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# A Comparison of F2 Transitions in the Disfluent Speech of Persistent and Recovered Preschool Children Who Stutter

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Jennifer K. Niemann

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A COMPARISON OF F2 TRANSITIONS IN
THE DISFLUENT SPEECH OF PERSISTENT
AND RECOVERED PRESCHOOL
CHILDREN WHO STUTTER

By Jennifer K. Niemann

THESIS COMMITTEE MEMBERS

# A Comparison of F2 Transitions in the Disfluent Speech of Persistent and Recovered Preschool Children Who Stutter

By Jennifer Niemann

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Abstract

This study 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. These children were enrolled in the longitudinal Stuttering Research Project at the University cf Illinois at Urbana. 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 were analyzed for each subject in the stuttering subgroups, and between one and three transitions were analyzed for each control subject. The transitions were 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 existed

between the control and persistent groups, and the control and recovered groups. This study was supported by grant #R01-DC00459 from the National Institute of Deafness and Other Communication Disorders, National Institutes of Health, Principal Investigator: Ehud Yairi.

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# CHAPTER I

## Introduction

Stuttering can be found in all cultures, and among all races. It can effect people regardless of their sex, race, age, intelligence, or social status. Evidence has been found that stuttering existed as early as 40 centuries ago in Chinese, Egyptian, and Mesopotamian cultures. Currently, the incidence of stuttering in the population is estimated at 5 percent (Curlee, 1993).

The cause of stuttering remains a mystery, although neurophysiological, psychological, social, and linguistic factors may contribute to its onset and development. Approximately 15 percent of preschool age children experience a period of stuttering (Glasner and Rosenthal, 1957), and in at least one-fifth of these children, stuttering will persist. Some children who begin to stutter, however, recover without therapy. In fact, spontaneous recovery rates have been reported as high as 79 (Andrews & Harris, 1964) and 89 percent (Yairi & Ambrose, 1992). Unfortunately, no reliable predictive variables are known to determine which of the children who stutter need therapy, and which will spontaneously recover.

Perceptually, the disfluencies of recovered and persistent stutterers may be the same. Similar symptoms, however, do not necessarily mean that the etiology of stuttering is the same for the recovered as it is for the persistent stutterers. One view suggests that those who recover may have a milder subtype of stuttering, possibly caused by less genetic predisposition than those who persist in stuttering (Ambrose & Yairi, 1997). Another possibility is that recovery and persistence are caused by two separate etiologies, although both present similar symptomatology. While an absolute conclusion regarding the nature of recovery and persistence may not be possible, it is possible to study the acoustic features of the disfluent speech of both recovered and persistent stutterers in an attempt to make a distinction between the groups.

Past attempts at predicting recovery by evaluating second formant transitions in the disfluent speech of recovered and persistent stutterers have been contradictory. The contradictions may have resulted from vague or questionable methods. Regardless of the reason, the use of the F2 transition in predicting stuttering chronicity has not been verified. It remains unclear which children will recover from or persist in stuttering based on the evaluation of acoustical information.

The purpose of the present study was to investigate the second formant characteristics during disfluent speech of preschoolers, to determine their ability to differentiate young children beginning to stutter who eventually recover, from those who will persist in stuttering. A secondary purpose was to compare the two stuttering groups' F2 transitions to a normally fluent control group.

# CHAPTER II

## Review of the Literature

In reviewing the literature for the present study, several areas of related research were considered. This chapter begins with a review of some early theories in which childhood stuttering was depicted as a disorder whose severity progressively worsened over time (Froeschels, 1921; Bluemel, 1931; Bloodstein, 1960a, 1960b, 1961). More recent studies, however, have demonstrated that many cases of childhood stuttering decrease in severity over time and recovery frequently occurs (Yairi & Ambrose, 1992; Yairi, Ambrose, & Niermann, 1993; Yairi, Ambrose, Paden, & Throneburg, 1996). Following discussion of recovery from stuttering, the review then focuses on attempts to make early predictions of which children will persist in or recover from stuttering. Because a specific goal of this study is to use acoustic measures in predicting stuttering trends, the remainder of this chapter is concerned with acoustic characteristics of disfluent speech.

### Development of Childhood Stuttering

#### Retrospective Studies and Clinical Findings

Many researchers described stuttering as progressing through certain stages. Froeschels (1921) believed stuttering frequently began between 3 and 5 years of age with simple repetitions. During this period, breathing was normal, and no accompanying secondary characteristics or signs of fear were evidenced by the stutterer. Repetition rate had a normal tempo without any tension. As stuttering progressed, early signs of tension became evident and subsequently the rate of repetitions increased. The next change was characterized by an increase in tension, but the rate of repetition became slower. Finally, in addition to the slow tempo and marked tension, the stutterer began to prolong sounds and articulatory postures. Froeschels believed that all stutterers progressed as stated unless therapy was implemented.

Bluemel (1931) defined the development of stuttering by dividing it into primary and secondary stages. The first stage, "primary stammering", consisted of easy repetitions of initial consonants, syllables, and words. Stuttering could disappear and re-emerge over subsequent months or years, but Bluemel believed "secondary stammering" would eventually be reached. This stage was characterized by fear of certain sounds, words, and speaking situations. Like Froeschels, Bluemel's categories implied a similar progressive developmental pattern for children who stuttered.

Bloodstein (1960a, 1960b, 1961) characterized the development of stuttering using cross-sectional studies. The subjects of the studies were 418 stutterers who had been examined at the Brooklyn College Speech and Hearing Center from 1950 to 1956. The group ranged in age from 2 to 16 years, and consisted of children with varying histories of speech services. Bloodstein proposed four phases of stuttering development. He cautioned, however, that not all stutterers progressed in the same manner, and further stated that severe stuttering may exist even in young children. The phases were meant to act as reference points. Phase I was characterized by repetitions of sounds, syllables, and words at the beginning of utterances. Long periods of remission were common during this stage. In Phase II, hard contacts and speech blocks became more evident. The child was aware of the stuttered speech, but did not experience embarrassment. Phase III was characterized by increased secondary symptoms, although the stutterer did not avoid speech opportunities. Hard contacts and speech blocks were common while repetitions became less significant. Phase IV was characterized by fear and embarrassment associated with stuttering.

In 1982, Van Riper examined 300 clinical files of childhood stuttering cases. He tracked 44 children for whom longitudinal clinical information was available. From these, he determined four tracks of progressive changes in the development of stuttering. The children in Track I experienced gradual stuttering onset with disfluencies beginning as easy repetitions of sounds and words. In Track II stuttering was evident earlier than in Track I. Initial repetitions were rapid and irregular, and speech blocks, revisions, and interjections were added. Stuttering in these children was predicted to persist. Stuttering onset occurred suddenly for children in Track III which was characterized by prolongations, blocks, and tremors. It was predicted that children in this track would also persist in stuttering. For children in Track IV, stuttering was characterized by sudden onset, and consisted primarily of whole word and phrase repetitions. Van Riper predicted that this group would persist, and disfluencies would remain the same as the initial stuttered speech.

The studies discussed above indicated that stuttering was generally a disorder that became progressively worse as an individual aged. Several recent studies have shown, however, that disfluencies did not increase and may even decrease as time progressed (Yairi & Ambrose, 1992; Yairi, Ambrose, & Niermann, 1993).

## Recovery from Stuttering

### Longitudinal Studies of the Development of Stuttering

From 1946 to 1962 Andrews and Harris (1964) examined the speech development of 1,000 children between the ages of 2 and 7 years old, 43 of which were identified as stutterers. The children were seen on a regular basis by health professionals, although the exact time interval was not specified. Age of stuttering onset ranged from 2 to 10 years old, but occurred primarily during the pre-school years, and became less common as age increased. Seventy-nine percent of the children in this study recovered from stuttering. Andrews and Harris observed that two-thirds of the stutterers had symptoms for less than 2 years, and recommended that treatment be sought only when symptoms persisted over a 2 year period. The authors of this study did not provide explicit criteria for stuttering or recovery and, in addition, results were based on observations by health workers rather than speech language pathologists.

In a recent longitudinal study, Yairi and Ambrose (1992a) examined the development of stuttering in children. Twenty-seven preschool age children, 19 males and 8 females, were observed for up to a 12 year period. The children were less than 1 year post onset of stuttering, and exhibited a minimum of 3 Stuttering-Like

Disfluencies (SLDs) (i.e. part-word repetition, single-syllable word repetition, and disrhythmic phonation) per 100 syllables. The age of the children ranged from 23 to 52 months (m=36.96 months) at the initial visit.

Speech samples were obtained from the children during sessions of approximately 30 minutes. The children were recorded in 3 subsequent evaluations at intervals of several months over a 2 year period. Twenty-one children were seen for a fifth recording 3 to 12 years after their initial visit. Mean SLDs declined from 10.47 to 4.8 during the first 2 years of the study, and further declined to 2.72 in later recordings. In order to be termed as recovered, the clinician and parent had to indicate that the child did not exhibit a stuttering problem, and the child had an SLD frequency of 2.99 or fewer per 100 syllables. Out of 27 children, 18 met the requirements for recovery by 2 years post onset, and 9 continued to stutter. Of the 9, 6 recovered in the early elementary school years and 3 continued to stutter. Overall, 24 of the 27 children (89 percent) recovered by the early elementary school years.

