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THE EFFECTS OF DELAYED AUDITORY FEEDBACK AND MASKING
ON THE FUNDAMENTAL FREQUENCY OF
STUTTERERS AND NONSTUTTERERS

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the Degree Doctor of Philosophy in the Graduate
School of The Ohio State University

By
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The Ohio State University

1976

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CHAPTER I

INTRODUCTION

After surveying the relevant data and considering the possible bias of the reports, Young concluded that .7% of the population (school age and adult) were nonfluent speakers.¹ A projection of this

¹Martin Young, "Onset, Prevalence, and Recovery from Stuttering," J. Speech Hearing Dis., 40 (1975), 49-58.

proportion on the entire population will show that any study that has as its purpose further definition of the nature of stuttering is of potential benefit to a significant number of the members of our society.

Young (1975) in a letter to the editor in the Journal of Speech and Hearing Research commented that in the 1920's and 1930's Scripture, Travis, and others were demonstrating substantial differences in the phonatory characteristics of stutterers and nonstutterers.² He ex-

²Martin Young, "Letter to the Editor: Comment on Stuttering Frequency and the Onset of Phonation," J. Speech Hearing Res., 18 (1975), 601.

pressed regret that interest in quantifying the fundamental frequency characteristics of stutterers had waned in spite of significant improvements in equipment for extracting measures.

In a reference cited by Young, Scripture (1923) used a mouth recorder to obtain melody plots of the speech of stutterers and non-stutterers.³ He concluded that the stutterer had a monotonous voice,

³Edward W. Scripture, Stuttering, Lispings, and Correction of the Speech of the Deaf (New York: The MacMillan Company, 1923).

began and ended vowels with a glottal catch, and used a voice that was abnormally low. He proposed a therapy regimen that included training in melody and flexibility.

Subsequent to Scripture's work, Travis (1926) compared the voices of stutterers and nonstutterers in conditions which he defined as emotional, speaking while doing mental arthimetic or in the presence of threatened injury, and normal, speaking while making an habitual statement.⁴ The results showed that nonstutterers had more range in pitch in

⁴Lee Edward Travis, "A Phono-Photographic Study of the Stutterer's Voice and Speech," Psychological Monogr., 36 (1926), 109-141.

the "normal" condition while stutterers had more range in pitch in the "emotional" condition.

Travis (1931) reported that

....periodic fluctuations in pitch of a rate of from four to nine pulsations per second (vibrato) occur in a certain number of the stutterer's tones during unemotional conversational speech.... In the case of the normal speaker they do not occur in any tones of similar speech.⁵

⁵Lee Edward Travis, Speech Pathology (New York: D. Appleton and Company, 1931), p. 114.

He further noted periods of tonal fixation that were more than twice the duration of the longest normal tones, greater variation in the duration

of tones, large differences in the duration of consecutive waves, extremely brief approximations of the vocal folds before and between tones, groups of oscillations of high frequency and low amplitude occurring periodically between tones, and abrupt initiations of tones. 3

Bryngelson (1932) studied the vocal disturbances during stuttering. 6

⁶Bryng Bryngelson, "A Photophonographic Analysis of the Vocal Disturbances in Stuttering," Psychological Monogr., 43 (1932), 1-30.

He reported a difference of as much as 33 semitones between the frequencies of consecutive waves, as many as 143 consecutive waves that did not vary from one another as much as .0005 second in duration, a variety of isolated wave forms, and a variety of abnormal attacks and endings of tones. These phenomena did not occur in the records of normal speech and could not be duplicated voluntarily by stutterers or nonstutterers.

Adams, a student of Travis, (1932) published the results of her study of the sound-wave characteristics of stutterers and nonstutterers. 7

⁷L. H. Adams, "A Comparison of Certain Sound Wave Characteristics of Stutterers and Nonstutterers," in Stuttering in Children and Adults, ed. by W. Johnson (Minneapolis: University of Minnesota Press, 1963), pp. 398-400.

She found that the two groups were not significantly different in average pitch level but that stutterers were more limited in total pitch range and variation in successive wave lengths than were nonstutterers and had smaller average pitch inflections.

Fairbanks (1937) reported that the median frequency with which stuttering occurs on speech sounds was directly related to the fundamental

pitch of the vowels.⁸ Stromsta also suggested (1962) that there may

4

⁸Grant Fairbanks, "Some Correlates of Sound Difficulty in Stuttering," Quarterly J. Speech, 37 (1937), 67-69.

be a relationship between vocal pitch and stuttering.⁹ He found that

⁹Courtney Stromsta, "Delays Associated with Certain Sidetone Pathways," J. Acoust. Soc. Amer., 34 (1962), 392-96.

stutterers differ from nonstutterers in the relative phase angle of bone conducted speech sound energy. This discrepancy in phase increased as fundamental frequency decreased. This could relate to prevalence of male stutterers.

Two methods of increasing the fluency of the speech of stutterers, delayed auditory feedback (DAF) and aural masking, are used by various clinicians. Of note are Gross and Nathanson (1967), Van Riper (1970), Curlee and Perkins (1973), and Ryan and Van Kirk (1974) who used delayed auditory feedback and Van Riper (1965), Trotter and Lesch (1967), and Perkins and Curlee (1969) who used masking.¹⁰

¹⁰M. S. Gross and S. N. Nathanson, "A Study of the Use of a DAF Shaping Procedure for Adult Stutterers," Program of the 43rd Annual Convention, Amer. Speech Hearing Assoc., (1967), 39.

Charles Van Riper, "The Use of DAF in Stuttering Therapy," British Journal of Disorders of Communication, 5 (1970), 40-45.

R. F. Curlee and W. H. Perkins, "A DAF Conditioning Program for Adolescent and Adult Stutterers," Behavior Research Therapy, 11 (1973), 395-401.

B. Ryan and B. Van Kirk, "The Establishment, Transfer, and Maintenance of Fluent Speech in 50 Stutterers Using Delayed Auditory Feedback and Operant Procedures," J. Speech Hearing Dis., 39 (1974), 3-10.

Charles Van Riper "Clinical Use of Intermittent Masking in Stuttering Therapy," Asha, 7 (1965), 381.

