4-19-1991

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Trista Farmer
Utah State University

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Scholars' Day Paper Submission

Trista Farmer
504-04-0027

Dept. of Communicative Disorders
Area to be judged: Education
April 19, 1991

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Introduction

Stuttering is one of the most complex of all speech and language disorders (Caruso, Conture, & Colton, 1988). Understanding of its etiology and treatment is vague, yet growing. Much research is needed in the area of disfluency to increase our knowledge of the disorder and to provide a clearer picture of how to improve therapeutic intervention. Routine evaluation of disfluency typically includes the assessment of stuttering frequency and rate. However, as stated by Ingham (1984), the minimum evaluation data collected (fluency and rate) should be supplemented by the assessment of a number of additional aspects of speech quality (Ingham, 1984, cited by Franken, 1985). "When the evaluation is carried out with the intention to improve treatment practice (Ingham, 1984), then it will be obvious that overall descriptions of the speech quality will not suffice, but that elaborate descriptions of the speech quality before and after treatment are necessary (Franken, 1985)." One of the conclusions drawn from Franken's study (1985) was that acoustic measurements have proven to be sufficiently sensitive to measure the effects of stuttering treatment on a number of relevant aspects of speech quality. Some of these relevant aspects of speech quality include temporal measures of laryngeal behavior such as vowel durations, VOT (voice onset time), and voicing characteristics.

In the present study, these laryngeal behaviors in a young stutterer's fluent speech are acoustically measured and examined. The research questions address the changes that occur in the temporal characteristics of a young stutterer's fluent speech as a result of direct fluency treatment.

REVIEW OF LITERATURE

Review of Adult Measures

Metz, Onufrak, and Ogburn (1979) conducted a study in which they acoustically analyzed stutterer's speech prior to and at the termination of speech therapy. The purpose of the study was to determine whether fluency treatment affected more than just the audible fluency characteristic of the stutterers' speech. The speech of nine adult stutterers was acoustically analyzed before and after a modified Van Riperian (1973) stuttering treatment program (Metz et al., 1979). Treatment sessions were held daily for a period of six weeks. The subjects were taught to anticipate the moment of stuttering, to slowly initiate phonation and maintain a forward flow of air when a stuttering moment was anticipated, and to reduce their rate of articulation (Metz et al., 1979). Stimulus materials to elicit the speech samples used for measurement purposes consisted of an 800 word prose passage in which 18 CVC target words were embedded in the last 400 words. The acoustic variables analyzed included (1) stuttering frequency, (2) reading rate, (3) vowel duration, and (4) voicing through stop consonants. Results were summarized by the authors, "At the end of the six-week treatment program, the subjects' stuttering frequency had significantly decreased and reading rate had nonsignificantly decreased. Vowel duration and the occurrence of voicing through stop consonants had significantly increased (Metz et al., 1979, p.252)." These results indicate that treatment has an effect on selected temporal characteristics of stutterers' speech, that their speech should be fully evaluated both prior to and at the termination of treatment, and that continued research of stutterers' pre- and posttreatment fluent speech appears warranted.

A similar experiment was conducted by Metz, Samar, and Sacco (1983) a few years later. Their study was entitled "Acoustic Analysis of Stutterer's Fluent Speech Before and After Therapy." The purpose of the study was to examine the relationship between nine selected acoustic variables and stuttering frequency. The speech of fourteen adult stutterers was acoustically analyzed and their frequency of stuttering was calculated prior to and at the termination of a stuttering treatment program. The subjects received both group and individual treatment daily for five weeks. Treatment was based on a Van Riperian (1973) approach. Stimulus materials consisted of a 1,000 word prose passage in which 16 CVC target words were located in the middle of the passage. In addition, each subject read a list of twenty-four monosyllabic words (CV), half of which contained initial voiced consonants while the other half contained initial voiceless consonants. The subjects' stuttering frequency was determined both before and after treatment. This measure was compared to nine acoustic characteristics, which were also calculated before and after treatment. These variables included:

(1) VOT-voiceless stops
(2) voicing-voiceless stop intervocalic intervals
(3) frication-voiceless stop intervocalic intervals
(4) silence-voiceless stop consonant intervocalic intervals
(5) VOT-voiced stops
(6) voicing-voiced stop intervocalic intervals
(7) frication-voiced stop intervocalic intervals
(8) silence-voiced stop intervocalic intervals
(9) vowel duration

As stated by the authors, "Results indicated a significant and dramatic decrease in stuttering frequency between the pre- and posttest. Furthermore, both voiceless and voiced VOT duration and vowel duration significantly increased following treatment. Of the intervocalic interval parameters, frication duration significantly increased during production of voiceless stop consonant intervocalic intervals and voicing duration significantly increased during production of voiced stop consonant intervocalic intervals (Metz et al., 1983, p. 533)." These results indicate that decreases in the duration of silence in the stutterers' fluent speech relates to decreases in their disfluency. These findings suggest that improvements in fluency are associated with manipulations which reduce or regularize the duration of silent hesitations in stutterers' speech to approximate normal limits (Metz et al., 1983, p. 536).