In a later longitudinal study, Yairi, Ambrose, and Niermann (1993) investigated the development of stuttering during the first 6 months of the children's stuttering history. Data was obtained from 16 subjects, 10 males and 6 females, ranging in age from 25 to 39 months (m=32.63). The subjects were regarded by both parents and the first two authors as having stuttered speech. They exhibited at least 3 SLDs per 100 syllables, and had a stuttering history no longer than 12 weeks.

The children were seen at an initial visit and at 3 and 6 month follow-up visits. Using multiple measures, the study found that early stuttering was often more severe than had been previously thought. Like the data from the Yairi and Ambrose study (1992a), these data revealed high levels of disfluency near stuttering onset with a quick decline in disfluency levels over time. During the 6 month interval, mean SLDs decreased from 11.99 to 4.46 per 100 syllables. Mean facial-head movements declined from 3.18 to 1.91 per disfluency and mean stuttering severity ratings decreased from 4.43 to 1.99 on a seven-point scale. After the 6 month visit, 19 percent (three) of the subjects had recovered, and an additional 4 subjects were regarded as possibly recovered. Follow-up evaluations showed that none of the recovered children relapsed and most of the stutterers continued to have fewer disfluencies. The researchers found that stuttering reached its highest level during 2 to 3 months of onset and then quickly declined for many stuttering children.

In a more recent study, Yairi et al. (1996) obtained data from 3 groups (Early Recovered, Late Recovered, and Persistent Stutterers) of preschool children over a 3 year period. The Early and Late Recovered stutterers produced 12.5 SLDs per 100 syllables initially, and declined to 3.98 and 2.46 SLDs per 100 syllables, respectively, at recordings 13 to 18 months later.

These more recent studies contradicted the belief that stuttering generally increases in frequency and severity with time, and contrastingly provided support for high rates of recovery during childhood. Due to the high rates of recovery, identification of early indicators of stuttering chronicity or recovery would be prudent.

## Prediction of Stuttering Chronicity

The development of stuttering is important, but that information cannot determine which stutterers will persist and which will recover. Speech-language pathologists need predictive criteria in order to determine which clients will benefit from therapy and which are likely to recover spontaneously.

### Clinical Accounts

Van Riper (1982) tracked 44 children by reviewing longitudinal clinical files and determined 4 categories of progressive changes in the development of stuttering. He provided characteristics of each group, and made predictions regarding stuttering chronicity within each group. The following characteristics were considered to be indicative of stuttering persistence: rapid and irregular repetitions, silent intervals, revisions, interjections, prolongations, blocks, and tremors.

Conture (1990) discussed stuttering chronicity and indicated that no one behavior or test accurately determined whether a child would outgrow stuttering or if intervention would be needed. He recommended therapy if two or more of the following characteristics were observed:

a) sound prolongations that made up more than 25 percent of the total disfluencies produced by the child,

b) avoidance of or averted eye contact with listeners more than 50 percent of the time during conversations,

c) frequent and/or unusual phonological processes,

d) instances of sound/syllable repetitions or sound prolongations on the first mono-, bi- or tri-syllabic production of diadochokinesis tasks,

e) delays in speech and non-speech neuromotor development, and

f) Stuttering Prediction Instrument (Riley, 1981) score of 18 or above.

Formal Instruments for Predicting Stuttering Chronicity

Riley (1981) developed the Stuttering Prediction Instrument (SPI) to aid in predicting persistence/recovery of stuttering in young children. The SPI is divided into five sections which examine stuttering history, reactions to stuttering, rating of the number and abnormality of repetitions, rating of the duration of stuttering incidents, and frequency of stuttering in a speech sample. The child can score between 0 and 40 on all of the sections combined. A score of 10 or more indicated that the child would continue to stutter, while a score less than 10 suggested spontaneous recovery.

The SPI was based on a comparison of 85 children, ranging in age from 3 to 8.9 years old, who received services for stuttering versus 11 children who were monitored for 1 to 3 years by Riley. The author did not provide a definition for stuttering chronicity, nor did he state the criteria for the 11 children who were monitored or the criteria for enrolling the 85 children in therapy.

Cooper and Cooper (1985) provided another instrument to aid in the prediction of stuttering development called the Chronicity

Prediction Checklist (CPC). The checklist is comprised of 27 questions related to stuttering history, stuttering severity, types of disfluencies, reactions to stuttering, and the duration of stuttering. The authors stated that scores of 0 to 6 were indicative of those who would recover, 7 to 15 would require monitoring, and 16 to 27 indicated that the child would persist in stuttering. The CPC is based on data reported by McClelland and Cooper (1978) whose conclusions were based on clinical observations rather than longitudinal data. Therefore, the authors recommended that the CPC be used to supplement other information in the prediction of stuttering chronicity.

Longitudinal Data Regarding the Prediction of Stuttering Chronicity

In the longitudinal study by Yairi et al. (1996), 36 preschool age children who stuttered were examined over a 3 year period to determine their risk for stuttering chronicity. The study found no factor(s) that could positively identify stuttering chronicity but found that the following factors aided in prediction: (a) age of onset, (b) length of time since onset, (c) family history of persistent and recovered stuttering, and (d) scores on language, phonology, and nonverbal measures. In contrast to other researchers (Conture, 1990; Cooper and Cooper, 1985; Curlee, 1993; and Riley, 1981), the data indicated that severity at onset and the early presence of physical secondary characteristics did not seem to be predictive of stuttering chronicity.

Acoustic Characteristics of the Speech of Stutterers

One prominent theory of stuttering attributes its cause to a disorder of temporal programming (Kent, 1984). Van Riper (1971) suggested that the primary difficulty during stuttering lies in the programming of sequence and timing aspects of articulatory movements. In an effort to uncover temporal differences in a noninvasive manner, many researchers (Zebrowski, Conture, Cudahy, 1985; Howell & Williams, 1992; and Montgomery & Cooke, 1976) have investigated speech timing characteristics which can be measured in the acoustic waveform. Such measures include voice onset time, stop-gap duration, aspiration duration, and vowel and consonant durations.

General Acoustic Characteristics of Fluent Speech

Zebrowski, Conture, and Cudahy (1985) compared the temporal aspects of speech of 11 young stutterers (m=60 months), all males, to matched pairs of normally fluent peers. The subjects were told to repeat a CVC or CV word after the examiner provided a model. The initial consonant in the CVC and CV segments was either /p/ or /b/, and the vowel was either /i, I, e, or E/. The study found no significant differences between the groups in stop-gap, frication, and aspiration durations, voice onset time, and vowel duration during fluent utterances.

General Acoustic Characteristics of Disfluent Speech

In 1992 Howell and Williams conducted a study that examined the presence of vowel neutralization (i.e. schwə) in the speech of childhood and teenage stutterers, and further examined possible causes for this neutralization. Part-word repetitions of 24 children and 8 teenagers were analyzed. Previously in adults, Howell and Vause (1986) and Howell and Williams (1988) found that the acoustic factors that caused adults' disfluent vowels to sound neutral included: (a) short duration, (b) low intensity, and (c) more energy in the lower frequencies than fluent vowels. This more recent study in children found that vowels in the repeated portions were shorter in duration than vowels in the final productions. The duration differences, however, were smaller for children than for teenagers. The intensity of vowels in final productions was higher than vowels in repeated portions. The difference was again larger for the teenage group. The study found no significant differences between the formant frequencies of the vowels in repeated and final productions for either the children or teenagers.

Montgomery and Cooke (1976) examined part-word repetitions in words beginning with a CV combination in adults who stuttered. The study investigated the consonant and vowel duration. The researchers concluded that the stutterers did not produce the schwa vowel as often as previous research had suggested. They mentioned, however, that since their study consisted of mainly one or two repetitions, the samples may not have been severe enough to bring out the schwa vowel. Using a spectrographic analysis, a mean difference of only 15 ms was found for the vowel durational measures between repeated and final productions. The study found a mean difference of initial consonant length of almost 40 msec. Further, it was observed that the vowel of the repetition was not usually a neutral vowel, but instead often approximated the intended vowel.

Second Formant Characteristics

Another theory regarding the nature of stuttering was suggested by Wingate (1964, 1969). He proposed that stuttering was a phonetic transition defect where, "the difficulty is not manifested in the articulatory postures essential to that sound, but instead in moving on to the succeeding one(s)" (p.107). Phonetic transitions during speech can be visually discerned on a spectrogram in the form of formant transitions. Previous investigators (Robb & Blomgren, 1997; Kowalczyk, 1996; Howell & Vause, 1986; Montgomery & Cooke, 1976; Stromsta, 1965; and Yaruss & Conture, 1993) have examined formant transition characteristics such as duration, direction, slope, and rate.

Many researchers have examined characteristics of the *second* formant (F2) transition. The F2 transition usually represents the place of articulation for a phoneme within the oral cavity. Although other factors may influence the second formant's attributes, it generally represents the anterior and posterior movement of the tongue during phoneme production.