W. Trotter and M. Lesch, "Personal Experiences with a Stutter-Aid," J. Speech Hearing Dis., 32 (1967), 270-272.

W. Perkins and R. Curlee, "Clinical Impressions of Portable Masking Unit Effects in Stuttering," J. Speech Hearing Dis., 34 (1969), 360-362.

Investigators have studied the changes in duration--Neeley (1951), Naylor (1953), Spilka (1954), Nessel (1958), Soderberg (1959), Lotzmann (1961), Goldiamond (1965), Stromsta (1967), and Ham and Steer (1967)--and intensity of the speech of stutterers under delayed auditory feedback--Neeley (1951) and Ham and Steer (1967)--and changes in intensity and duration of the speech of stutters in the presence of masking--Hanley and Steer (1949), Adams and Moore (1972), Adams and Hutchinson (1974), and Conture (1974).¹¹

¹¹K. K. Neeley, "The Effect of Oral Practice in the Presence of Different Conditions of Side-Tone Upon the Rate and Sound Pressure Level of the Speech of a Group of Stutterers" (unpublished Ph.D. dissertation, The Ohio State University, 1951).

R. Naylor "A Comparative Study of Methods of Estimating Severity of Stuttering," J. Speech Hearing Dis., 18 (1953), 30-37.

B. Spilka, "Some Vocal Effects of Different Reading Passages and Time Delays in Speech Feedback," J. Speech Hearing Dis., 19 (1954), 34-47.

E. Nessel, "Die verzogerts sprachruckkopplung (Lee-effelt) bei der stottern," Folia Phoniast., 10 (1958), 199-204.

George A. Soderberg, "A Study of the Effects of Delayed Auditory Sidetone on Four Aspects of Stutterers' Speech During Oral Reading and Spontaneous Speaking " (unpublished Ph.D. dissertation, The Ohio State University, 1959).

Von Geert Lotzmann, "Zur Anwendung Variierter Verzogerungszeiten bei Balbuties," Folia Phoniast., 13 (1961), 276-312.

I. Goldiamond, "Stuttering and Fluency as Manipulatable Operant Response Classes," in Research in Behavior Modifications: New Developments and Implications, ed. by L. Krasner and L. Ullmann (New York: Holt, Rinehart, Winston, 1965).

Courtney Stromsta, "The Effects of Altering the Fundamental Frequency of Auditory Masking on the Speech Performance of Stutterers," Tech. Rept. of Public Service Grant No. B-1331, Ohio State Univ. (1967).

R. Ham and M. D. Steer, "Certain Effects of Alteration in Auditory Feedback," Folia Phoniat., 19 (1967), 53-62.

T. D. Hanley and M. D. Steer, "Effect of Level of Distracting Noise on Speaking Rate, Duration and Intensity," J. Speech Hearing Dis., 14 (1949), 363-368.

Martin R. Adams and W. Moore, "The Effects of Auditory Masking on the Anxiety Level, Frequency of Dysfluency and Selected Vocal Characteristics of Stutterers," J. Speech Hearing Res., 15 (1972), 572-578.

Martin R. Adams and John Hutchinson, "The Effects of Three Levels of Auditory Masking on Selected Vocal Characteristics and the Frequency of Disfluency of Adult Stutterers," J. Speech Hearing Res., 17 (1974), 682-688.

Edward G. Conture, "Some Effects of Noise on the Speaking Behavior of Stutterers," J. Speech Hearing Res., 17 (1974), 714-723.

Soderberg (1959) and Stromsta (1967) investigated the changes in fundamental frequency in a stutterer's voice under delayed auditory feedback and masking respectively. Soderberg found significant increases in the fundamental frequency of prolonged vowels produced by stutterers after reading and speaking in the presence of delayed auditory feedback.¹²

¹²Soderberg, "Effects of Delayed Auditory Sidetone."

Stromsta found that as the fundamental frequency of a masking noise was decreased there was a progressive increase in vocal pitch and a decrease in stuttering.¹³

¹³Stromsta, "Effects of Altering the Fundamental Frequency."

Van Riper noted that "All of the researches have shown that masking does reduce the frequency and severity of stuttering though there is no

real certainty concerning the reason for this effect."¹⁴ This reduction

¹⁴Charles Van Riper, The Treatment of Stuttering (Englewood Cliffs, N. J.: Prentice Hall, 1973), p. 123.

was thought to be the result of the stutterer's speaking louder. However, Cherry and Sayers (1956) and Parker and Christopherson (1963) reported that their subjects were able to maintain fluency when instructed to speak quietly under masking.¹⁵ As the intensity is increased, there are assoc-

¹⁵C. Cherry and B. Sayers, "Experiments Upon the Total Inhibition of Stammering by External Control and Some Clinical Results," J. Psychosom. Res., 1 (1956), 233-246.

C. S. Parker and F. Christopherson, "Electronic Aid in the Treatment of Stammer," Med. Electron. Biol. Engng., 1 (1963), 121-145.

iated changes in other vocal characteristics, i.e. pitch, and it might be that, though loudness has returned to normal, pitch remains changed and contributes to fluency.

Studies of normal speakers subjected to masking and delayed auditory feedback (DAF) have demonstrated systematic changes in fundamental frequency. Black (1950) and Atkinson (1952) reported increases in vocal intensity and vocal frequency as a function of the intensity of masking.¹⁶

¹⁶John W. Black, "Some Effects Upon Voice of Hearing Tones of Varying Intensity and Frequency While Reading," Speech Monogr., 17 (1950), 95-98.

C. J. Atkinson, "Vocal Responses During Controlled Aural Stimulation," J. Speech Hearing Dis., 17 (1952), 419-426.

Fairbanks (1955) had normal speaking male college students read under

various time of delayed feedback.¹⁷ Fundamental frequency showed an initial

¹⁷Grant Fairbanks, "Selected Vocal Effects of Delayed Auditory Feedback," J. Speech Hearing Dis., 20 (1955), 333-346.

rise of 3.5 semitones at .1-second delay and remained at that level through delays of .2-, .4-, and .8-second. There were no changes in other measures of change of pitch. The forms of melody curves were changed considerably in conditions of delay.