A study by Adams, Freeman, and Conture (1984) examined the laryngeal dynamics of stutterers. Three of the variables researched in their study were the stutterers' VOT (voice onset), VIT (voice initiation), and SIT (speech initiation) times. Researchers examined the past findings of seventeen different studies which had tested these variables. Adams et al. (1984) drew their conclusions based on the combined findings of all the experimenters. The research revealed that stutterers as a group are likely to have slower VOTs (voice onset time) and VITs/SITs (voice initiation time/speech initiation time) than normal subjects. These conclusions were based on the findings of the following researchers as reported by Adams et al. (1984): Agnello & Wingate (1972); Wendell (1973); Hillman & Glibert (1977); Zimmerman (1980); Hayden (1975); Adams & Hayden (1976); Starkweather, Hirschman, & Tannenbaum (1976); Reardon (1977); Cross, Shadden & Luper (1979); Cross & Luper (1979); Cross & Cooke (1979); Alder & Starkweather (1979); Cullinan & Springer (1980); McFarlane & Shipley (1981); Reich, Till, & Goldsmith (1981); and Hayden, Adams, & Jordahl (1982). All these researcherss found that stutterers have longer (slower) voice onset time scores than normally speaking children. Adams et al. (1984) also drew conclusions on the VOT/VIT/SIT measures in children. For a description of these conclusions, refer to the section of this study entitled "Review of Child Measures."

In 1985, Webster, Morgan, and Cannon (1987) presented a study entitled "Voice Onset Abruptness in Stutterers Before and

After Therapy," at a conference on Speech Motor Dynamics in Stuttering held at the University of Nijmegen in the Netherlands. The purpose of the study was to assess the extent to which certain fluency generating target behaviors were acquired by participants in the 'Precision Fluency Shaping Program (Webster, 1974).' In order to conduct this experiment, speech samples of ten adult stutterers were recorded prior to treatment, at specified points during treatment, and at the conclusion of the treatment program. Treatment sessions were held over a three-week time period. Stimulus materials consisted of ten monosyllabic words (VC), which the subjects read from cards. The fluent productions were collected and spectrographically analyzed seven different times over the course of the stutterers' treatment. The acoustic variable which the researchers examined was voice onset time. Results demonstrated "that the voice onset index increased significantly for stutterers at two-second syllable durations when compared with pretreatment utterances (Webster, et al., 1987, p.302)." In other words, voice onsets became more gentle.

Additional research has been conducted in the area of acoustic measurement of stutterers' speech. Several studies which compare the speech of stutterers to the speech of nonstutterers have been conducted. Most of these studies have concluded that stutterers have different speech characteristics than nonstutterers.

For example, Klich and May (1982) found stutterers' vowel production to be more restricted, both spatially and temporally, from the vowel production of nonstutterers. Metz, Conture, and Caruso (1979) found that stutterers' VOT during fluency was within normal limits and was of little assistance in distinguishing between stutterers and nonstutterers. Results from a study by Adams and Ramig (1980) showed that during choral reading, normal speakers increase vowel duration by a statistically insignificant amount, while stutterers significantly shortened theirs. Peters, Hulstijn, and Starkweather (1989) found that the reaction times of stutterers and nonstutterers were both increased by longer utterances and that the effect was proportionally greater for the stutterers. A study by Shaferskupper and Dames (1987) revealed that stutterers had longer reading times than the nonstutterers, but about the same articulation times. In addition, they found that stutterers tended to equalize their syllable durations. Most of these studies show a consistent finding -- that the speech of stutterers has different characteristics than the speech of nonstutterers.

Review of Child Measures

Caruso, Conture, and Colton (1988) conducted an extensive study entitled "Selected Temporal Parameters of Coordination Associated with Stuttering in Children." The purpose of the study was to describe specific temporal parameters of coordination - sequencing of muscle activity and structural movement - associated with five young stutterers' stuttered and five normally fluent children's fluent speech productions (Caruso et al., 1988). The median age of the five young stutterers was 5 years, 0 months (range 3;6 - 6;8) and the median age of the normally fluent children was 4 years 8 months (range 3;6 - 6;5). Recordings of physiological events in the three major components of the speech production system (respiratory, laryngeal, and supralaryngeal) were made. Variables measured included offsets, onsets, and durations of movements. Measurements were obtained to allow a comparison of the physiological behaviors within a particular component of the speech production system and between different components of the speech production system. The results of the study indicated that "certain temporal parameters of coordination during young stutterers' stutterings are impressively similar to those associated with normal fluent youngsters fluent productions (Caruso et al., 1988, p. 76)." These findings suggest that young stutterers are within normal limits with regard to selected temporal aspects of coordination for speech production.

A study by Adams, Freeman, and Conture (1984) examined the laryngeal dynamics of stutterers. From the results of past studies, Adams et al. (1984) studied the VOT/VIT/SIT measures of young stutterers. Adams et al. (1984) reported the findings of several researchers, including the findings of Wendell (1973) and Cross & Luper (1979). Both Wedell (1973) and Cross and Luper

(1979) found that young stutterers were likely to have slower VOTs (voice onset time) and VITs/SITs (voice initiation time/speech initiation time) than normal subjects. It was also found that young stutterers had less muscular tension in their speech acts than adult stutterers. The authors quoted Wendell (1973) by stating, "Both VOT and VIT scores for young stutterers were slower than those of control subjects (Wendell, 1973, cited by Adams et al., 1984, p. 101)."

A study by Schwartz (1987), "Subgrouping Young Stutterers," examined the temporal onsets of speech physiology associated with stuttering to determine if the temporal aspects of speech physiology (ie, respiratory activity, lip muscle movement, vocal fold initiation, etc.) further differentiate among behavioral subgroups. The behavioral subgroups were described as a classification of stutterers based upon audible characteristics of stutterers' speech such as speech disfluency type, number, and variety of associated behaviors. Schwartz physiologically examined the speech of fifteen young stutterers, whose mean age was 5 years, 7 months (range 3;10 - 7;5). The study resulted in the conclusion that the onsets of speech physiology (ie, respiratory activity, lip muscle activity, vocal fold initiation of phonation) associated with stuttering did not differentiate among the behavioral subgroups of stutterers.