### F2 Transitions in Fluent Speech

The Zebrowski, Conture, and Cudahy (1985) study, previously mentioned, also analyzed the second formant transition of the CV and CVC segments. The study indicated that there were no significant differences between fluent and non-fluent subjects in the acoustic measurements of vowel-consonant transition duration (msec) and rate (Hz/msec), or consonant-vowel transition duration and rate during fluent utterances.

Robb and Blomgren (1997) examined the use of the second formant transition to evaluate and compare the effects of coarticulation in the fluent utterances of a group of stutterers and nonstutterers. The authors tested the hypothesis that the perceptually fluent speech of stutterers differs from nonstutterers in the slope of the F2 transition as a result of abnormal lingual coarticulation behavior. Five adult males who stuttered (m=28 years) and 5 nonstuttering adult males (m=35 years) served as subjects. The subjects were asked to read aloud a word that consisted of a consonant+vowel+/t/ (C+V+/t/). Only words that were produced fluently and correctly articulated were further analyzed. The authors found that the nonstuttering group's F2 slope coefficients for C+V+/t/ words beginning with stop-plosives were consistently lower than those for the stuttering group. The larger F2 slope coefficients among the stutterers indicated greater or quicker movement of the tongue within the oral cavity in transitioning from closing-to-opening-to-closing vocal tract gestures than was evident among the nonstutterers. Certain authors (Lindblom, 1983; and Nittrouer et al., 1983) suggested that a relatively flat F2 slope reflected less gestural overlap between phonetic segments. In other words, the articulatory movements were more refined in the speech of nonstuttering individuals. The study demonstrated the usefulness of using F2 transitions as a means of differentiating between the fluent speech of stutterers and nonstutterers.

Kowalczyk and Yairi (1996) examined the second formant transition rate during fluent speech of stuttering children within 1 year of onset to determine if it could be used to differentiate between children who eventually recover from or persist in stuttering. Twenty-four children, 16 with stuttering histories and 8 who were normally fluent, ranging in age from 28 to 75 months served as subjects. The children were asked to repeat the same set of sentences presented by an examiner. He found that children who persisted in stuttering showed significantly faster rates of second formant transitions than those who recovered. No significant differences were found between the recovered and the control group. Significant differences were found between the persistent group and the recovered and control groups.

F2 Transitions in Disfluent Speech

Howell and Vause (1986) examined the production of the schwa vowel in place of the appropriate vowel in adult stutterers. Part-word repetitions that consisted of a voiceless consonant and a vowel were analyzed. For stutterers, they found that 85% of the spectrograms for final productions and 84.8% of the spectrograms for the repeated portions of words lacked a complete transition between the consonant and the vowel. The part of the formant transitions that were present did however occur at about the same frequency as that for the intended vowel.

In the Montgomery and Cooke (1976) study previously mentioned, the pattern of first and second formant frequency transitions in the vowel following the initial consonant in the repeated portion and the final production (e.g. b - but, repeated portion - final production) were analyzed. In 62% of the pairs of repeated and final productions, a difference in the rate and/or extent of first or second formant consonant to vowel transitions was observed.

## Using F2 Transitions in the Disfluent Speech of Children as Predictors of Chronicity

Two studies have examined whether stuttering chronicity could be predicted using the acoustic information from children's disfluencies. The first study was performed by Stromsta in 1965. His subjects included 63 preschool age children, who were identified as stutterers by their parents. Tape recordings of the children's speech were obtained during an initial evaluation. Stromsta then examined F2 transitions in the disfluent speech of his preschool subjects. The disfluencies were spectrographically analyzed to determine which showed the presence of normal formant transitions and normal terminations of phonation, and which displayed abnormal formant transitions and/or abnormal terminations of phonation. An abnormal formant transition was operationally defined as the "lack of or aberrant second-formant frequency changes as if following sounds were not anticipated in the sense of requisite coarticulation", and abnormal terminations of phonation were defined operationally as "abrupt stoppages of vocal-fold vibration within the usual duration of phonemes. Such terminations of phonation were associated in time with lack of breathstream through the vocal tract" (Stromsta, 1986, p.4).

Ten years after the initial speech samples were obtained, estimates of the children's fluency were made using personal interviews, telephone conversations, and in some cases tape-recorded samples of conversation, and parent questionnaires. The children were then judged to be recovered or currently stuttering. The spectrograms recorded at the beginning of the study were reevaluated for their ability to predict stuttering chronicity 10 years later.

Stromsta found that 24 of 27 children (89 percent) who showed abnormal transitions and abnormal terminations of phonation were still stuttering after the 10 year period. More specifically, the children who exhibited part-sound, part-syllable, and part-word repetitions containing abnormal consonant to vowel transitions and abnormal terminations of phonation were likely to persist in stuttering. Further, 10 of 11 (91%) children with normal F2 transitions and normal terminations of phonation were not stuttering. The children who exhibited whole-sound, whole-syllable, and whole-word repetitions evidencing normal transitions and terminations of phonation were likely to recover. Children with this type of "normal disfluency" generally recovered by the age of 7 years. Stromsta interpreted his results as indicating that childhood stuttering chronicity may be predicted by the nature of the F2 transitions.

Several weaknesses were present in Stromsta's study. First, he provided limited information on his subjects. In addition, his methods were vaguely defined. He failed to report the number of repetitions that were analyzed for each subject. Finally, specific criteria for distinguishing a normal from an abnormal F2 transition was not provided. Due to a lack of a control group, the theoretical implications from this study were further limited.

The second study, performed by Yaruss and Conture in 1993, examined the F2 transitions in part-word repetitions of 13 stuttering children to determine if chronicity could be predicted. The subjects were divided into high- and low-risk groups for chronicity based only on scores from the Stuttering Prediction Instrument (SPI) (Riley, 1981), rather than determining chronicity through a longitudinal study. The high-risk group consisted of 7 males (mean age=50.57 months), and the low-risk group consisted of 5 males and 1 female (mean age=48.50). The children were audio- and videotaped during a 30-35 minute conversational speech sample.

Ten part-word repetitions were examined for each subject. The first repetition was compared to the final production (e.g. b-but) using spectrographic analysis. The investigators labeled the transition in the repetition as being nonmeasurable or missing, measurable but discrepant, or measurable and nondiscrepant. The authors defined nonmeasurable or missing transitions as those that "could not be identified through visual examination of the spectrogram. These F2 transitions were missing or simply not measurable due to mechanical limitations of the equipment or measurement or recording techniques" (Yaruss & Conture, 1993, p. 890). Measurable but discrepant transitions were defined as those that "differed markedly from that of their fluent counterparts" (Yaruss & Conture, 1993, p.891). An example of this type of transition was when the repeated portion moved from a high to a low frequency whereas the transition in the final production moved from a low to a high frequency. Measurable and nondiscrepant transitions were those that could be visually identified, and did not differ markedly from the final production.

The results of this classification indicated that 29% of the high-risk group's transitions, and 25% of the low-risk group's transitions were missing or nonmeasurable. Sixteen percent of the high-risk group's transitions, and 10% of the low-risk group's transitions were measurable but discrepant. Fifty-six percent of the high-risk group's transitions, and 65% of the low-risk group's transitions were measurable and nondiscrepant. Although the authors found differences between the high- and low-risk groups in the occurrence of the three types of transitions, these differences were not statistically significant.

Additionally, Yaruss and Conture (1993) examined specific frequency and durational characteristics of F2 transitions in the measurable and nondiscrepant category. They measured: 1) the duration of the F2 transition, believed to represent the amount of time the articulators spent moving from one position to another during the transition; 2) the extent or length of the difference between onset and offset frequencies, believed to represent the overall movement of the articulators during the transition; and 3) the rate of frequency change. This third measure was derived by dividing the length of the F2 transition by the duration of the transition. This measure was thought to approximate the speed in which the articulators moved from one location to the next.

Results indicated that the mean durations of the F2 transition for the high- and low-risk groups were similar (41.47 msec and 39.75 msec respectively) and nonsignificant. The transition length was longer for the high-risk group (436.46 Hz) than the low-risk group (271.00 Hz) although it did not reach significance. Finally, the transition rate was faster for the high-risk (8.83 Hz/msec) than the low-risk group (4.82 Hz/msec), but again did not reach significance.

A major weakness of this study was that subjects were grouped according to scores on the Stuttering Prediction Instrument (SPI). The power of the SPI to accurately classify stuttering chronicity has not been determined. Although Yaruss and Conture did not find significant differences between the groups in any of their measures, this may be due to the questionable grouping of subjects. This does not mean that the measures may not be helpful for predicting stuttering chronicity.

A second weakness of the study was the small number of part-word repetitions that were measured acoustically. The frequency, duration, and rate of the F2 transitions were obtained only from the measurable and nondiscrepant category. The mean number of part-word repetitions measured was 5.57 and 6.50 for the high- and low-risk groups respectively. Justification was not provided for excluding measurable and discrepant transitions.

## Summary and Statement of Objectives

A review of the literature has shown that spontaneous recovery from stuttering is common in early childhood. Although two instruments to aid in prediction of chronicity have been published, these instruments lack validity.