Stromsta (1959) had eight normal hearing males sustain a vowel at falsetto and at the lowest pitch the subject could maintain. DAF resulted in more phonatory blockages, greater total time, and extreme pitch changes, and voice quality of an undesirable nature.¹⁸

¹⁸Courtney Stromsta, "Experimental Blockage of Phonation by Distorted Sidetone," J. Speech Hearing Res., 2 (1959), 286-301.

In two articles Wingate (1969, 1970) reported the speaking conditions under which most stutterers are fluent.¹⁹ These conditions included

¹⁹M. E. Wingate, "Sound and Pattern in 'Artificial' Fluency," J. Speech Hearing Res., 10, (1969), 677-686.

M. E. Wingate, "Effect on Stuttering of Changes in Audition," J. Speech Hearing Res., 13, (1970) 861-873.

delayed auditory feedback and auditory masking.

In sum both analyses indicate that in almost all circumstances where stuttering is substantially reduced, certain changes in vocal expression seem to be significantly involved if not, in fact responsible for the improved fluency.

In the substantial literature on stuttering one can find very little evidence of attention to the matter of vocal function beyond the limited interest expressed sporadically quite some time ago. The analyses presented here....strongly suggest that renewed inquiry into

this neglected area should lead to a more fundamental understanding of the nature of stuttering.²⁰

²⁰Ibid., 871.

The existence of a primary laryngeal component of stuttering has been proposed in reports of studies by Adams and Reis (1971); Gautheron, Liorzou, Even, and Vallancien (1973); Schwartz (1974); Wyke (1974); and Freeman and Ushijima (1975).²¹

²¹Martin R. Adams and Ronald Reis, "The Influence of the Onset of Phonation on the Frequency of Stuttering," J. Speech Hearing Res., 14 (1971), 639-644.

B. Gautheron, A. Liorzou, C. Even, and B. Vallancien, "The Role of the Larynx in Stuttering." in Neurolinguistic Approaches to Stuttering, Proceedings of the International Symposium on Stuttering, Brussels, 1972, ed. by Yvan Lebrun and Richard Hoops (Paris: Mouton, 1973), p. 45.

M. F. Schwartz, "The Core of the Stuttering Block," J. Speech Hearing Dis., 39 (1974), 169-177.

Barry Wyke, "Phonatory Reflex Mechanisms and Stammering," Folia Phoniatic. 26 (1974), 321-328.

F. Freeman and T. Ushijima, "The Stuttering Larynx: An EMG, Fiber-optic Study of Laryngeal Activity Accompanying the Moment of Stuttering," Haskins Laboratories Status Report on Speech Research, SR-41 (1975), 217-228.

Freeman and Ushijima compared EMG recordings of all five intrinsic muscles and three upper tract articulatory muscles of a stutterer during stuttered reading and during frequency-producing situations - white noise, DAF, rhythmic and choral speaking, and whispering. They found that moments of stuttering were characterized by disruption of the normal synchrony and reciprocity between abductors and adductors and usually higher levels of activity in four of the five intrinsic laryngeal muscles.

Schwartz has conceptualized a model of the stuttering block. He believes that the core of the block is an "inappropriate vigorous contraction of the posterior cricoarytenoid (PCA) in response to the subglottic air pressures required for speech."²² Contraction of this muscle

²²Schwartz, "Core", p. 169.

causes the cords to open in response to changes in subglottic air pressures. The PCA would inevitably contract in response to the increased subglottic pressures needed for speech if it were not inhibited by supramedullary centers. If psychological stress is present, as in foreknowledge of the occurrence of a feared speech stimulus, there may be a loss of supramedullary control, and the PCA will contract.

Purpose of the Study

The investigation reported here was designed to determine experimentally the nature and extent of long-term fundamental frequency characteristics in a stutterer's voice that might distinguish him from a nonstutterer. An additional purpose was to determine if situations generally acknowledged to produce fluency in stutterers, delayed auditory feedback and masking, also produce alterations in the fundamental frequency characteristics of a stutterer or nonstutterer.

More specifically the object of the study reported here was to compare the fundamental frequency characteristics of stutterers and nonstutterers while reading and subsequently to compare the fundamental frequency characteristics of stutters and nonstutterers reading under normal auditory feedback (NAF), under delayed auditory feedback (DAF),

and under masking. The measures of fundamental frequency characteristics include

1. Mean pitch
2. Median pitch
3. Functional pitch range
4. Number of upward, downward, and total inflections
5. Number of upward, downward, and total pitch shifts
6. Average rate and extent of upward and downward inflections
7. Average extent of upward and downward pitch shifts
8. Percentage of vocalized time.

The analyses of these characteristics were made from measurements of recorded sentences reproduced through an appropriate transducer to yield Mingographic tracings.

Hypotheses

Two hypotheses were formulated to be tested.

1. There are no differences in measures of fundamental frequency and duration between stutterers and nonstutterers while reading.
2. There are no differences in measures of fundamental frequency and duration made during reading in three conditions of auditory feedback (normal auditory feedback, delayed auditory feedback, and masking).

Summary

Research has not entirely defined the characteristics of fundamental frequency of stutterers in spite of early reports of quantitative differences between stutterers and nonstutterers and recent investigations that implicate the larynx as a primary site of the stuttering spasm. The effects

of delayed auditory feedback and masking on the fundamental frequency characteristics of stutterers have not been studied as extensively as have the effects of these two altered types of feedback on other vocal characteristics, i.e., loudness and duration. An investigation was planned to determine if the fluency of the reader or the type of auditory feedback affected the changes in the characteristics of fundamental frequency or duration of stutterers or nonstutterers.

CHAPTER 2

REVIEW OF THE LITERATURE ON FUNDAMENTAL FREQUENCY

The review of literature will be divided into four sections containing summaries of reports of studies which pertain directly to the present investigation. The first section will be concerned with historical developments in technology which led to the instrumentation used here to record fundamental frequency; the second, investigations of long-term fundamental frequency characteristics produced by adult male stutterers or nonstutterers; the third, investigations of the effects of delayed auditory feedback on the fundamental frequency characteristics; and the fourth, investigations of the effects of masking on fundamental frequency characteristics.