McGee, Hutchinson, and Deputy (1981) conducted a study in which they examined the influence of the onset of phonation on the frequency of disfluency among children who stutter (McGee.

Hutchinson, and Deputy, 1981). This study was designed to assess the on-off voice adjustments on the frequency of stuttering in young stutterers. Fifteen school-aged stutterers were asked to read two passages, one that contained a normal distribution of voiced and voiceless sounds, and another that contained primarily voiceless sounds. In a similar study by Adams and Reis (1971, 1974) conducted on adult subjects, it was found that stutterers evidenced much greater stuttering and comparatively more gradual adaptation while reading the passage containing both voiced and voiceless phonemes (McGee et al, 1981, p. 269). However, results of the study by McGee et al. revealed that children did not stutter less nor adapt more rapidly with the all-voiced passage as compared with the passage which contained both voiced and voiceless phonemes.

Problems with Available Measures

A review of similar studies conducted in the area of analysis of the acoustic characteristics of a stutterers' speech revealed an interesting trend. The majority of the research in the area had been conducted with adults rather than with children. "As Wall and Myers (1984) point out, the research literature are replete with descriptive as well as experimental studies of older, adult stutterers. Consequently, this same literature contains very little factual information regarding young stutterers' speech production (Conture, 1987)."

Conture points out that this trend is unfortunate in that by studying adult stutterers rather than child stutterers, researchers are missing an opportunity for obtaining more valid results. This is due to the fact that young stutterers are closer to the onset of their stuttering problem and thus exhibit behavior which is less "contaminated" by the learned reactions and adjustments typically developed by adult stutterers (Conture, 1987).

Yet, even when examining a sample of young stutterers, the question still remains - are the deviant acoustic and physiological characteristics of a young stutterer's speech the actual underlying condition, or are they due to the child's reaction to his/her stuttering? According to Schwartz (1987), if we view variation in speech physiology data as being related to each child's ability to produce speech and his/her adaptation strategy for coping with communicative and environmental stress, it is possible that as the stuttering problem continues to develop, the sequence of temporal onsets of speech physiology may also be affected to some degree (p. 224). He speculates that perhaps the children's initial adaptation strategy or method of reacting to the problem may be affecting fluency type, nature, and number. If so, the adaptation strategies may also be disrupting the temporal sequence of physiological onsets associated with stuttering, ie, respiratory activity, lip muscle movement, initiation of phonation (Schwartz, 1987). This "cause versus reaction" issue is one that can only be resolved by additional research on very young stutterers and a comparison of the results with similar research on school-aged and adult stutterers.

Among the studies which examined the speech characteristics of child stutterers, most of the data had been collected on school-aged children (5 years - 11 years) rather than preschool-aged children. Again, researchers are missing an opportunity of obtaining unaffected results when they do not test very young children.

As noted earlier, the majority of the literature in this area examines adult rather than child subjects. Why does such a trend exist in the literature? A number of variables could be responsible, ranging from the likelihood of subject-induced errors to instrumental and procedural complications when working with young children.

Conture (1987) addressed the issue of the procedural challenges that accompany the study of young stutterers' speech productions. Results of the study identified specific instrumentation that could be successfully used in the assessment of physiological behaviors of speech. In addition, Conture (1987) stated, "Whatever the instrumentation, whatever the procedure, and whatever the intent of the study, objective assessment of young stutterers' speech productions will necessitate a compromise between the realities of what these youngsters can and will do, and the ideal procedures for collecting speech production data (Conture, 1985, p. 132). Table

1 provides examples of experimental difficulties due to subject-induced error.

Table 1. Some subject experimental difficulties or errors encountered during the recording of youngsters acoustic speech signal and/or speech physiology

Subject-induced errors

1. Child speaks in an extremely soft (low intensity) voice.
2. Child saliva "drool" causes surface EMG electrodes to fall off or become loose on the child's skin.
3. Child physically "squirms" in chair causing sensors to fall off or become loose.
4. Child becomes fatigued or uncooperative and/or has trouble performing because of short attention span.
5. Child is not sufficiently "electrically quiet" during recording so that surface EMG has very high "noise" floor making determination of muscle activity during particular speech act very difficult if not impossible.
6. Child is unable to correctly and/or reliably articulate speech sounds under study.
7. Child is able to say target words or syllables but not when embedded in carrier phrase; related to this is the child who consistently truncates carrier phrase and/or seemingly can't produce the phrase.

Note: From "Studying Young Stutterers' Speech Productions: A Procedural Challenge," by E.G. Conture, 1987, in Speech Motor Dynamics in Stuttering, H. Peters and W. Hulstijn, 1987.

Even though these problems exist in research procedures involving children, it is felt that the importance of obtaining acoustic data from young stutterers outweighs the experimental difficulties.

When operating under the limited availability of research on children in this area, researchers must depend on the results of similar studies performed with adult subjects. This brings to view another problem, namely, the question of whether or not observations of adult stutterers' speech production can be extrapolated to young stutterers. The answer to this question is unknown. The issue can only be solved by additional research in the area of speech production of young stutterers and a comparison of the results to similar studies on adults. Meanwhile, results of the adult-based studies can be used only as a general guide rather than an absolute when conducting similar studies with children.