Current longitudinal research (Yairi et al., 1996) has suggested that several factors such as the developmental characteristics of disfluency, genetics, and language/phonological skills as well as F2 transitions in fluent speech (Kowalczyk & Yairi, 1996) may be useful to aid in the prediction of stuttering chronicity. Previous attempts to predict chronicity by evaluating second formant transitions in disfluent speech have been contradictory. The contradiction may have resulted from vague or inadequate methods. Regardless of the reason, the unfortunate reality at present is that the optimism of Stromsta's claims that F2 deviations could predict stuttering chronicity in children have not been verified. Currently it remains unclear who will recover, or what criteria are most predictive of stuttering chronicity.

The purpose of the present study was to investigate second formant characteristics during part-word repetitions, and to determine their ability to differentiate young children beginning to stutter who eventually recover, from those who will persist in stuttering. Comparisons were also made between the 2 groups of children who stutter and a control group of normally fluent children. More specifically, the following questions were addressed:

1. Are there significant differences in the *presence* and *direction* of the consonant to vowel transitions of the second formant, in the repeated portion when compared to the final production of part-word repetitions, between persistent and recovered stutterers?
2. Are there significant differences in the *presence* and *direction* of the consonant to vowel transitions of the second formant, in the repeated portion when compared to the final production of part-word repetitions, between stuttering and nonstuttering children?

# CHAPTER III

## Methods

### Overview

The primary purpose of this study was to compare second formant transitions within part-word repetitions of preschool age children who eventually became persistent stutterers from those children who eventually recovered from stuttering. These stuttering children were regularly evaluated over a period of several years during the study performed at the University of Illinois (see Appendices A & B). All subjects were diagnosed as stutterers during the initial evaluations, and recordings were made of their speech. Subsequently, many of the children recovered from stuttering. The repetitions produced by the recovered and persistent groups from these early recordings were re-evaluated for the present study. In addition, the repetitions from normally fluent control subjects were included. 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. The transitions were judged to be: 1) absent, 2) present/different direction, 3) present/same direction/did not reach target frequency, or 4) present/same direction/reached target frequency. The acoustic data obtained from the persistent, recovered, and control groups were compared to determine if differences existed.

## Speech Samples

Conversational speech samples were obtained from 120 preschool age children who stuttered and 50 control subjects as part of the University of Illinois stuttering research project (principal investigator Dr. Ehud Yairi). Speech samples were gathered in a sound treated room, and were audio and video tape-recorded. The subjects were seen for an initial evaluation, and follow-up visits every 6 months for at least 3 years. Each visit consisted of 2 sessions separated by 1 week. Speech samples were obtained during each session with a total combined duration of 30 to 45 minutes per visit. Speech samples were elicited by one parent and also by one investigator. Standard toys (e.g., Playdoh, blocks) were used in a play setting to elicit conversation.

Each tape was orthographically transcribed by 1 of 8 stuttering research project staff members. The children's disfluenies were classified into 7 categories including part-word repetitions, monosyllabic word repetitions, disrhythmic phonations (sound prolongations and broken words), polysyllabic word repetitions, phrase repetitions, interjections, and revised or incomplete phrases. The number of each disfluency type and the total number of disfluencies was counted for each subject. Because of differences in the speech sample length, those numbers were converted to reflect the frequency of disfluencies per 100 syllables. The combined frequency of the 3 types of stuttering-like disfluencies (SLDs); part-word repetitions, monosyllabic word repetitions, and disrhythmic phonations, was also calculated. Further descriptions of the above disfluency categories are provided in Appendix C. Two senior investigators also listened to the tapes and marked disfluencies. Average point-by-point agreement for location and type of disfluency was .84 using Sanders Agreement Index (1961).

## Subjects

In order to qualify as a subject who stuttered for the University of Illinois project, the child had to meet the following criteria at the time of the initial visit: a)under 6 years old at the time of first visit, b)first evaluation occurring no longer than 13 months after the onset of stuttering, c)judged by both parents as having a stuttering problem, d)judged by 2 senior staff members, speech-language pathologists experienced with stuttering, as having a stuttering problem, e)exhibited stuttering at the time of the initial evaluation rated as 2 or higher on an 8-point stuttering severity scale (0=normal speech, 7=very severe stuttering) by the 2 staff members, f)parent severity rating of stuttering of at least 2 on an 8-point scale, g)a minimum of 3 stuttering-like disfluencies per 100 spoken syllables, h)no history of neurological disorders, and i)had not received therapy for stuttering.

For the present study, longitudinal information from the University of Illinois records for each subject were examined. In order to be judged as a child who persisted in stuttering, the child had to meet the criteria mentioned above initially, exhibit continuous stuttering for at least 36 months at follow-up visits, and currently be judged as still stuttering. At the time this study began, 10 of the 120 subjects had been followed for the required 3 years and were judged to be persistent stutterers. Two of these subjects produced less than 10 measurable part-word repetitions and therefore were not included in the present study. The remaining 8 persistent stutterers served as subjects for the present study. At the time the present investigation began, 20 of the 120 subjects at the University of Illinois were judged to have recovered from stuttering. A subject was considered recovered from stuttering for the present investigation when the following criteria were met during follow-up visits at the

University of Illinois: a)parental judgement that stuttering had ceased, b)senior University of Illinois investigator's judgement that the child no longer stuttered, c)parent and investigator stuttering severity rating of 1 or lower on an 8-point scale, and d)a maximum of 2.99 SLDs per 100 syllables. At the time of the present investigation, all recovered subjects had 24 consecutive months of stutter-free speech. Of the 20 subjects who were considered to be recovered, 8 were used for the present investigation who matched most closely with the persistent group for age of onset, chronological age, and sex.

There were 7 boys and 1 girl in the persistent group. The age of stuttering onset for the children in the persistent group ranged from 28 to 54 months with a mean of 36.4 months. The children's age at the initial visit ranged from 33 to 65 months with a mean of 44.6 months. The post-onset time at the initial visit ranged from 3 to 16 months (m=8.25 months). Persistent subjects were monitored for a mean of 6 years (see Appendix A). For the recovered group, the age of onset ranged from 31 to 44 months with a mean of 35.3 months. Seven of the recovered subjects were boys and 1 was a girl. Their age at the initial visit ranged from 32 to 47 months with a mean of 38.25 months. The children ranged from 1 to 7 months (m=3.0 months) post-onset at the initial visit. Subjects were monitored for a mean of 2.5 years after stuttering recovery (see Appendix B). Individual subject's ages at the initial visit, months post onset at the initial visit, and age of onset can be found in Appendix D.

Sixteen control subjects were obtained from a pool of 50 subjects from the University of Illinois research project, and used for the present study. Initially, the control group consisted of 14 boys and 2 girls. Four of the control subjects did not produce any part-word repetitions, and therefore were not included in the study. The control subject's ages ranged from 27 to 63 months with a mean of 42.92 months. In order to be considered control subjects, the children had to be regarded by their parents as not having a history of stuttering or other neurologic disorders. They also were judged by 2 University of Illinois senior staff members as not exhibiting a stuttering problem, and their speech samples contained fewer than 3 SLDs per 100 syllables. Their number of SLDs ranged from .47 to 2.80, with a mean of 1.32. Twice as many control subjects were chosen due to the smaller number of disfluencies each child produced to analyze.

## Instrumentation

Conversational speech was obtained at the University of

Illinois in an IAC sound-proof room using a Crown PPC-160 cardioid microphone. The microphone was connected to a Yamaha KM608 preamplifier (mixer). The audio signal was then directed to a high quality Tascam 122 MKII stereo cassette recorder with Maxell II S-90 recording cassette tapes.

For acoustic analysis in the present study, the audio signal on tape was transmitted through a low-pass filter (Frequency Devices, model 901) with a high-frequency cutoff at 7.5 KHz to one channel of a Data Translation 2821 series analog-to-digital (A/D) converter board that interfaced with a microprocessor-based personal computer.

A software system for digital signal processing of the acoustical signal, C-Speech Version 4 (Milenkovic, 1994), was used. This program was used because of its usefulness in visualizing temporal and spectrographic properties of the acoustic speech signal. Part-word repetitions were low-pass filtered at 7.5 KHz, digitized at 20,000 samples per second, and stored on a computer disk. Acoustic measurements were made from an FFT-based spectrogram display (Milenkovic, 1994).

## Acoustic Measures

For the purpose of this study, disfluencies from the first speech sample, within 1 year of stuttering onset, were analyzed.

Ten part-word repetitions were selected for the recovered and persistent subjects. If the spectrogram was unclear due to an interfering signal, it was excluded from the study and a new repetition was chosen. All measurable part-word repetitions for each of the control subjects, ranging from 1 to 3, were used for the present study. The units were spectrographically analyzed using the C-Speech computer program. The spectrograms were first visually inspected to identify the second formant transitions. In order to increase the reliability of identification, the C-Speech software computed the center of the formants using linear prediction coefficients and traced a thin line where it judged the center to be. To further increase the reliability, data regarding F2 frequencies in target vowels in children (see Appendix E-1) was also consulted as needed to aid the author in making the final judgements of the location of the second formant.