Development of Instrumentation

One of the earliest records of the analysis of fundamental frequency contained a description of a method in which the unknown frequency was compared with a known frequency. The number of beats within a certain time interval was counted and subsequently added to or subtracted from the known frequency in order to ascertain the unknown frequency.¹

¹M. D. Steer and T. D. Hanley, "Instruments of Diagnosis, Therapy, and Research," in Handbook of Speech Pathology, ed. by Lee Edward Travis (New York: Appleton-Century-Crofts Inc., 1957), p. 193.

Scheibler (1834) improved this technique by his use of the

tonometer.² This instrument consisted of a series of tuning forks

²Elbert R. Moses, Jr., Phonetics, History and Interpretation (Englewood Cliffs, New Jersey: Prentice Hall, Inc., 1964), p. 175.

encompassing an octave in equal frequency increments. The sound in question caused the two forks nearest to it in pitch to vibrate, and the beats thus generated could be counted. In Koenig's modification of the tonometer, there were 154 forks, with adjustable resonators and sliding weights, ranging from 16 to 12,845 double vibrations.³

³double vibrations (dv) = cycles per second (cps) = Hertz (Hz)

The initial work on the phonautograph was begun by Scott (1856).⁴

⁴Dayton Clarence Miller, The Science of Musical Sounds (2d ed.; New York: The MacMillan Co., 1934), p. 71.

Three years later Scott and Koenig introduced a more refined model in which the forced vibrations of a thin membrane at the end of a receiving trumpet were transmitted via a small recording lever to the smoked surface of a hand rotated drum.

In order to eliminate the errors in transcription that resulted from the use of a recording lever, Koenig (1862) described his use of the manometric flame. With it he transformed fluctuations of sound waves into observable form.

The vowel is sung or spoken into a trumpet leading to a small box known as the "manometric capsule". This box is divided into two parts by a thin rubber membrane.....One part is a tight chamber through which illuminating gas is flowing; the gas is lighted at the end of the small jet. As the sound waves descend they strike the rubber membrane, set it in vibration and thus produce movements

of the gas analogous to those of the air in sound waves. The vibrations of the flame can be seen when the eye is suddenly moved sidewise; owing to the lag of sensation the image remains in the eye and the successive vibrations seem simultaneous. They are conveniently studied.....by means of revolving mirrors.⁵

⁵Edward W. Scripture, The Elements of Experimental Phonetics (New York: Charles Scribner's Sons, 1902), p. 26.

Nichols and Merritt and, concurrently, Nagel and Samojloff determined the composition of a gas that would enable them to photograph the movements of the manometric flame.⁶

⁶Ibid., pp. 27-29.

An innovation of Seashore, the tonoscope, was a revolving drum with rows of holes, in steps of one vibration from 110 to 219, which passed between the manometric capsule and the eye of the viewer.⁷ When

⁷Milton Metfessel, "Technique for Objective Studies of Vocal Art," Psychological Monogr., 36 (1926), 21.

the number of holes equalled the frequency of the flashes of light, the flashes were seen as stationary dots.

Barlow (1866) named his version of the phonautograph a logograph.⁸

⁸Scripture, Experimental Phonetics, pp. 18-31.

He employed a thin pointed lever of aluminum dipped in color which wrote on a band of paper. Other versions were designed and used by C. Blake (1876), Schneebeli (1878), E. W. Blake (1878), Preece and Stroh (1879), Martins (1889), Herman (1889), Lebedeff (1894), Pipping (1899), and Samojloff (1900).

Hensen (1887) in his attempt to increase the sensitivity of the phonoautograph used a membrane of gold beaters skin which has a low natural sensitivity.⁹ The recording head, a thin glass thread, wrote

⁹Ibid., p. 18.

on a thinly smoked strip of glass. This instrumentation resulted in a recording in which high frequencies were not registered. Pipping substituted a diamond for the glass thread.

The invention of the phonograph in 1877 demanded the development of a method to trace the fluctuations of the sound that had been recorded. Hermann (1890) and Bevier (1900) devised the method whereby a fine knob of glass traveled in the record and deflected a mirror.¹⁰ A

¹⁰Miller, Musical Sounds, p. 77.

beam of light produced by a vertical slit in front of an arc lamp was reflected from the mirror and fell upon a slit in a light-tight recording box. Inside the box a cylindrical drum rotated with a paper that was sensitive to light on its surface.

The oscillograph, a specialized type of galvanometer developed by Blondel and Duddell (1893), received the electromagnetic waves from the telephone or the microphone.¹¹ These waves set a mirror into corres-

¹¹Ibid., p. 75.

ponding vibrations that could be photographed.

Scripture invented the Sprachseiche (1906) in response to a need

for more detail in the tracing.¹² With this apparatus he copied phonograph

¹²Scripture, Experimental Phonetics, pp. 55-61.

or gramophone records on smoked paper and enlarged the tracing as much as 300 times laterally and five times in length. In order to produce this expansion it was necessary to slow the disc to a speed of only one revolution in five hours.

Miller's Phonodeik (1909) was also developed to give more detailed information about sound waves.¹³ Some versions of this instrument allowed

¹³Miller, Musical Sounds, pp. 78-88.

for the movements of the diaphragm to be magnified 40,000 times or more. There was no lever linkage in the Phonodeik; instead, the vibrations of a thin glass diaphragm were imparted to a mirror by means of a silk fiber on thin platinum wire and a small pulley. The movement of the mirror deflected a beam of light, the movements of which were reflected on moving sensitized paper. Raman and Dey (1920) and Anderson (1925) devised similar instruments.

Garten (1915) sought to eliminate the errors of Hensen's technique by employing a soap film membrane with a natural frequency of 2,000 cps.¹⁴

¹⁴F. Trendelenburg, "Technical Development of Phonetics," in Manual of Phonetics, ed. by L. Kaiser (Amsterdam: North-Holland Publishing Company, 1957), pp. 20-21.

In another innovation he attempted to eliminate the error caused by the use of mechanical linkage between the membrane and the paper by photographing through a microscope the motions of a minute iron particle held

in suspension in the center of the film between the poles of a powerful electromagnet. In addition he interposed an acoustic resonator between the sound source and the recorder.

Scripture (1923) in his book, Stuttering, Lispings, and Correction of the Speech of the Deaf, described the use of a mouth recorder to obtain melody plots of the speech of stutterers and nonstutterers. The mouth recorder consisted of a rubber funnel held over the mouth; the funnel was connected to a delicate registering tambour. The length of each wave of a vowel was measured by a microscope, converted into frequency, and plotted as frequency versus time.