Another problem that exists among the child-based literature is that no research has been conducted that tests acoustic measures of a young stutterer's speech before and after treatment. Investigations have been conducted which test selected temporal parameters of coordination in children (Caruso et al., 1988), which study classifications of young stutterers according to physiological characteristics of their speech (Schwartz, 1987), and which examine the procedural challenges of studying young stutterers speech productions (Conture, 1987), etc. However, no studies that I am aware of that use children as subjects examine acoustic measures of a stutterers' fluent speech before and after treatment. Although several studies of this nature that use adults as subjects exist, none that I am aware of use children as subjects. Due to this fact, it appears warranted that research be conducted using a study of this type -- a study that uses children as subjects and that examines the acoustic measures of their fluent speech before and after fluency treatment.

General Research Procedures

After being formally diagnosed as having a fluency disorder, a young stutterer (age 2 years, 11 months) was admitted into a direct fluency treatment program at the Utah State University Speech-Language-Hearing Center. The child's fluent speech was spectrographically analyzed before and after the eight week treatment program. This required the subject's use of target words in the sentence, "I see a __(target word)__ on a box." The words were illustrated on index cards and placed on top of a small box. The target words were analyzed for three acoustic characteristics: vowel duration, voice onset time, and the presence/absence of voicing in consonants. Results of the two testing sessions were compared to determine whether changes in laryngeal behavior occurred as a function of the treatment.

Temporal Measures Taken

Three acoustic characteristics were measured and analyzed in this study, specifically, (1) duration of vowels, (2) voice onset time, and (3) the presence/absence of voicing in consonants.

Research Questions

1. In what way is the laryngeal behavior occurring in the fluent utterances of this preschool child identified as a stutterer similar to or different from the laryngeal behavior of normally speaking preschool children?

2. Do changes in laryngeal behavior occur in a young stutterers' fluent speech as a function of fluency treatment?

    a. Does voice onset time decrease as a function of fluency treatment?
    b. Does vowel duration increase as a function of fluency treatment?
    c. Do characteristics of voicing in voiced and voiceless consonants occur as a function of fluency treatment?

METHOD

Treatment Assumption

Before being able to proceed with this study, it is necessary to justify the assumption under which this study is conducted. This study is conducted under the assumption that clinical intervention is an effective means of treating disfluency. In their research, Onslow, Costa, and Rue (1990) found that parental and clinical treatment of cases of early stuttering is an effective means of managing disfluency (p. 402). In the present study, it is assumed that the differences found between the child's pre- and posttreatment testing results are caused by one major variable -- the child's enrollment in direct fluency treatment.

Subject

The subject selected for participation in this study was a young male stutterer, age 2 years 11 months. He was selected after being formally diagnosed with disfluency at the Utah State University Speech-Language-Hearing Center. To be considered at risk for disfluency, a child must exhibit atypical speech and nonspeech behaviors (Schwartz, Sebrowski, and Conture, 1990). According to the criteria at the USU Speech-Language-Hearing Center, atypical disfluencies include one or more of the following characteristics in the child's speech: (1) part-word repetitions during which three or more units are repeated, (2) blocks, (3) audible prolongations, (4) disfluency associated physiological struggle, and (5) total number of disfluencies exceeding 8% (McKeehan, 1991). After formal evaluation, the child was determined to be within normal age limits for speech articulation, language development, hearing, and middle ear function. He had not been enrolled in direct fluency treatment prior to this study.

Treatment

After the initial diagnosis of a fluency disorder was made, the subject received individual direct fluency treatment at the Utah State University Speech-Language-Hearing clinic over an eight week time period. Sessions were held two times weekly for a period of fifty minutes each session. The child had a total of twelve treatment sessions. The procedure used generally followed the treatment procedure outlined by McKeehan (1991) in "Training Parents As Partners." The goals of treatment were to (1) facilitate understanding for parents and children regarding the nature of stuttering and to (2) elicit, practice, and normalize techniques that alter physiologic speech behaviors and allow for the development of a sense of self-control over the speech act. Table 2 summarizes the goals and activities of each phase of the treatment.

Table 2. Seven-Phase Direct Fluency Treatment

<u>Phase 1</u>

The clinician carefully models fluency facilitating speech changes (slow rate of speech, increased vowel length, linguistic simplicity) and insures that both situational and linguistic demands are low.

<u>Phase 2</u>

The clinician begins to talk about talking. Clinician notes and rewards smooth speech (ie, the child follows the adult model of slowed, shortened speech).

<u>Phase 3</u>

The clinician trains the child to discriminate bumpy from smooth speech.

<u>Phase 4</u>

Client listens to the clinician model fluent and disfluent models and specifies whether the speech is smooth or bumpy. The child then produces the same words with and without the clinician's model. Bumps are pointed out and fluency is reinforced. Parents are asked to participate in short fluency elicitation tasks during the therapy session and at home.

<u>Phase 5</u>

The clinician reinforces the client's fluent speech by returning the model. Fluency is directly elicited. The clinician sets up simple linguistic tasks, indicates that "smooth speech" will be used, and reinforces the client's use of the techniques. Parents are more involved in direct intervention.

<u>Phase 6</u>

Sessions move the child from the use of the fluency techniques in single words and phrases to short carrier sentences to other kinds of simple sentences. Clinician adjusts the linguistic demand depending on the progress of the child (increased fluency).

<u>Phase 7</u>

Sessions are designed to allow the child to self-generate, self-monitor, and self-reward bump-free speech in more normalized speech situations. Sessions are also designed to elicit and reward the child's self-generated use of bump-free speech that lasts for longer periods of time across linguistic tasks and speaking situations (McKeehan, 1991).

Note: From "Training Parents as Partners," by A. McKeehan, 1991.