The initial consonant to vowel transition in the first repeated portion of the part-word repetition was compared to the consonant to vowel transition in the final production of the word (e.g. b-b-but). Although true spectrograms were analyzed for the present study, idealized spectrograms are presented to provide the reader with a clear understanding of each type of F2 transition. The F2 transitions were classified into 1 of the 4 following categories:

1. Absent: This was defined as a lack of acoustic energy between the consonant to vowel in the repeated segment. The transition was not observed during visual examination. Figure 1 illustrates an absent transition.

2. Present/Different Direction: This was operationally defined as the presence of a consonant to vowel transition in the repeated portion that occurred in a different direction than the transition in the final production. For example, in Figure 2 the F2 transition in the repeated portion (point A to B) moves from a high to a low frequency whereas the transition in the final production (point C to D) moves from a low to a high frequency.

3. Present/Same Direction/Non-Target Frequency: This was operationally defined as the presence of a consonant to vowel transition in the repeated portion moving in the same direction as the transition in the final production but did not extend within 215 Hz of the frequency for the target vowel. For example, in Figure 3 the F2 transition in both the repeated portion (point A to B) and the final production (point C to D) moves from a low to a high frequency. The

transition in the repeated portion, however, extends to a frequency of only 1250 Hz (point B) while the target vowel is produced at 1500 Hz (point D).

Appendix E contains a table listing the formant frequencies for vowels produced by children, and also mean differences in F2 Hz between adjacent vowels. As can be seen, the mean difference between F2 vowel frequencies is 215 Hz. This value was chosen in an attempt to separate an approximation of the target vowel from the production of a different vowel.

4. Present/Same Direction/Target Frequency: This was operationally defined as the presence of a consonant to vowel transition in the repeated portion moving in the same direction as the transition in the final production, and that extended within 215 Hz of the frequency for the target vowel. For example, in Figure 4 the F2 transition in both the repeated portion (point A to B) and the final production (point C to D) moves from a low to a high frequency. In addition, the transition in the repeated portion (point B) extends within 215 Hz of the frequency for the target vowel (point D).

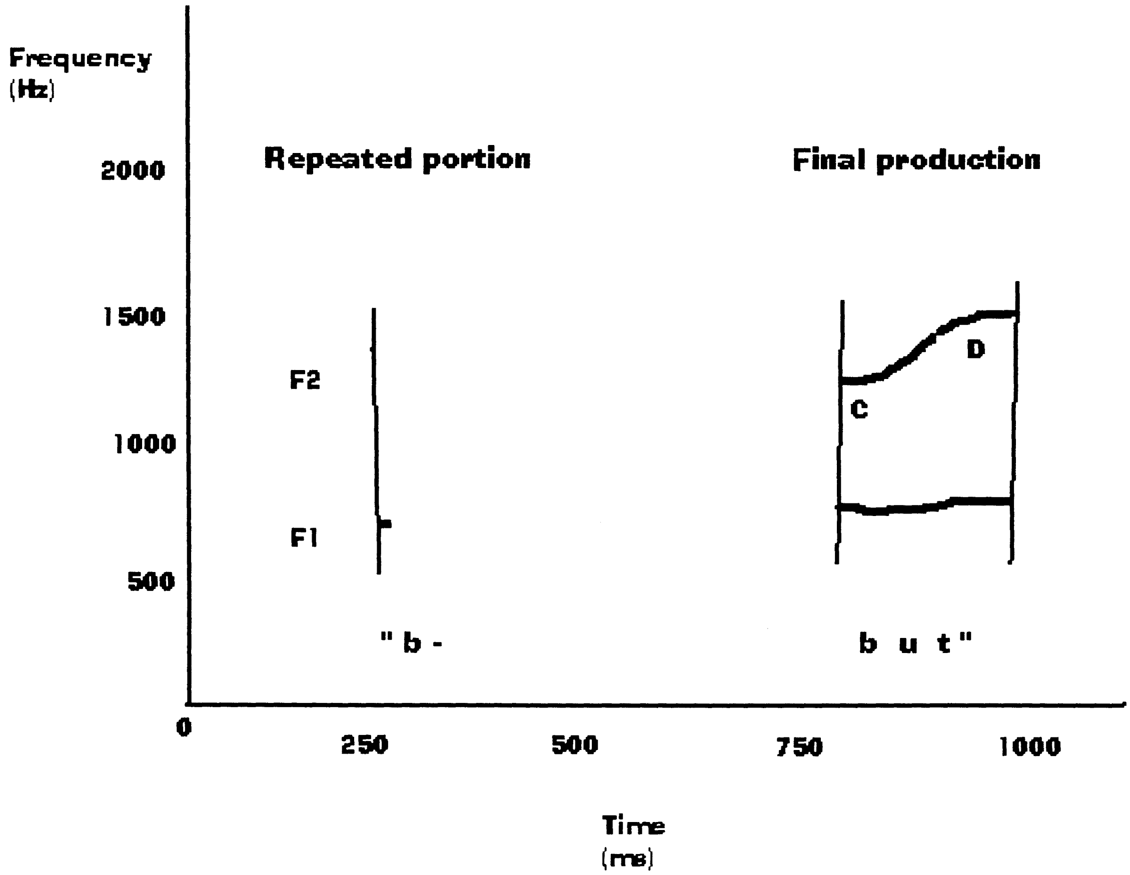



Figure 1. An example of an absent F2 transition.

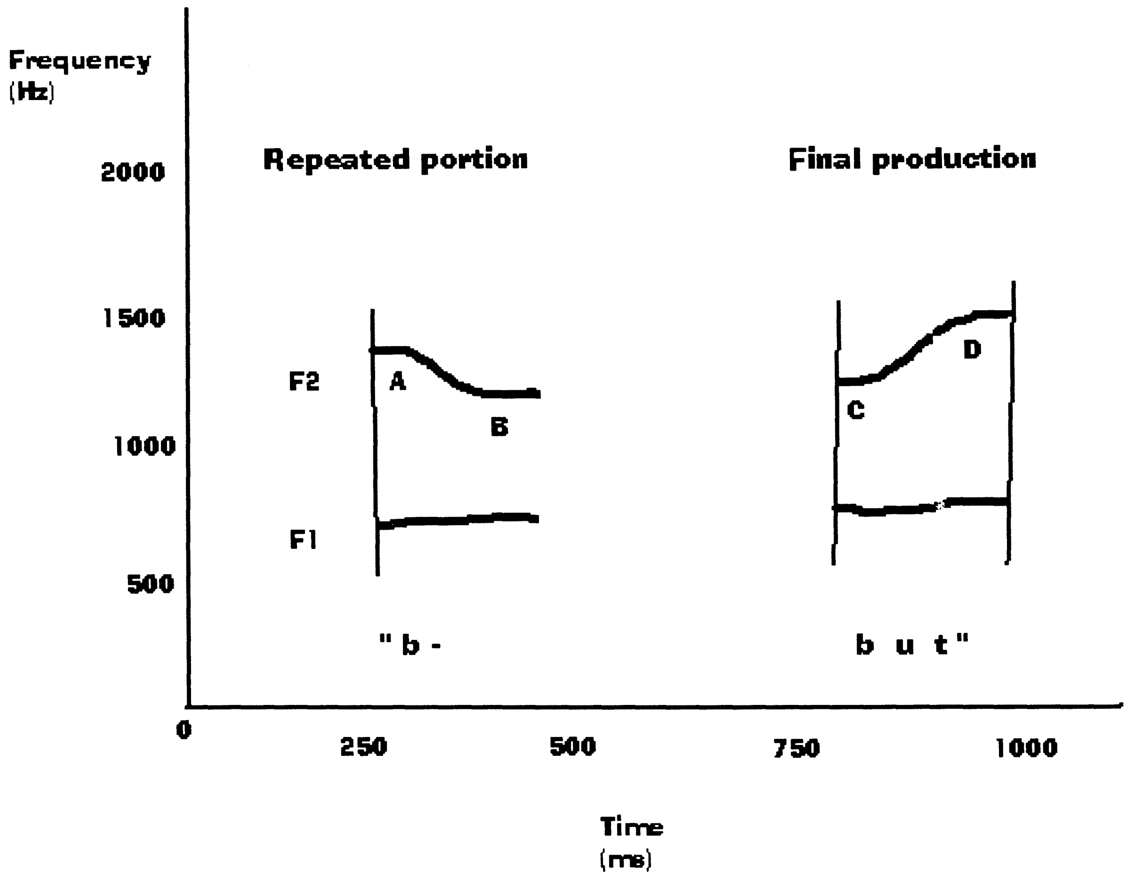



Figure 2. An example of a present/different direction F2 transition.