Einhaven and Hoogerwerf (1924) developed an instrument with the highest possible natural frequencies.¹⁵ The motions of a highly tuned

¹⁵Ibid., p. 22.

thin string that were created by the friction of oscillating air particles were microscopically photographed.

Trendelenburg's (1924) use of a Riegger high-frequency condensor microphone as a detector and a loop oscillograph as a recorder led to his "confirmation" of the vowel theory of Helmholtz.¹⁶ Crandall (1925) and

¹⁶F. Trendelenburg, "Technical Development," p. 163.

Gemelli and Pastore (1934) also conducted oscillographic research on vowel sounds.

Until Metfessel (1926) designed an instrument, the photophonophonelescope to measure long-time fluctuations in successive wave lengths researchers were unable to determine efficiently such factors as pitch

range, average pitch, and time.¹⁷ A conical horn communicated sound

¹⁷Milton Metfessel, "Technique for Objective Studies of the Vocal Art," Psychological Monogr., 36 (1926), 1-40.

waves to the diaphragm of a phonelescope, an optical lever. A light was reflected from the mirror attached to the phonelescope to a moving picture film in greatly magnified form. The light point vibrated vertically as the phonelescope vibrated horizontally. A second phonelescope received the sound waves from an electrically driven tuning fork of known frequency. Calculation of the unknown frequency was made possible by a comparison of the tracings from the two phonelescopes. Simon refined this method of measuring frequency in 1926.¹⁸ In his refinement only one

¹⁸Clarence Simon, "The Variability of Consecutive Wave Lengths in Vocal and Instrumental Sounds," Psychological Monogr., 36 (1926), 41-83.

phonelescope was needed because film passage was maintained at a constant rate. Cowan electrified the technique.¹⁹ Metfessel also originated the

¹⁹Milton Cowan, "Pitch and Intensity Characteristics of Stage Speech," Archives of Speech. Supplement, (December, 1936), 1-92.

phonoprojectoscope in which a light ray was projected against a revolving four-sided mirror mounted on a phonograph. He pioneered the use of the phonelescope to replace the use of the manometric capsule to get readings from a tonoscope. Determination of the mean and upper and lower pitches of a fluctuating sound wave, determination of harmonics, and differentiation of orchestral interference from the pitch of the singer's voice could be made with this combination.

The Vibrograph described by Tiffin and Steer (1939) was a combination of features of the oscillograph, the Sprachseiche, the Phonodeik, and the photophonophonelescope.²⁰ It consisted of motor driven phonograph

²⁰J. Tiffin and M. D. Steer, "The Vibrograph: A Combination Apparatus for the Speech Laboratory," Quarterly J. Speech, 25 (1939), 272-278.

turntable and film drum, phonograph recording and pick up heads, amplifier, and phonoscope optical system.

In the 1930's and 40's at least four direct reading pitch recorders were reported. Hunt (1935) described a frequency meter circuit and discussed its application to laryngeal frequency analysis. Obata and Kibayashi (1937) reported such a recorder. Dempsey and Gruenz (1949) and Schott (1949) simultaneously developed two more versions.²¹ These re-

²¹M. D. Steer and T. D. Hanley, "Instruments of Diagnosis," p. 197.

corders commonly include a preprocessor which may consist of a nonlinear transformation circuit or simply a low-pass filter followed by a frequency meter. This meter may be followed by a post processor, most commonly a low-pass filter to perform short-time integration of the pulses.²²

²²Norris Paul McKinney, Laryngeal Frequency Analysis for Linguistic Research (Ann Arbor: The University of Michigan Communication Sciences Laboratory, 1965), pp. 46-49.

Grutzmacher and Lottermoser (1938) developed a melody recorder capable of making continuous recordings of the pitch of sung or spoken texts.²³ The momentary pitch was displayed via a sawtooth oscillation

²³F. Trendelenburg, "Technical Development," p. 24.

circuit on the screen of a cathode-ray tube. The oscilloscope portrayed voltage or current wave forms on a fluorescent screen as amplitude versus time.

The sound spectrograph developed by Koenig, Dunn, and Lacy (1946) was based on the heterodyne technique evolved by Grutzmacher. In the heterodyne technique the sound wave under study was swept by a sine tone of continuously adjusted pitch. Every time the tone swept over one of the components coming from the sound field, the intensity of the tone was photographically registered. This technique is unsuitable for immediate analyzation of rapidly changing phenomena because of its long build-up time. Conventionally only 2.4 seconds are analyzed. The signal, recorded on magnetic tape, is scanned by a band pass filter. When energy is detected, the recording stylus is caused to fire resulting in a black line on the recording paper. The permanent visible record produced by the spectrograph portrays frequency on the vertical axis and time on the horizontal axis. Relative intensity is revealed by the blackness of the pattern.

Trendelenburg and Franz used a large number of filters, each of which passed on octave bandwidth of the sound wave, in their octave-band filter oscillograph.²⁴ An oscillograph loop was connected to the output of each

²⁴Ibid., p. 25.

octave-band filter. The audio-frequency spectrometer of Freystedt had three filters per octave and a rotary switch that operated at a speed of 20 revolutions per second. These were more satisfactory for the immediate analysis of rapidly changing phenomena.

The photophonophonelescope and the Purdue Pitch Meter developed by Dempsey continued to be used in the 1950's for long-term fundamental frequency analysis. In the 1960's Hollien modified the photophonophonelescope of Cowan so that it was motor driven, had a centrally located control panel, and was constructed with commercially available components. He named this version the phonellegraph. Later he constructed the fundamental frequency indicator (FFI).²⁵ This instrument consists of a series

²⁵Harry Hollien and Patricia Paul, "A Second Evaluation of the Speaking Fundamental Frequency Characteristics of Post Adolescent Girls," Language Speech, 12 (1969), 119-124.

of one-half octave low-pass filters and high-speed switching circuits to extract automatically fundamental period from complex waves. The extracted signal is stored on magnetic tape as a constantly varying (frequency modulated) sine wave. The speed of the tape is reduced by a factor of four, and the output fed to an electric counter which samples the signal period every 33 msec. A Teletype unit punches these data on paper tape; the information is transferred to IBM cards and processed by an IBM 709 computer. The computer program includes conversion of each period value to frequency and the computation of the geometric mean frequency and the standard deviation of the distribution.

