney U test revealed a statistically significant difference between the overall values of the two groups. Comparison of the performance of the two groups are graphically represented in figure 4. As depicted in the figure the performance on all four parameters of F2 transition were better in control group when compared to that of clinical group.

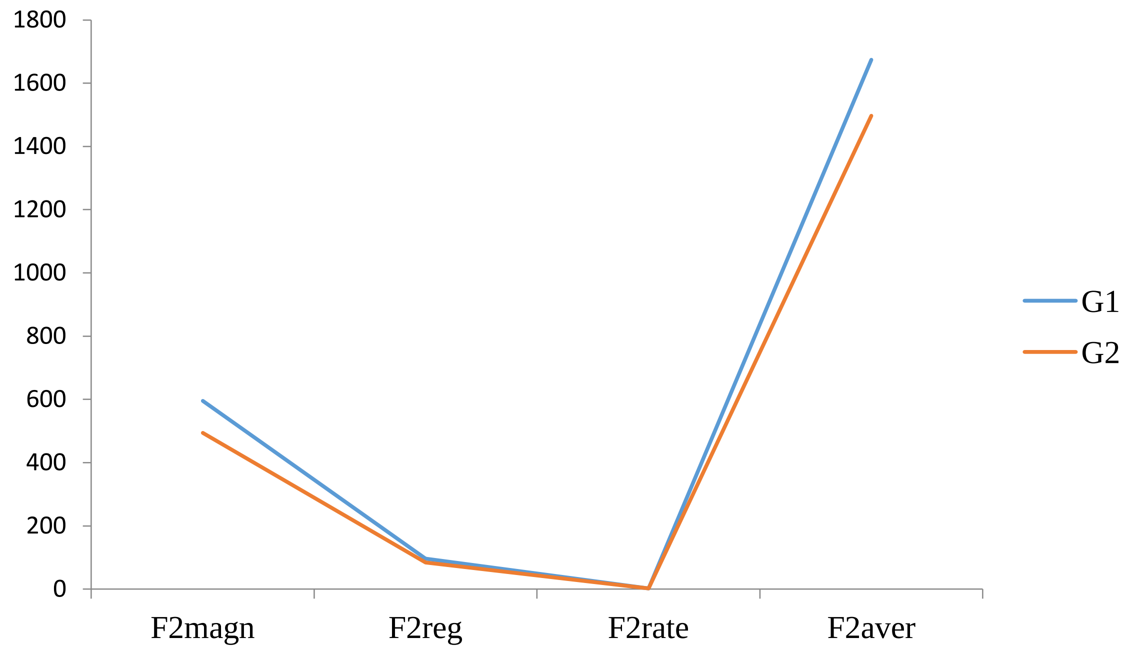

Figure 4: Overall Performance of the two groups (G1=control group; G2=clinical group)

Table 2 depicts the comparison of groups i.e. G1 (control group) and G2 (clinical group) using Mann Whitney U test. F2 transition of 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 2: ***Results of Mann Whitney U test for the groups***

Parameters	**|z|**	**p value**
F2magn	6.52	**.00***
F2reg	6.60	**.00***
F2rate	5.84	**.00***
F2aver	6.43	**.00***

Note: $^*p \leq 0.05$

The results of the present study suggests lower values for all the four parameters of F2 transition in clinical group compared to control group.

Lower F2 magnitude value indicate that adults with stuttering (AWS) vocalization had neutralized vowels, reflecting reduced motility of the articulators.

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

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

Lower F2 average value indicate that adults 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 nonstutterers.

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).

The F2 transition of experimental group may also be different when compared to control group that less efficient and less flexible in their adaptation to lower (motor) and higher (cognitive–linguistic) order requirements that impact on speech motor functions. These findings in general provide 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 (Van Lieshout, Hulstijn, & Peters, 2004). One of the study found that stuttering may result in part from impaired readout of feedforward 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 and this was 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 output 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 the results supported the hypothesis that many dysfluencies in stuttering are due to a bias away from feedforward control and toward feedback control(Civier et al., 2012)

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.

Our findings is contrary to one of the study (Padareva et al., 2012) that, F2 magn in stuttering group are consistently low compared to the high values for nonstutterers but significantly different are the median values of F2reg but the SD offered in MSP protocol for this parameter is high. and they also found that high F2reg values for stutterers are not inadmissible and do not show a deviation from the normal regularity, F2rate and

F2aver differ between two stutterers and their controls but the median values was not significantly different (Padareva et al., 2012). This difference may be because that the sample size which they were selected for study was too small when compared to that of our study and they included participants who were enrolled in maintenance therapy but our study included the participants who were not involved in any previous therapy.