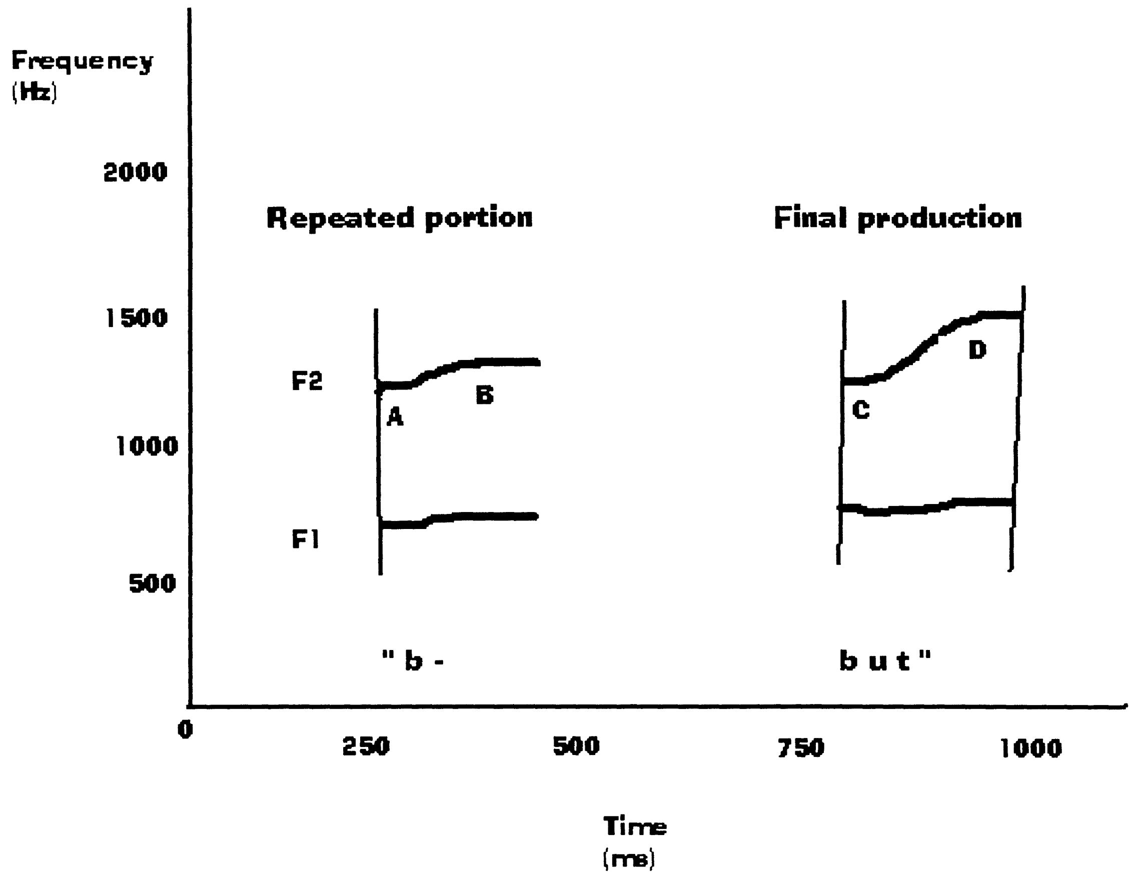



Figure 3. An example of a present/same direction/non-target frequency F2 transition.

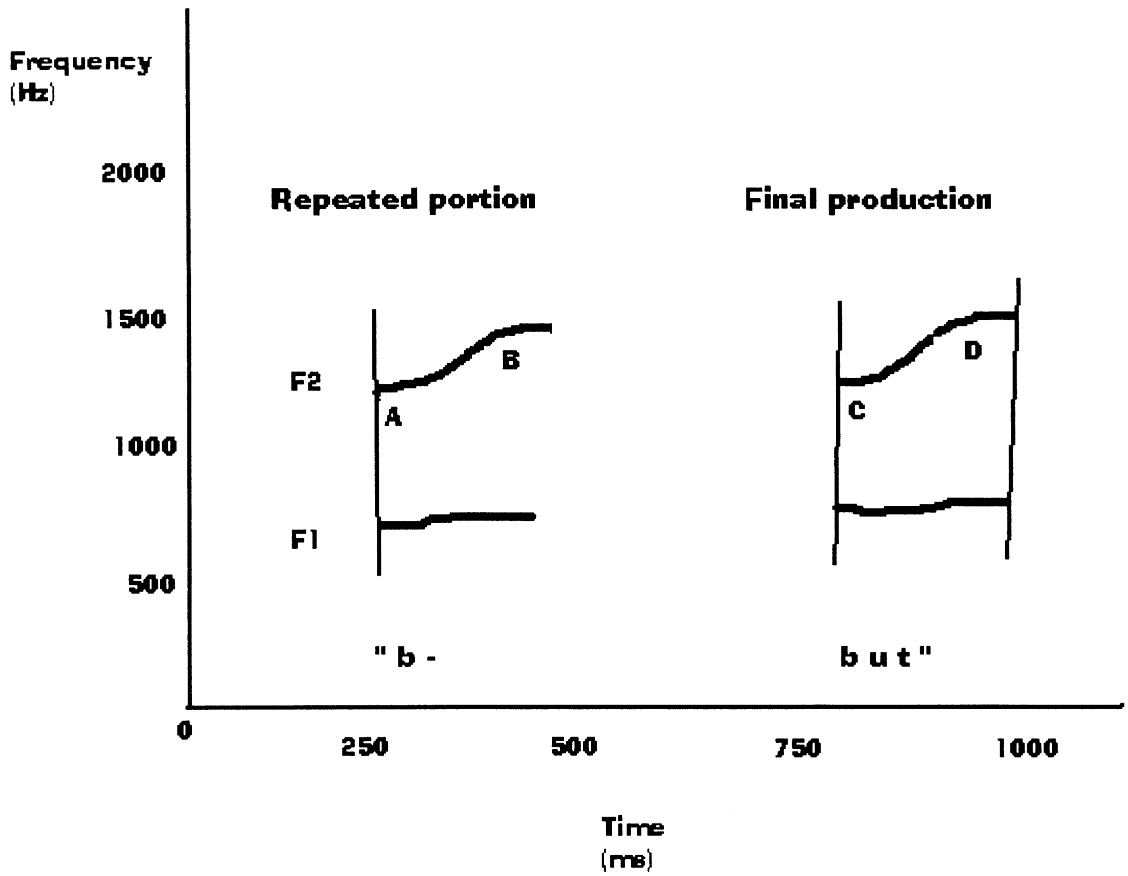



Figure 4. An example of a present/same direction/target frequency F2 transition.

## Reliability

Intrajudge reliability was estimated by the investigator reclassifying 30% of the transitions from each subject. Interjudge reliability was estimated by a second investigator classifying 30% of the transitions from each subject. Disagreements with the original classifications were marked. Average point by point reliability was calculated using Sanders (1961) Agreement Index. Reliability values were derived by totaling the number of agreements and disagreements. Total agreements were divided by total agreements plus disagreements, with a resulting intrajudge reliability of 94.3% and interjudge reliability of 84.9%. Instances of disagreement were resolved through repeated viewings of the spectrogram by the two judges together until mutual agreement was achieved.

## Statistical Treatment

The number of F2 transitions produced by each subject in each of the 4 categories (i.e. absent, present/different direction, present/same direction/non-target frequency, present/same direction/target frequency) was totaled. Due to the proportional nature of the data, arcsin transformations were performed prior to statistical analysis. In order to evaluate the statistical significance of differences among the 3 groups, in the distribution of the 4 categories of F2 transitions, a one-way analysis of variance was performed on the combined proportional data. The .05 level of confidence was used to determine statistically significant differences. The Tukey HSD multiple comparisons post-hoc test was then performed to inspect where the significant differences occurred between each pair of comparison measures.

# CHAPTER IV

## Results

The disfluent speech of 8 recovered and 8 persistent childhood stutterers, determined longitudinally, as well as that of 12 control subjects were analyzed. Ten part-word repetitions were randomly chosen for each child in the persistent and recovered groups. All part-word repetitions produced by each control subject, ranging from 1 to 3 repetitive units, were analyzed. The second formant transitions in the part-word repetitions were categorized into 4 groups: a) absent, b) present/different direction, c) present/same direction/non-target frequency, or d) present/same direction/target frequency as previously described. The number of F2 transitions produced by each subject in each of the 4 categories was totaled. The distribution of the F2 transitions into the 4 categories was analyzed statistically to determine if significant differences existed between the persistent, recovered, and control groups.

In the first step of data summary, group totals and means for direction and extent of F2 transitions were calculated. Group data were compiled for the control subjects and subgroups of stutterers by calculating mean occurrences for presence and direction of F2 transitions (e.g. absent, present/different direction, present/same direction/non-target frequency, present/same direction/target frequency). The mean for production of absent transitions was 2.0 for persistent subjects, 1.5 for recovered subjects, and .00 for control subjects. As indicated by these results, the persistent subjects had the highest number of absent transitions, while control subjects did not produce any absent transitions. The highest mean for production of present/different direction transitions was for recovered subjects (5.88) although persistent subjects produced a comparable amount (5.50). Control subjects produced considerably fewer present/different direction transitions (.83). The most similar means were observed in the production of present/same direction/non-target frequency transitions by the persistent (.63), recovered (.38), and control (.33) subjects. Recovered subjects had the largest mean (2.25) for production of present/same direction/target frequency transitions followed by persistent (1.88) and control (.33) subjects. It is interesting to note that 3 persistent subjects produced 3-4 repetition transitions classified as present/same direction/target frequency. Additionally, as previously stated, none of the control subjects produced any absent transitions. Individual subject data as well as means for each group are presented in

Appendix F.