In this same decade the reading from the oscilloscope was converted into a permanent trace by photographing the tracing, by using the Visicorder, and by making oscillograms. Spectral analysis was performed. Computer programs for determination of long-term fundamental frequency characteristics were initiated. However, these techniques are still being validated and are infrequently used in studies.

Renewed usage was made of the phonellegraph in the 1970's. The FFI, the Visicorder, the spectrograph, and an occasional computer program were employed to obtain measures of fundamental frequency.

Investigations of Long-Term Fundamental Frequency
Characteristics of Adult Male Stutterers and Nonstutterers

As noted in Chapter 1, Scripture (1923) concluded that the stutterer had a monotonous voice, began and ended vowels with a glottal catch, and used a voice that was abnormally low.²⁶ The tracings on which he based

²⁶Edward W. Scripture, Stuttering, Lispings, and Correction of the Speech of the Deaf (New York: The Mac-Millan Co., 1923).

these conclusions were made by a mouth recorder. He proposed a therapy regimen that included training in melody and flexibility. In melody training the stutterer was taught to sing a sentence then say the words on the same notes. In flexibility training the stutterer was taught to speak various words in such a way that the laryngeal tone passed over two octaves in the first important vowel.

Travis (1926) conducted three experiments to compare the voices of stutterers and nonstutterers under normal and emotional conditions.²⁷

²⁷Lee Edward Travis, "A Phono-Photographic Study of the Stutterer's Voice and Speech." Psychological Monogr., (1926), 109-141.

These experiments were cited in Chapter 1. The first experiment was concerned with momentary fundamental frequency characteristics. In the second experiment the photophonophonelescope of Metfessel was used to compare range of pitch, time, and average pitch of the two groups while speaking a habitual sentence and a belittling sentence. In the final experiment each

stutterer and nonstutterer was requested to speak in three distinctly different situations. The first situation was of mild relaxation; the second, of mental flurry; and the third, of threatened injury. Making an habitual statement and speaking in a situation of mild relaxation were considered, for purposes of his report, normal conditions. Making a belittling statement and speaking in a situation of mental flurry or threatened injury were considered emotional conditions. The results of the last two experiments showed that stutterers had more range in pitch under emotional than under normal conditions while for nonstutterers the effect was opposite. Under normal conditions the nonstutterer had more range in pitch than the stutterer.

Bryngelson (1932), as reported earlier, employed the condensor microphone, amplification, an oscillograph, and an oscillator to study vocal disturbances in stuttering.²⁸ Each of 17 male stutterers was questioned,

²⁸Bryng Bryngelson, "A Photophonographic Analysis of the Vocal Disturbances in Stuttering," Psychological Monogr., 43 (1932), 1-30.

engaged in conversation, asked to read, or embarrassed, in order to get an adequate sampling of his vocal difficulties. Additionally, each was asked to change real to voluntary stuttering. Normal speakers and the stutterers imitated stuttering and produced the shortest tone possible. Bryngelson reported (1) a difference of as much as 33 semitones between consecutive wave frequencies, (2) as many as 143 consecutive waves that did not vary from one another as much as .0005 of a second in duration, (3) isolated wave forms, (4) highly damped transient series of oscillations, (5) single oscillations of extremely short duration, (6) vibration couplets, (7) waves of exceedingly high frequency initiated by waves of much larger excursion,

(8) waves of bizarre form, (9) abnormal attacks, and (10) abnormal endings of tones.

According to Cowan the concept of the graphical speech score originated with Metfessel in Phonophotography in Folk Music.²⁹ Time, represented

²⁹Milton Cowan, "Pitch and Intensity Characteristics of Stage Speech," Archives of Speech-Supplement, (December, 1936), 9.

Milton Metfessel, Phonophotography in Folk Music (Chapel Hill: University of North Carolina Press, 1928), pp. 24-26.

along with horizontal axis, was divided into seconds with vertical lines. The area between these lines was further subdivided into units of .1-second by dots, dashes, and spaces of the background. The vertical measurement was divided into semitones of the even tempered musical scale.

Tiffin (1934) used the photophonelscopic Metfessel technique to obtain melody curves of good and poor speakers in order to describe the physical factors which make up a pleasing and effective voice.³⁰

³⁰Joseph Tiffin, "Pitch and Intensity Measurements of Speech," J. Acoust. Soc. Amer., 5 (1933-1934), 225-234.

The melody curves for the six voices in a study by Lewis and Tiffin were obtained by the technique of Metfessel.³¹ The purpose of this study

³¹Don Lewis and Joseph Tiffin, "A Psychophysical Study of Individual Difference in Speaking Ability," Archives of Speech, 1 (1934), 43-60.

was to indicate how effective speech increases or decreases with continuous variations in the measurable physical factors. With respect to pitch, they concluded that better voices had a normal distribution of pitches within the range of an octave and that a high pitch level is not necessarily a handicap.

Cowan (1936) defined the concept of pitch shift as the interval [of pitch] between the end of one phonation and the beginning of the next.³² He possibly initiated the measurement of average extent of

³²Cowan, "Pitch and Intensity Characteristics," p. 9.

falling (rising) inflection, average extent of downward (upward) shifts, number of upward (downwards) shifts. In his study of the characteristics of stage speech he used the apparatus described by Metfessel but improved it by using electrical energy instead of acoustical energy to motivate the recording device. This resulted in an increase of sensitivity.

Tiffin and Steer (1937) used Metfessel's technique to investigate the relationship between stressed words in a sentence and pitch, intensity, and duration.³³ They concluded that inflectional pattern was of small

³³J. Tiffin and M. Steer, "An Experimental Analysis of Emphasis," Speech Monogr., 4, (1937), 69-74.

importance in determining emphasis and that a combination of pitch, intensity, and duration was employed in obtaining emphasis.