4.2 Comparison of Second formant transition across three degrees of stuttering: The performance of the three degrees of stuttering groups on all the four parameters were analysed using Kruskal-Wallis test. Results suggested significant difference while comparing within the clinical group. Further Mann Whitney U test was employed for comparing pair wise severity differences.

Table 3 depicts the results for comparison Kruskal-Wallis test within the clinical group. F2 transition of each parameters were significantly different in mild stuttering when compared to moderate and severe degree of stuttering ($p<0.05$). Findings suggest that AWS exhibited F2magn significantly lower when compared to control group so that AWS vocalization had neutralized vowels, reflecting reduced motility of the articulators. F2reg was significantly higher for control group when compared to clinical group so that AWS had irregular vocalization which showed lower regularity, F2rate was significantly higher for control group when compared to clinical group so that AWS had reduced motility of the articulators which reflected as reduced rate of variations and F2aver was significantly higher for control group when compared to clinical group so that AWS lower average F2 value for the vocalization.

Table 3: Results of Kruskal-Wallis test for clinical group

Parameters	Chi-Square (χ^2)	p value
F2magn	25.818	**.00***
F2reg	25.557	**.00***
F2rate	20.503	**.00***
F2aver	6.529	**.03***

*Note=*p ≤ 0.05*

Table 4 depicts the comparison of mild and moderate degrees of severity i.e. G2a (mild stuttering) and G2b (moderate stuttering) using Mann Whitney U test. F2 transition of each parameters except F2rate were significantly different across two degrees of stuttering ($p<0.05$) i.e. all the values of F2 transition except F2rate was significantly lower in moderate degree of stuttering when compared to mild degree of stuttering. Findings suggests that F2magn was significantly higher for G2a when compared to G2b reflecting that G2b had highest neutralization of vowels and reduced motility of articulators. F2reg was significantly higher for G2a when compared to G2b reflecting that G2b had highest irregular vocalization which showed lower regularity. F2aver was significantly higher for G2a when compared to G2b reflecting that G2b had lower average F2 value for the vocalization. F2rate did not show significant difference between G2a and G2b so that rate of variations in the vocalization were less between G2a and G2b groups and both behaved in almost similar pattern.

Table 4: Results of Mann Whitney U test on comparison of mild and moderate severity of stuttering

Parameters	**|z|**	**p value**
F2magn	3.78	**.00***
F2reg	3.78	**.00***
F2rate	1.55	.11
F2aver	2.19	**.02***

Note=$p \leq 0.05$*

Table 5 depicts the comparison of mild and severe degrees of severity i.e. G2a (mild stuttering) and G2c (severe stuttering) using Mann Whitney U test. F2 transition of each parameters were significantly different across two degrees of stuttering. All the values of F2 transition was significantly lower in severe degree of stuttering when compared to mild degree of stuttering ($p<0.05$). Findings suggests that F2magn was significantly higher for G2a when compared to G2c reflecting that G2c had highest neutralization of vowels and reduced motility of articulators. F2reg was significantly higher for G2a when compared to G2c reflecting that G2c had highest irregular vocalization which showed lower regularity. F2rate was significantly higher for G2a when compared to G2c because this group had reduced motility of the articulators which reflected as reduced rate of variations. F2aver was significantly higher for G2a when compared to G2c reflecting that G2c had lower average F2 value for the vocalization.

Table 5: Results of Mann Whitney U test on comparison of mild and severe stuttering.

Parameters	**|z|**	**p value**
F2magn	3.78	**.00***
F2reg	3.78	**.00***
F2rate	3.78	**.00***
F2aver	2.19	**.02***

*Note=*p ≤ 0.05*

Table 6 depicts the comparison of moderate and severe degrees of severity i.e. G2b (moderate stuttering) and G2c (severe stuttering) using Mann Whitney U test. F2 transition of each parameter except F2avg were significantly different across two degrees of stuttering . All the values of F2 transition except F2aver was significantly lower in severe degree of stuttering when compared to moderate degree of stuttering ($p<0.05$). F2aver values of severe degree of stuttering were not significantly different when compared to moderate degree of stuttering($p=0.850$). Findings suggest that F2magn was significantly higher for G2b when compared to G2c reflecting that G2c had highest neutralization of vowels and reduced motility of articulators. F2reg was significantly higher for G2b when compared to G2c reflecting that G2c had highest irregular vocalization which showed lower regularity. F2rate was significantly higher for G2b when compared to G2c because this group had reduced motility of the articulators which reflected as reduced rate of variations.