Stimulus Material of Laryngeal Behavioral Analysis

Thirty monosyllabic words were selected as target words to be spectrographically displayed and analyzed for vowel duration, voice onset time, and the presence/absence of voicing in consonants. Criteria for word selection included (1) age appropriateness in both semantic and phonetic content, (2) the presence of phonetic characteristics which would contribute to occurrences of the desired temporal measures, and (3) the word's ability to be illustrated on 4 x 6 inch index cards. A list of the thirty target words is included in Table 3.

Table 3. Target Words

1. ball	11. dog	21. feather
2. cat	12. dot	22. tub
3. bat	13. baby	23. kite
4. cake	14. fish	24. key
5. bug	15. house	25. bee
6. pig	16. book	26. shoe
7. kiss	17. cup	27. dad
8. foot	18. bed	28. pot
9. vase	19. zipper	29. soap
10.teeth	20. duck	30. toe

Picture cards were created depicting drawings of the target words. The pictures were drawn on 4 x 6 inch cards and arranged to flip easily from one picture to the next.

To create a connected speech context, the subject was instructed to identify the pictures of the target words by using a carrier phrase. An appropriate context for a carrier phrase was created by placing the target word "flip chart" on top of a small cardboard box. As the subject viewed the cards, he identified the target words by using the carrier phrase, "That's a ______ on a box." For example, if the picture card displayed a dog, the response would be, "That's a dog on a box." Five to ten practice trials were performed to condition the child in the use of the carrier phrase.

Due to the fact that this study examined fluent rather than stuttered productions, the examiner persisted in eliciting the target words until a fluent production of the targeted word was obtained. Productions were perceptually judged to be fluent by the absence of (1) whole word repetitions, (2) part word repetitions, (3) prolongations (4) blocks, or (5) visual or auditory evidence of associated physiological struggle. If the child was disfluent on the target word upon the first presentation of the stimulus card, the examiner would set the card aside and present the card again upon completion of the rest of the cards. If the child was disfluent on the second presentation, the same process was repeated. If the child was disfluent on the third presentation of the card, the attempt to obtain a fluent production of that particular word was abandoned.

Recording Environment

All acoustic measures were recorded in a voice laboratory at the Utah State University Speech-Language-Hearing Center. Testing was performed before and after the subject's eight-week treatment program. Two researchers, a parent, and the child's clinician were present during the testing session. Efforts were made to create a comfortable, noninvasive testing environment for the subject.

Instrumentation

Speech samples were recorded on a Sony three head stereo tape recorder (Realistic, Solid State TC - 570) using a Kay Elemetrics microphone. The Kay Elemetrics DSP Sona-Graph 5500 produced wideband spectrographs which were used to analyze the data.

Measurement Procedures and Data Analysis

After obtaining spectrograms of the targeted speech material, the target words were analyzed for duration of vowels, voice onset time, and the presence/absence of voicing in consonants in word final positions. Only fluent productions were analyzed.

First, pretreatment and posttreatment vowel durations were determined. Vowel onset was defined as the point in time where regularly appearing vertical striations were observed in the second and higher formants following initial stop consonant release. Vowel offset was defined as the point in time when formant energy in the second and higher formants ended in association with oral occlusion of the terminal stop consonant (Peterson and Lehiste, 1960 cited by Metz, et al., 1979).

Temporal duration was calculated through manipulation of the cursors on the computerized speech spectrogram display (DSP Sona-graph, Model 5500/5500-1). The points of vowel onset and offset (according to the previously stated definitions) were determined, marked, and stored with cursors. The DSP Son-graph 5500 calculated the temporal durations in accordance with an internally programmed algorithm (FFT). Table 4 provides a brief description of how the FFT processed the data. After the DSP Sona-graph 5500 calculated temporal durations, the information (in fractions of a second) was displayed on the computer screen and recorded by the researchers.

Table 4. FFT Analysis - Transform Size

Included in the DSP Sona-graph 5500 manual is a menu of the selections for the FFT transform size. The FFT analysis process which produces the Power Spectrum and Spectrograph requires that the signal data stream is broken up into processing blocks. The Transform size selection made in the transform size menu presented the selections for transform size. The number of points in the transform determines the effective analysis filter. The transform size does not affect the waveform, amplitude display, or combination. A narrow filter (larger transform size) has better frequency resolution and a wider filter (shorter transform size) has better timing response. The analysis filter resolution and the amount of time in each transform (timing resolution) are listed in the DSP Sona-Graph 5500 operating manual (Kay Elemetrics 1989, p. 170, 171, and Appendix) The process of breaking up the data stream to blocks can cause analysis errors unless the event can be exactly positioned in the transform or a window weighting process is performed on the blocks of data. Hamming and Blackman are window weighting algorithms, named after their developers, which reduce the errors caused by the FFT. The 5500 includes this window weighting program.

Note: From the Kay Elemetrics Sona-Graph 5500/5500-1 Operating Manual, 1989, p. 170, 171).

Next, pre-and posttreatment voice onset time was analyzed. Voice onset time was defined as the time between the release of the consonant and the beginning of voicing in the vowel (Nicolosi et al., 1989). The temporal duration of voice onset time was also calculated with using cursors to mark the boundaries and the FFT algorithm described in Table 4.

Lastly, the presence/absence of voicing in final consonants was observed. The number of times voicing energy was observed where one would normally predict a high frequency burst or an acoustic gap was computed and the percentages derived. The subject's continued voicing through a consonant was characterized by clearly visible acoustic energy in the second and higher formants. Voicing energy in the stop consonant gap was differentiated from vowel energy by its weak relative amplitude (Metz et al., 1979). The occurrences of voicing of final consonants were tallied and converted to percentages then compared to the percentages computed earlier.