Using Cowan's technique of acoustic measurement Fairbanks and Pronovost (1939) studied the pitch characteristics of the male voice during the simulation of emotion.³⁴ Six "versatile male actors" were asked to read

³⁴G. Fairbanks and W. Pronovost, "An Experimental Study of the Pitch Characteristics of the Voice During the Expression of Emotion," Speech Monogr. 6, (1939), 87-104.

a passage and simulate contempt, anger, fear, grief, and indifference. Sixty-four observers were asked to judge each actor's simulation and apply the term which named the emotion most accurately. A typical curve of the

simulation that was correctly identified most often showed "the few extremely wide downward inflections in the simulation of contempt, the generally wide, rapid inflections of anger, the irregularity of pitch changes in fear, the consistent vibrato in grief, and the lack of distinguishing features in indifference."³⁵ Fairbanks and Pronovost depicted their

³⁵Ibid., p. 93.

findings with frequency distributions and defined rate of pitch change as a measure of the rapidity with which frequency is modulated per unit of time during inflections.

Cowan's instrument was also used by McIntosh (1939) who found that superior male speakers raised their normal pitch when asked to read with more variability and lowered their normal pitch when asked to read with less variability.³⁶ McIntosh concluded that mean standard deviation,

³⁶C. W. McIntosh, Jr., "A Study of the Relationship Between Pitch Level and Pitch Variability in the Voices of Superior Speakers" (unpublished Ph.D. dissertation, State University of Iowa, 1939).

mean functional pitch range, mean extent of inflections, mean extent of phonations, and mean extent of shifts were descriptive of general pitch variability in speech. Rate of pitch change was also a differentiating factor except for normal readings. The number of changes of pitch per second was larger for the less variable than for the more variable readings. McIntosh used the concept of mean functional pitch range rather than pitch range because the former tended to be influenced less by a few extreme frequencies.

Black (1942) attempted to correlate group preferences for a voice reading a sentence with measurements of some physical characteristics of the voice.³⁷ He used the concepts of functional range, shift, inflection,

³⁷John W. Black, "A Study of Voice Merit," Quarterly J. Speech, 28 (1942), 67-74.

and rate of inflection and the sound-wave photography procedure of Cowan. He found 9 of 18 measurements to be discriminative. These included all temporal means and some measures of pitch variability, especially functional range.

Snidecor (1943) had each of six superior male speakers give a one-minute impromptu talk on a given subject and one week later read the corpus of his impromptu speech.³⁸ The impromptu and reading samples were

³⁸John Snidecor, "A Comparative Study of Pitch and Duration Characteristics of Impromptu Speaking and Oral Reading," Speech Monogr., 10 (1943), 50-56.

analyzed by means of Cowan's modification of Metfessel's photophonelescopic technique. The results showed that the median pitch and the standard deviation of the mean for reading were greater than for impromptu speaking. Phonations, inflections, mean rate of pitch change, number of changes in pitch direction, and upward shifts were greater in mean extent for reading. The proportion of phonation time to total time was identical in both conditions, but there were more phonations and pauses of longer duration in speaking than in reading.

Hanley (1951) compared pitch measures during reading and impromptu speaking of three groups of speakers representing General (GA), Eastern

(EA), and Southern American (SA) dialects.³⁹ Mean and median frequency

³⁹T. D. Hanley, "An Analysis of Vocal Frequency and Duration Characteristics of Selected Samples of Speech from Three American Dialects," Speech Monogr., 18 (1951), 78-93.

levels were significantly higher for the SA group than for the EA and GA groups during impromptu speaking. The ratio of the number of downward inflections to the total number of inflections was greatest for the EA group. The following trends were suggested - greater flexibility for the GA group, ratio of upward inflections to total inflections was higher for the EA group, larger within phrase and smaller end phrase inflections were made by the SA group while the converse was true for the EA group, total and functional ranges were smaller for impromptu speaking than for reading.

Fairbanks (1955) analyzed articulation, total sentence duration, mean sound pressure, and mean fundamental frequency with time delay in an experiment already noted in Chapter I.⁴⁰ Sixteen young male college

⁴⁰Grant Fairbanks, "Selected Vocal Effects of Delayed Auditory Feedback," J. Speech Hearing Dis., 20 (1955), 333-346.

students read the "Rainbow Passage" under conditions of 0-, .1-, .2-, .4-, and .8-second delay with amplification of a constant amount. Fundamental frequency was measured by an instrument like Cowan's and oscillograms. He determined that there was a peak at .2-second delay in the instances of articulatory error and total sentence duration. Fundamental frequency and vocal sound pressure were elevated to the same high levels throughout the range of delays; fundamental frequency was elevated 3.5 semitones. Plots of frequency versus time showed curves that were radically changed in delay conditions.

Bowler (1964) analyzed oscillograms of subjects with harsh and non-harsh voice reading the "Rainbow Passage" using the measures of Cowan, Fairbanks, and Curry.⁴¹ He measured a single glottal pulse interval within

⁴¹N. W. Bowler, "A Fundamental Frequency Analysis of Harsh Vocal Quality," Speech Monogr., 31 (1964), 128-134.

each 50 msec. increment and assigned the corresponding fundamental frequency to the entire increment. He found the median value of the fundamental frequency to be 95.4 cps (three tones lower than the nonharsh samples). The range of harsh portions was twice that of the nonharsh portions. Up and down pitch breaks of typically one octave in extent occurred only in the harsh samples.

Michel (1968) compared mean fundamental frequencies of normal male speakers with clinically diagnosed harsh voices using the FFI and the phonellegraph.⁴² He found that mean fundamental frequency can be used to

⁴²J. Michel, "Fundamental Frequency Investigation of Vocal Fry and Harshness," J. Speech Hearing Res., 11 (1968), 590-594.

differentiate between vocal fry (36.4 cps) and harsh (122.1 cps) or normal (110.6 cps) voices but not between harsh and normal voices.

Hecker and Kruei (1970) correlated spectrograms and oscillograms using a time signal to determine the occurrence of a glottal pulse.⁴³

⁴³M. Hecker and E. Kruei, "Descriptions of the Speech of Patients with Cancer of the Vocal Folds. Part I; Measures of Fundamental Frequency," J. Acoust. Soc. Amer., 49 (1970), 1275-1281.

The reciprocal of a single glottal pulse interval was defined as "instantaneous" fundamental frequency. They found that patients with cancer had a lower maximal rate of change of fundamental frequency, higher directional perturbation factors, more restricted fundamental frequency distributions,

and greater ranges of fundamental frequency perturbations related to specific consonants than normal speakers.