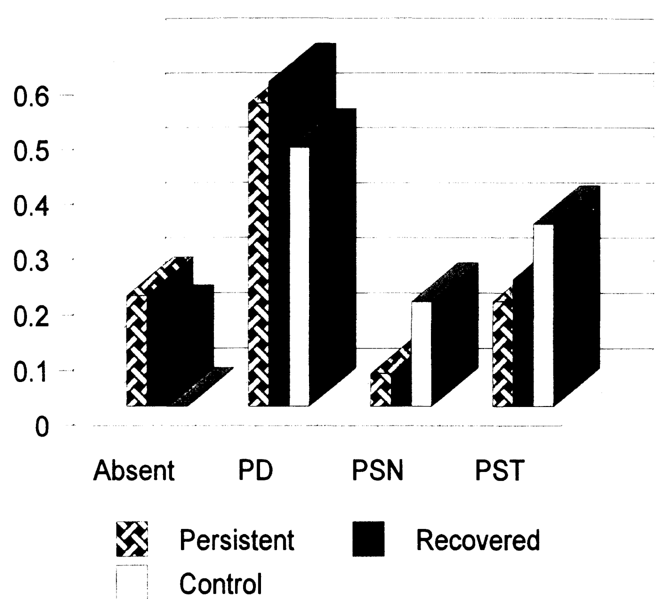
Equal numbers of transitions were analyzed for the recovered and persistent groups. Subjects in the control group, however, produced significantly fewer part-word repetitions than either of the stuttering groups. Consequently fewer transitions were available for analysis for the control group. In an attempt to weight all transitions produced by the 3 subject groups equally, the proportion rather than the actual number of transitions was calculated. The proportion of each type of transition compared to total transitions produced was calculated for each individual, and the group mean was then computed (see Table 1 and Figure 5).

Table 1

Mean proportions and standard deviations (SD) for the four types of F2 transitions for the recovered, persistent, and control groups.

| Group | Absent (A) | Present/Different (PD) | Present/Same Non-Target (PSN) | Present/ Same/ Target (PST) |
|---|---|---|---|---|
| Persistent | .20 | .55 | .06 | .19 |
| S.D. | (.12) | (.15) | (.09) | (.14) |
| Recovered | .15 | .59 | .04 | .23 |
| S.D. | (.13) | (.10) | (.07) | (.07) |
| Control | .00 | .47 | .19 | .33 |
| S.D. | (.00) | (.50) | (.39) | (.49) |

Figure 5. Proportion of F2 transitions produced by each group.




Note. (PD) Present/Different Direction; (PSN) Present/Same Direction/Non-Target Frequency; (PST) Present/Same Direction/Target Frequency.

As Table 1 and Figure 5 illustrate, persistent subjects produced more absent transitions (.20) than the other 2 groups. The largest proportion of transitions produced by all 3 groups were categorized as present/different direction (PD). Control subjects produced a larger proportion of present/same direction/non-target (PSN) and present/same direction/target frequency (PST) transitions than the subjects who stuttered. Overall, the distribution of F2 transitions appeared to be the most similar between the persistent and recovered groups.

Due to the proportional nature of the data, arcsin transformations were performed prior to statistical analysis. A one-way analysis of variance was performed on the combined proportional data for all subjects (N=28). A significant main effect was found for the number of absent F2 transitions produced (F=12.15; df=2; p=.0002). A Tukey HSD multiple comparisons post-hoc test revealed significant differences between the control (mean=.00) and persistent (mean=.20) groups, and the control and recovered (mean=.15) groups. No statistically significant differences were found between groups for the number of present/different direction (F=.1381; df=2; p=.8717), present/same direction/non-target frequency (F=1.1989; df=2; p=.3183), or present/same direction/target frequency (F=1.2673; df=2; p=.2991) transitions produced.

# CHAPTER V

## Discussion

The purpose of the present study was to investigate the use of second formant transition presence and direction for early differentiation of young beginning stutterers who eventually recover from those who will persist in stuttering. Further, the study examined how the recovered and persistent groups compared to a control group.

In general, the results indicated that the second formant transition direction and extent occurred in similar proportions between the 2 groups of children who stuttered. Present/different direction (PD) transitions were the most frequently produced by all 3 groups. The 2 groups who stuttered produced significantly more absent transitions than the control group. The control group produced more present same direction transitions (both target and non-target) than the 2 groups who stuttered.

The results of the present study do not support those obtained in Stromsta's (1965) study. Stromsta's longitudinal study determined that 89% of the children who showed abnormal transitions and abnormal terminations of phonation were still stuttering after a 10 year period while those who had normal transitions and terminations of phonation had recovered. Stromsta provided no specific criteria for distinguishing a normal from an abnormal F2 transition. Therefore, his study may have used additional factors to determine abnormality other than the method of F2 transition classification by presence and direction which was analyzed in the present study.

Although Stromsta's writing was not clear, conversations with him (Dell, 1972) revealed that he believed the acoustic differences in disfluent speech of persistent and recovered stutterers were evident in the second formant of the vowel. He discussed differences in terms of vowel duration. He speculated that an abrupt vowel was characteristic of a persistent stutterer, whereas a vowel of longer duration was indicative of a child who would recover from stuttering. Examination of the whole second formant, including the transition and the vowel, may show differences between the disfluent speech of persistent and recovered childhood stutterers.

The present study may have yielded results more similar to those obtained by Stromsta (1965) if the recovered and persistent subjects were determined after a more lengthy longitudinal study. Subjects for the present study were labeled as persistent after a minimum period of 3.7 years and a maximum of 9.0 years (mean=6.0

years) (see Appendix A) while Stromsta confirmed persistence after 10 years. Recovery from stuttering may occur in the future for some subjects classified as persistent in the present study.

Another factor which may have caused the discrepancies between Stromsta's results and the present study's findings was the duration since stuttering onset. Stromsta did not state the length of time his subjects had been stuttering when first examined, whereas subjects for the present study were within 1 year of stuttering onset. Investigations of the course of early stuttering have suggested that distinctions between persistent and recovered subjects may become apparent by approximately 18-20 months post-onset (Yairi & Ambrose, 1992a). Results of the present study are consistent with two recent studies (Throneburg & Yairi, 1994; Throneburg, 1997). These studies indicated durational disfluency characteristics differentiated stutterers from control subjects, but not persistent from recovered subjects within 1 year of onset. The Throneburg (1997) investigation provided evidence that durational disfluency characteristics of recovered subjects only became similar to control subjects as time progressed. Therefore, the difference between the present study and Stromsta's data may have resulted because examination of his subjects may have occurred after the course of recovery had begun.

The results of the current study seem to support the data obtained by Yaruss and Conture (1993). Neither study found a statistically significant difference in the number of present/same direction and present/different direction transitions between the recovered and persistent groups. However, these two studies have some distinct differences. One difference between the studies was that Yaruss and Conture (1993) divided subjects into high- and low-risk groups for chronicity using the Stuttering Prediction Instrument for Young Children (Riley, 1981), whereas subjects for the present study were divided into recovered and persistent groups as determined by a prior longitudinal study. Another difference was that Yaruss and Conture (1993) found that both the recovered and persistent subjects produced the highest number of transitions in the present/same direction category while the present study found the greatest number of transitions occurred in the present/different direction category.

Another study related to the present research was performed by Kowalczyk and Yairi (1996). They investigated the use of F2 transition rate in fluent speech of stuttering and nonstuttering subjects to determine stuttering chronicity. Results of the study indicated that transition rate was a useful predictor of stuttering persistence/recovery. Transition rate was calculated by computing the ratio of change in frequency over time. The study did not determine whether the duration or the change in frequency (i.e. transition extent) had a greater impact on the data since different values could result in the same ratios. The present study measured transition extent by classifying transitions as non-target or target frequency. Since no significant differences were found between the subject groups in the number of non-target and target frequency transitions produced, significant differences in the duration of transitions produced might be expected.

The present study has several strengths. Subjects were determined to be recovered from or persistent in stuttering through a previous longitudinal study which followed the children for up to 9 years. In addition, more part-word repetitions were measured than in the Yaruss and Conture study (1993). Specific criteria for classifying transitions by direction was provided so replications would be possible. Objectivity of data measurement was increased by using C-Speech software which computed the center of formants using linear prediction coefficients and traced a thin line through the second formant.

Although the present study was characterized by several improvements to facilitate more reliable and accurate data, some areas could be improved further. The F2 classification system may not have been sensitive enough to detect differences between early childhood stutterers. More specifically, measurement of F2 transition did not allow for such factors as abrupt vowel termination or misarticulation. Another measure of F2 transition characteristics, such as slope, may result in distinction. Robb and Blomgren (1997) found significant differences in fluent F2 transition slopes between adult stutterers and control subjects.