RESULTS

Results of Fluency Treatment

Before beginning direct fluency treatment, the subject exhibited moderate stuttering. He was disfluent on 12% of his utterances across all linguistic tasks. Disfluencies were characterized by whole and part word repetitions with an average of 4 units per repetition and a range of 2 to 17 repetitions per unit. His mother stated that this figure was not totally representative of his speech; some stuttering episodes at home were typically more severe.

At the end of the eight week treatment program, which consisted of twelve treatment sessions, the subject's frequency of stuttered speech had significantly decreased. Upon retest, he was only 3% disfluent across all linguistic tasks, showing mostly whole word and phrase repetitions with an average of 2 units per repetition. The subject's mother reported that this data was representative of his fluency behavior at home. These results indicate that after treatment, the subject's fluency behavior is within the range of normally speaking children of the same age.

Results of Spectrographic Analysis

A spectrographic analysis of the pre- and posttreatment target words revealed the following data:

Table 5. Pretreatment Testing Results

Target Word	V-less VOT	Voiced VOT Stopgap	Voiced VOT Rel.trans.	Voiced VOT Total	Vowel duration	FC Voicing errors
1. ball / bal /		.04531	.01563	.06094	.1750	dv
2. cat / [illegible] /	.1047				.3187	ok
3. bat / bæ /		.01094	.01563	.02657	.1734	del
4. cake / [illegible] /	.1219				.0516	ok
5. bug / bɔk /		.01875	.34370	.36245	.1922	dv
6. pig / pɪk /	.0828				.1625	dv
7. kiss / tɪs /	.0406				.3687	ok
8. foot / bi /		.02812	.04844	.07656	.2344	del
9. vase / ves /		.04531	.01875	.06406	.1750	ok
10. teeth / [illegible] /	.1797				.0891	ok
11. dog / dak /		.01719	.01250	.02969	.1937	dv
12. dot / dat /		.01094	.06562	.07656	.2078	ok
13. baby / pe /		.04844	.02500	.07344	.8377	--
/ pi /		.07031	.01563	.08594	.1375	--
14. fish / fɪs /	.1594				.3906	ok
15. house / [illegible] /	.8906				.5796	ok
16. book / [illegible] /		.04375	.02188	.06563	.1859	ok
17. cup / [illegible] /	.1281				.0250	ok
18. bed / bed /		.01563	.02812	.04375	.2422	ok
19. zipper / [illegible] /	.1719				.1125	ok
20. duck / dak /		.01719	.03125	.04844	.0906	ok
21. feather / [illegible] /	.1891				.2781	del
22. tub / [illegible] /	.1531				.1484	ok
23. kite / [illegible] /	.1969				.1641	ok
24. key / [illegible] /	.2156				.0781	--
25. bee / [illegible] /		.23440	.04062	.27502	.1078	--
26. shoe / [illegible] /	.1422				.3500	--
27. dad / dæd /		.02969	.03750	.06719	.2813	ok
28. pot / bat /	.0328				.1516	ok
29. soap / [illegible] /	.0250				.2141	ok
30. toe / [illegible] /	.0469				.2078	--
TOTALS	2.8813	.63597	.72027	1.35624	6.925	7 dv
AVERAGES	.1695	.04543	.05145	.09687	.2234	57%
AVE. MILLISECONDS	170	45	51	97	223	

<u>KEY</u>

V-less.................................voiceless
VOT.................................voice onset time
Rel.trans.................................release transient
FC.................................final consonant
IC.................................initial consonant
dv.................................devoiced
del.................................deleted
ok.................................no voicing error
msec.................................milliseconds

Table 6. Posttreatment Testing Results

1.	ball	/ [illegible] /		.01719	.01719	.03438	.2578	ok
2.	cat	/ [illegible] /	.1031				.2000	del
3.	bat	/ [illegible] /		.02188	.01406	.03594	.1984	del
4.	cake	/ [illegible] /	.0172				.1719	ok
5.	bug	/ [illegible] /		.01250	.02031	.03281	.1931	dv
6.	pig	/ [illegible] /	.0547				.1687	ok
7.	kiss	/ [illegible] /	.0109				.0844	ok
8.	foot	/ [illegible] /	.2031				.2422	ok
9.	vase	/ [illegible] /	.2266				.2281	ok
10.	teeth	/ [illegible] /	.0609				.1703	ok
11.	dog	/ [illegible] /		.02188	.05625	.07813	.1797	ok
12.	dot	/ [illegible] /		.01563	.01563	.03126	.2094	ok
13.	baby	/ [illegible] /		.01094	.02188	.03282	.2250	--
		/ [illegible] /		.02187	.02188	.04375	.2328	--
14.	fish	/ [illegible] /	.0718				.1156	ok
15.	house	/ [illegible] /	.0500				.2000	ok
16.	book	/ [illegible] /		.02188	.02969	.05157	.1234	ok
17.	cup	/ [illegible] /	.1719				.1687	ok
18.	bed	/ [illegible] /		.02344	.02656	.05000	.1625	ok
19.	zipper	/ [illegible] /	.0000				.1016	--
		/ [illegible] /	.0422				.0906	--
20.	duck	/ [illegible] /		.00781	.00938	.01719	.1641	ok
21.	feather	/ [illegible] /	.0641				.1000	--
		/ [illegible] /		.02031	.04060	.06091	.1922	--
22.	tub	/ [illegible] /	.0813				.1266	ok
23.	kite	/ [illegible] /	.1094				.0531	ok
24.	key	/ [illegible] /	.0328				.3328	--
25.	bee	/ [illegible] /	.0281				.1672	--
26.	shoe	/ [illegible] /	.0703				.1672	--
27.	dad	/ [illegible] /		.02500	.01406	.03906	.2234	dv
28.	pot	/ [illegible] /	.0469				.2859	del
29.	soap	/ [illegible] /	.0000				.0672	ok
30.	toe	/ [illegible] /	.0047				.2087	--
TOTALS			1.4500	.22033	.28749	.50782	5.8126	dv
AVERAGES			.0690	.01836	.02396	.04232	.1761	14%
AVE. MILLISECONDS			69	18	24	42	176	