Table 6: Results of Mann Whitney U test on comparison of moderate and severe degree of stuttering

Parameters	**|z|**	**p value**
F2magn	3.78	**.00***
F2reg	3.70	**.00***
F2rate	3.78	**.00***
F2aver	.18	.85

Note=$p \leq 0.05$*

Considering the main objective of the study as to compare second formant transition across three degrees of stuttering , consistent finding was obtained with respect to speech rates in severity of stuttering. The group with mild/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).

The results of our study also holds good with argument that the stuttering severity and the speech rate present significant variation, i.e., the more severe the stuttering is, the lower the speech rate in words and syllables per minute and they suggested that speech rate is an important indicator of fluency levels and should be incorporated in the assessment and treatment of stuttering (Andrade, Cervone, & Sassi, 2003)

The data from the other study showed a left hemisphere superiority in the processing of words in both the mild person with stuttering and the fluent speakers, but a right hemisphere advantage in the severe person with stuttering and they also suggested a close relationship between the severity of stuttering and functional brain organization (Szelqg, Garwarska-Kolek, Herman, & Stqsiek, 1993)

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 was significantly lower in severe degree of stuttering when compared to mild and moderate degree of stuttering. F2magn, F2reg and F2aver except F2rate was significantly lower in moderate degree of stuttering when compared to mild degree of stuttering. F2magn, F2reg, F2rate and F2aver was significantly lower in severe degree of stuttering when compared to mild degree of stuttering. F2magn, F2reg and F2rate except F2aver was significantly lower in severe degree of stuttering when compared to moderate degree of stuttering.

Findings suggests that AWS vocalization tend to be neutralized, reflecting reduced motility of the articulators, irregular and more variations in the vocalizations. AWS vowel production is more restricted, spatially and temporally, than AWNS. 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 AWS 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. 60 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 was analysed using the SPSS software version 21. The data was subjected to descriptive statistics and based on the normality criteria, non-parametric tests were employed.

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 but to a different degree and these differences are more important when distinguishing Person With Stuttering (PWS) from Person With No Stuttering (PWNS). 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.

F2magn differs the most, F2magn in stuttering group are significantly low compared to the high values for PWNS and also within the stuttering group the F2magn values are significantly low in severe stuttering when compared to moderate and mild group of stuttering. F2rate was significantly reduced with moderate stuttering group compared to that of mild stuttering group because this group failed to maintain the regularity at the time of recording and this group needed more number of trials when compared to other groups. F2reg was significantly low in PWS when compared to that of PWNS and within the stuttering group F2rate was significantly reduced for severe stuttering when compared to that of moderate and mild group of stuttering. F2aver differ between PWS and PWNS and the values are significantly different and within the stuttering group the F2aver was significantly reduced for severe stuttering group when compared with mild and moderate stuttering group.

This study tested the ability of the subjects 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 PWS group in this research demonstrated reduced F2magn as a result of neutralization of the vowels. These findings indicated that stutterers' vowel production is more restricted, spatially and temporally, than nonstutterers 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 AWS who were Native Kannada speakers.

Thus, it can be concluded that F2 transition in Adults with stuttering (AWS) is different when compared to that of Adults with no stuttering (AWNS) and within the Stuttering group there was 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, this can be used as an additional tool for the assessment and intervention for the adults with stuttering.

Implications of the study

1. The results of the present study has lead to better understanding the nature of F2 transition in clinical group, Adults with stuttering.

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 AWS.

3. The study provided the information about the motor stability in AWS as a whole group.

4. The differences noted with F2 transition across AWS and AWNS is suggestive to add such objective measure in assessment and intervention among AWS.

5. The results of present findings adds to literature/theory on "Stuttering as a motor deficit". It's interesting to note that poor articulatory motility is confirmed in context of vowel-vowel combination.

Limitations of the study

1. In the present study only adults with stuttering were considered.
2. Limited sample size, especially with regards to degrees of severity was considered.
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 wider age range including children, adolescents and adults.
2. F2 transition can be measured as how they are different between the gender..
3. F2 transition can be investigated to determine the efficacy of the treatment during pre and post therapy conditions.
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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