Another area that may have affected the results was that of instrumentation. Possible instrumental bias such as filtering and sampling may have influenced the output spectrum (Kent & Read, 1992). That is, representation of the real acoustic properties is not always accurate. Regardless of instrumentation problems, researchers know that the acoustic output of speech does not accurately represent the acoustic properties of the vocal tract. For example, formant frequencies (poles) and zeros (i.e. opposition to sound transmission) may cancel each other when they have the same frequency and bandwidth. This results in a loss of information.

Results also may have been limited due to a small number of subjects in each group. A larger pool of subjects is likely to more accurately reflect trends of the population.

Using repetitions which occur on the same phoneme for all groups might yield more significant results. The place of articulation in the oral cavity affects the F2 values. In this study, considerable variation in the extent of F2 transitions existed because of the open set of words analyzed. Some words required a large change in the F2 value from the consonant to the vowel (e.g. /w/-600 Hz to /i/-2200 Hz) whereas other productions required less F2 change (e.g. /k/-2350 Hz to /i/-2200 Hz) (Kent & Read, 1992). The Kowalczyk and Yairi (1996) study that found significant differences between persistent and recovered subjects' fluent F2 productions analyzed the same set of words produced by the subjects in a structured task.

Although no differences were found between the persistent and recovered childhood stutterers, the present study provided valuable information. Investigations using acoustic measures are promising and should be pursued. Examination of the entire second formant, including the transition and the vowel, seems to hold a high probability for predicting stuttering chronicity. This measure would be more likely to account for factors such as abrupt vowel termination and misarticulation which were not included in the present study. Future research should continue the pursuit of an objective method for early differentiation of childhood stutterers. As more reliable means of distinction are developed, stuttering therapy can be provided with confidence for only those children who will benefit.

# Appendix A

## Duration of Stuttering

## for Persistent Subjects

Table A-1
Length of time individual persistent subjects were monitored.

| Subject | Years |
|---|---|
| E02 | 9.0 |
| E09 | 5.3 |
| E23 | 3.7 |
| E55 | 5.3 |
| E56 | 6.9 |
| E59 | 6.7 |
| E60 | 6.3 |
| E73 | 4.6 |
| Mean | 6.0 |

# Appendix B

# Stuttering Duration

# for Recovered Subjects

Table B-1

Stuttering duration and length of time monitored post-recovery.

| Subject | Duration of Stuttering (Number of Years) | Time Monitored Post-Recovery |
|---|---|---|
| E33 | 2.2 | 2.5 |
| E34 | 1.4 | 2.8 |
| E39 | 1.8 | 2.3 |
| E46 | 1.1 | 3.0 |
| E57 | 3.5 | 0.0 |
| E64 | 1.3 | 3.3 |
| E65 | 1.8 | 2.6 |
| E69 | 1.0 | 3.3 |
| Mean | 1.8 | 2.5 |

# Appendix C

## Stuttering-Like Disfluency Categories

Stuttering-Like Disfluency Categories (Yairi & Ambrose, 1992a, 1992b)

A. Part-word repetition. Repetition of sounds or syllables, containing no more than one vowel nucleus. Repetition must be contiguous with the whole word.

Example: t-t-toy

B. Monosyllabic-word repetition. Repetition of whole, single syllable words. A word repeated for emphasis or intentionally is not counted as a repetition. Repetition must be contiguous. Interposition of interjection or other sound cannot occur between elements.

Example: but-but-but

C. Disrhythmic phonation. Fixation, or audible or inaudible abnormal prolongation of a sound, also referred to as prolongations and blocks.

Examples: wwwwwwwent, ----go

# Appendix D

## Individual Subject Information

Table D-1
Individual persistent subject's chronological age at visit one and at stuttering onset, and months post-onset at visit one.

| Subject | Chronological Age at V1 | Age of Onset | Months Post Onset at V1 |
|---|---|---|---|
| E02 | 47.00 | 38.00 | 9.00 |
| E09 | 42.00 | 33.00 | 9.00 |
| E23 | 33.00 | 28.00 | 5.00 |
| E55 | 49.00 | 33.00 | 16.00 |
| E56 | 65.00 | 54.00 | 11.00 |
| E60 | 41.00 | 38.00 | 3.00 |
| E59 | 41.00 | 33.00 | 8.00 |
| E73 | 39.00 | 34.00 | 5.00 |
| Mean | 44.60 | 36.40 | 8.25 |

Table D-2

Individual recovered subject's age at visit one (V1) and at stuttering onset, and months post-onset at visit one.

| Subject | Chronological Age at V1 | Age of Onset | Months Post Onset at V1 |
|---|---|---|---|
| E33 | 38.00 | 33.00 | 5.00 |
| E34 | 36.00 | 35.00 | 1.00 |
| E39 | 32.00 | 31.00 | 1.00 |
| E46 | 32.00 | 31.00 | 1.00 |
| E57 | 39.00 | 36.00 | 3.00 |
| E64 | 44.00 | 37.00 | 7.00 |
| E65 | 38.00 | 35.00 | 3.00 |
| E69 | 47.00 | 44.00 | 3.00 |
| Mean | 38.25 | 35.30 | 3.00 |

Table D-3

Individual control subject's chronological age at visit one and at stuttering onset, and months post-onset at visit one.

| Subject | Chronological Age at V1 |
|---|---|
| C01 | 58.00 |
| C02 | 47.00 |
| C09 | 41.00 |
| C16 | 27.00 |
| C22 | 43.00 |
| C23 | 31.00 |
| C26 | 54.00 |
| C29 | 38.00 |
| C34 | 38.00 |
| C42 | 63.00 |
| C49 | 29.00 |
| C51 | 46.00 |
| Mean | 42.92 |

# Appendix E

## Formant Frequencies for Vowels Produced by Children

Table E-1
Formant frequencies in Hz for vowels produced by children (Kent, 1992).

| Vowel | F1 | F2 | F3 |
|---|---|---|---|
| /i/ | 370 | 3200 | 3700 |
| /I/ | 530 | 2750 | 3600 |
| /ɛ/ | 700 | 2600 | 3550 |
| / / | 1000 | 2300 | 3300 |
| /ɑ/ | 1030 | 1350 | 3200 |
| /ɔ/ | 680 | 1050 | 3200 |
| /ʊ/ | 560 | 1400 | 3300 |
| /u/ | 430 | 1150 | 3250 |
| /ʌ/ | 850 | 1600 | 3350 |
| /ɝ/ | 560 | 1650 | 2150 |

Table E-2
Mean differences in F2 Hz between adjacent vowels.

| Vowels | Mean Differences (Hz) |
|---|---|
| ɔ-u | 100 |
| u-ɑ | 200 |
| ɑ-ʊ | 50 |
| ʊ-ʌ | 200 |
| ʌ-ɝ | 50 |
| ɝ-ə | 250 |
| ə- | 400 |
| -ɛ | 300 |
| ɛ-I | 150 |
| I-i | 450 |
| Mean | 215 |

# Appendix F

## Individual Subject Data and Means for Number of Transitions Produced

Table F-1

Individual persistent subjects' number of transitions produced in each category.

| Subject | Absent | Present/ Different | Present/Same Non-Target | Present/Same Target |
|---|---|---|---|---|
| E09 | 1 | 6 | 2 | 1 |
| E23 | 3 | 5 | 2 | 0 |
| E73 | 2 | 5 | 0 | 3 |
| E55 | 1 | 5 | 0 | 4 |
| E56 | 1 | 8 | 0 | 1 |
| E59 | 3 | 3 | 1 | 3 |
| E60 | 1 | 7 | 0 | 2 |
| E02 | 4 | 5 | 0 | 1 |
| Mean | 2.00 | 5.50 | .63 | 1.88 |

Table F-2

Individual recovered subjects' number of transitions produced in each category.

| Subject | Absent | Present/ Different | Present/Same Non-Target | Present/Same Target |
|---|---|---|---|---|
| E64 | 2 | 6 | 0 | 2 |
| E57 | 1 | 6 | 0 | 3 |
| E65 | 2 | 5 | 0 | 3 |
| E46 | 0 | 6 | 2 | 2 |
| E34 | 2 | 7 | 0 | 1 |
| E33 | 4 | 4 | 0 | 2 |
| E69 | 0 | 6 | 1 | 3 |
| E39 | 1 | 7 | 0 | 3 |
| Mean | 1.5 | 5.88 | .38 | 2.25 |

Table F-3
Individual control subjects' number of transitions produced in each category.

| Subject | Absent | Present/ Different | Present/Same Non-Target | Present/Same Target |
|---|---|---|---|---|
| C01 | 0 | 2 | 0 | 0 |
| C16 | 0 | 0 | 2 | 0 |
| C26 | 0 | 1 | 0 | 0 |
| C42 | 0 | 0 | 0 | 1 |
| C51 | 0 | 0 | 0 | 1 |
| C09 | 0 | 1 | 0 | 0 |
| C02 | 0 | 0 | 0 | 1 |
| C22 | 0 | 0 | 1 | 0 |
| C23 | 0 | 2 | 0 | 0 |
| C29 | 0 | 0 | 0 | 1 |
| C34 | 0 | 2 | 0 | 0 |
| C49 | 0 | 2 | 1 | 0 |
| Mean | .00 | .83 | .33 | .33 |

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