Table 7. Pre- and posttreatment differences (in milliseconds)

Phonetic Type	VOT	Vowel Duration	Voicing
Voiced IC	-50 (-.05)	-30 (.03)	- 43% dv
Voiceless IC	-100 (-.1)	-90 (.09)	no change
Entire sample	-70 (-.07)	-50 (.05)	

Answers to Research Questions

1. In what way is the laryngeal behavior occurring in the fluent utterances of this preschool child identified as a stutterer similar to or different from the laryngeal behavior of normally speaking preschool children?

Vowel Duration

Due to a lack of normative data on the average vowel duration of normally speaking children, it was difficult to determine whether the subject differed from the norm. Kent (1976) states, "The developmental literature contains very little information even about such gross aspects of speech timing as the durations of vowels and consonants (Kent, 1976, p. 438)."

However, in a pilot study by DiSimoni (1974), approximate vowel duration of 10 normally speaking three-year-old children was found to range between 100-550 msec in duration. It is implicitly understood that the environment of the vowel affects its duration. Peterson and Lehiste (1960) have shown in adults that vowels in voiced consonant environments (as in the word bib) are of longer duration than vowels in unvoiced consonant environments. Duration of the vowel is also lengthened when in a sibilant environment as compared to a plosive one.

DiSimoni's (1974) pilot study examined these effects in the utterances of three groups of ten normally speaking children at three, six, and nine years of age. His findings indicated that while differences in consonant environment do affect vowel duration in three-year-old children, the differences did not reach statistical significance and the standard deviations were large.

The effect of environment on vowel duration is influenced by maturity and reaches significance at about 6 years of age, according to his results. When vowel duration is viewed in light of statistical non-significance between environments, the range of vowel durations found by DiSimoni fall between 100-550 msec. The means for voiceless plosives range from 230-290 msec and the means for voiced sibilants range from 350-500 msec.

In the present study, similar trends were identified. The subject's average vowel duration was longer when in a sibilant environment (181 msec) as compared to a plosive environment (166 msec). In an voiced environment, the subject's vowel duration was longer on the average (253 msec) than when in an unvoiced environment (236 msec). All of these values fall within the range identified by DiSimoni, but do fall below the mean values he reported.

During the pretreatment testing session, the subject's average vowel duration was 223 msec. This number is within the normal range. Thus, it can be concluded that the vowel durations in the fluent utterances of this disfluent preschool child were similar to the vowel durations of normal children of the same age.

Results of the posttreatment testing session showed that the subject's vowel durations were different from the vowel durations of the pretreatment testing session. During posttreatment testing, the subject's average vowel duration was slightly shorter than the pretreatment results. Average vowel duration was 176 msec at posttreatment testing, which is a difference of approximately 50 msec from the pretreatment results. The relationship between vowel duration in voiced/voiceless and plosive/sibilant environments remained consistent even though overall duration decreased. Even with this decrease in vowel duration, the child remained within the range of normal (100-550 msec) after receiving fluency treatment.

VOT

Although no standardized norms for the laryngeal behavior of normally speaking children were available in the literature, approximate normative values were described by Kent (1976). He stated that VOTs for voiced stops range from about -20 milliseconds (msec) to about +20 msec. Voiceless stops have VOTs that range from about 25 msec to as much as 100 msec.

During the pretreatment testing session, both voiceless and voiced VOT durations of the subject's' fluent speech fell outside the limits of the norms. The subject's average VOT for voiceless phonemes was 170 msec, which was outside the upper boundary of the norm (100 msec). His average VOT for voiced phonemes was 97 msec, which was also outside the upper boundary of the norm (20 msec). These figures show that this preschool child, diagnosed as a stutterer, had longer VOT durations in his fluent utterances than normally speaking preschool children. These results were consistent with the findings of Wendell (1973) and Cross & Luper (1979 as reported by Adams et al. (1984) Both these researchers found that young stutterers have longer (slower) voice onset time scores than normally speaking children.

After twelve sessions of direct fluency treatment, the temporal characteristics of this child's fluent speech had changed. Results of the posttreatment testing session showed that the subject's VOT durations were different from the results obtained on the pretreatment testing session. The subject's voiceless and voiced VOTs were significantly shorter in duration than they had been initially. After treatment they more closely resembled normally speaking children's VOT durations. On posttreatment testing, the subject's average VOT for voiced phonemes was 42 msec, which still remained outside the upper boundary of the norm (20 msec), but which was a reduction from the average voiced VOT durations from the pretreatment testing session (97 msec). His average VOT for voiceless phonemes was 69 msec, which is in the upper-middle range of the norm for normally speaking children (25-100 msec).

These results show that after twelve sessions of fluency treatment, this preschool child, identified as a stutterer, had voiced VOT durations in his fluent utterances that were approaching, but still longer in duration than the voiced VOT durations of normally speaking children. In addition, after fluency treatment, this child's voiceless VOT durations of his fluent utterances were within the normal range of normally speaking children. These results agreed with the findings of previous research.

Voicing

The voicing characteristics of this young stutterer's speech also differed from the voicing characteristics of normally speaking children. Devoicing of voiced consonants is not considered a developmental process in the sequence in which a normal child acquires speech. Yet, the subject in this study devoiced 57% of the voiced final consonants in the sample, as well as many of the initial consonants, which were not formally analyzed.

Results of the posttreatment testing session showed that the subject's voicing characteristics were different from the results obtained on the pretreatment testing session. After the twelve sessions of fluency treatment, the subject showed more normal voicing characteristics, only devoicing 14% of the final consonants in the sample, rather than 57%, as he did during pretreatment testing. This indicates that he moved toward the norm. He used the appropriate voicing in voiced consonants during the second testing session.

2. Do changes in laryngeal behavior occur in a young stutterer's fluent speech as a function of direct fluency treatment?

   a. Does voice onset time decrease as a function of fluency treatment?
   b. Do vowel duration characteristics increase as a function of fluency treatment?
   c. Do characteristics of voicing in voiced/voiceless consonants occur as a function of fluency treatment?

Changes in laryngeal behavior do occur in a young stutterer's fluent speech as a result of direct fluency treatment. The temporal values obtained on the first testing session were significantly different than the temporal values obtained on the second testing session. Many of these changes differed from the results found in studies examining changes in adult laryngeal behavior as a function of fluency treatment.

Vowel Duration

Vowel durations did not increase as a function of fluency treatment. In this case study, the subject's vowel durations slightly decreased after the eight weeks of direct fluency treatment. Before treatment, the subject's average vowel duration was 223 msec, and after treatment, his average vowel duration was 176 msec. A difference of approximately 50 msec existed between the two averages. The average vowel duration on the posttreatment testing session was about 50 msec shorter than the average vowel durations of the pretreatment testing session. This finding was a surprising one. Judging from the results of past studies (Metz et al., 1979, Metz et al., 1983) and the goals of direct fluency treatment (to lengthen vowels), vowel durations were expected to increase. Instead, vowel durations consistently decreased.

VOT

Voice onset characteristics do become shorter as a function of fluency treatment. VOT results obtained before treatment were different than the VOT results obtained after treatment. On the pretreatment testing session, the subject's average VOT for voiced phonemes was 97 msec and his average VOT for voiceless phonemes was 170 msec. On the posttreatment testing session, the subject's average VOT for voiced phonemes was 42 msec, which is a reduction of approximately 50 msec from the results of the pretreatment testing session (97 msec). His average VOT for voiceless phonemes was 69 msec, again, which was consistently shorter than the results of the pretreatment testing session (170) by approximately 100 msec. These results differed from the results of Metz et al. (1983) who found that adult stutterers' VOT durations in significantly increased as a result of treatment.

Voicing

Characteristics of voicing in voiced phonemes do occur as a result of fluency treatment. Before treatment, results showed that the subject devoiced 57% of the voiced final consonants in the sample. However, voicing errors did not occur in voiceless final consonants. The subject produced every voiceless consonant correctly, without adding extra voicing. After treatment, the subject had reduced his tendency to devoice voiced sounds. In the second sample, he devoiced 14% of the voiced sounds, which is a significant reduction from the initial devoicing figure obtained. Again, all voiceless sounds were produced appropriately. When these results were obtained, the child's file was checked to determine whether the devoicing in this child's speech had been noted in his diagnostic reports. No record of devoicing was found. Thus, it was concluded that characteristics of voicing in voiced, but not in voiceless, phonemes occurred as a result of fluency treatment.

These results agreed with previous studies which found that stutterers had a tendency to voice through intervocalic intervals of stop consonants (Metz et al., 1983), and that stutterers' voicing through stop consonants significantly increased after treatment (Metz et al., 1979). The results differed from the literature by the fact that voiceless phonemes were not affected by voicing.

Voice Onset Abruptness

During the analysis of the pretreatment data, the researcher noted four occurrences of a high intensity, solid glottal stop bar that spread across all the frequencies. This was observed twice at the onset of a vowel. Webster (1987) called this phenomena "voice onset abruptness" and analyzed it in his study of voice onset abruptness before and after therapy. Webster (1987) found that voice onsets became less abrupt after fluency treatment.

The results of the present case study were similar to Webster's (1987) results. During the posttreatment acoustic analysis, no occurrences of abrupt voice onset were observed. However, there were two cases of abrupt voice onset observed in the pretreatment analysis. Therefore, it can be concluded that voice onset became less abrupt as a result of fluency treatment.

Conclusions

The average vowel duration occurring in the fluent utterances of this preschool child identified as a stutterer was similar to the average vowel duration of normally speaking preschool children. However, the subject's average voice onset time was different than the average voice onset time of normally speaking preschool children.

Changes in laryngeal behavior occurred in this young stutterer's fluent speech as a function of direct fluency treatment. Voice onset time for both voiced and voiceless phonemes becames shorter as a function of fluency treatment. Vowel durations slightly decreased as a function of fluency treatment. Due to fluency treatment, voicing occurred in voiced consonants that had previously been devoiced. Voiceless consonants were not affected (voiced) as a function of fluency treatment. In addition, voice onset abruptness decreased as a function of fluency treatment.

Due to the fact that testing was performed on only one subject, the conclusions of this study must be interpreted with caution. The pilot nature of this study should be kept in mind. This study was not designed to conclusively answer the research questions addressed; rather, it was designed to bring these questions to the view of those who may be interested in the subject. Therefore, no implications can be generalized to other young stutterers from the results of this study. Additional research of this nature must be conducted before conclusive results can be obtained and implications can be drawn.

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