One hundred seventy-five males between the ages of 20-89 were the subjects in a study of Hollien and Shipp (1972).⁴⁴ The FFI was used to

⁴⁴Harry Hollien and Tom Shipp, "Speaking Fundamental Frequency and Chronological Age in Males," J. Speech Hearing Res., 15 (1972), 155-159.

obtain fundamental frequency measures during reading of the "Rainbow Passage". These measures showed a decrease from age 20 to 40 and an increase from age 60 through 80.

Cooper (1974) studied the fundamental frequencies of 155 dysphonic patients before and after vocal rehabilitation by means of spectrographic analysis of the sentence, "The rainbow is a division of white light," from the "Rainbow Passage".⁴⁵ Fundamental frequency was obtained from

⁴⁵M. Cooper, "Spectrographic Analysis of Fundamental Frequency and Hoarseness Before and After Vocal Rehabilitation," J. Speech Hearing Dis., 39 (1974), 286-297.

narrow band spectrograms by measuring the tenth harmonic at 50 msec. intervals and averaging these measurements. He concluded "that the use of a pitch that is below the optimal or natural level is a major factor in initiating, contributing to, or continuing most types of dysphonia."⁴⁶

⁴⁶Ibid., p. 296.

Investigations of the Effects of Delayed Auditory Feedback on Fundamental Frequency Characteristics

In a study already summarized, Fairbanks investigated the effects of delayed auditory feedback (DAF) on the long term fundamental frequency

characteristics of normal speakers. As far as can be determined, Soderberg is the only other researcher to study the effects of DAF on laryngeal frequency.⁴⁷ He investigated the effects of DAF on the fluency, duration,

⁴⁷George Soderberg, "A Study of the Effects of Delayed Side-Tone on Four Aspects of Stutterers' Speech During Oral Reading and Spontaneous Speech" (unpublished Ph.D. dissertation, The Ohio State University, 1959).

and fundamental frequency of the spontaneous speech and reading of 30 stutterers. He additionally compared the effects of DAF on least and most severe stutterers and determined the persistence of the effects of DAF. Measures of fundamental frequency were taken from a counter while the subject prolonged vowels after reading a list of 6-10 syllable phrases and after making six spontaneous descriptive statements about a picture. Stutterers responded to DAF with significant increases in fundamental frequency of sustained vowels, decreases in frequency and duration of stuttering blocks, and significant persistence of these effects. Mild stutterers decreased their rate of speaking in the presence of DAF; severe stutterers did not change their rate.

Investigations of the Effects of Masking on Fundamental Frequency Characteristics

Black (1950) reported a study in which 18 male normal speakers read nonsense syllables for four seconds in the presence of masking tones of different frequencies, different intensities, and different loudness levels.⁴⁸ He concluded that both intensity and pitch of the response

⁴⁸John W. Black, "Some Effects Upon Voice of Hearing Tones of Varying Intensity and Frequency While Reading," Speech Monogr., 17 (1950), 95-98.

increased as the loudness level of the stimulus tone increased. Frequency of the response did not vary with the frequency of the stimulus tone.

Atkinson (1952) extended the frequency range used by Black.⁴⁹ His

⁴⁹Chester J. Atkinson, "Vocal Responses During Controlled Aural Stimulation," J. Speech Hearing Dis., 17 (1952), 419-426.

subjects, 24 male normal speakers, read a monosyllable after hearing a tone, that varied in intensity and frequency, for three seconds. He modified Black's process of determining fundamental frequency by counting striations of iron filing across magnetic tape and verified Black's finding that while the fundamental frequency of the response varied with the loudness level of the stimulus tone, fundamental frequency of the response did not vary with the fundamental frequency of the stimulus.

Summary

The developments in instrumentation and methodology that led to the design of the study reported here were traced in this chapter. Included in this review of literature were summaries of reports in which the fundamental frequency characteristics of adult male stutterers and nonstutterers were measured. Reports which compared fundamental frequency characteristics measured in different feedback conditions were summarized.

CHAPTER III

EXPERIMENTAL PROCEDURES

This chapter will include descriptions of the subjects, stimulus material, experimental conditions, and instrumentation. The treatment of the data and the historical precedents for such treatment will be explained. Definitions will be given for the characteristics of fundamental frequency that were measured. The hypotheses formulated to be tested will be reiterated. Finally, the applicability of the analysis of variance chosen to test the differences among the means of the measures will be outlined.

Subjects

The subjects were 30 males from 18 to 62 years of age. Fifteen of the subjects considered themselves to be stutterers and had been clinically diagnosed as stutterers by the experimenter on the basis of history, struggle evidenced during speaking, and previous clinical treatment for nonfluency. This diagnosis was confirmed in one of the following ways:

1. The subject was currently enrolled in therapy for correction of a fluency problem.
2. The subject was considered to be a stutterer by at least two other lay college students or personnel (usually another stutterer).

3. The subject was diagnosed as a stutterer by a graduate student in Speech and Hearing Science at The Ohio State University.

All subjects, according to observations of the investigator and self-reports, were free from upper respiratory diseases, had no deviant vocal qualities, and had completed at least a high school education. They had normal hearing as determined by their responses to pure tones of 20 dB at all frequencies important to understanding speech, 500 - 4,000 Hz. The measurements were made in a quiet classroom. The vital statistics for these subjects are shown in Tables 6 - 7 in the Appendix.

Stimulus Material

The stimulus material consisted of the 98-word first paragraph of "Rainbow Passage" cited by Fairbanks.

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.¹

¹Grant Fairbanks, Voice and Articulation Drillbook (New York: Harper, 1940), p. 168.

This passage was chosen because it has been used in several previous studies of fundamental frequency characteristics. Among them are Fairbanks, (1955), Bowler (1964), Hollien and Shipp (1972), and Cooper (1974).

Experimental Conditions

Each subject was asked to read the first sentence of the paragraph

"My Grandfather" from Van Riper² in the presence of 90 dB SPL white noise

²Charles Van Riper, Speech Correction: Principles and Methods (Englewood Cliffs, N. J.: Prentice-Hall, 1954), p. 178.

that was presented binaurally through earphones and subsequently to read another sentence under the delay of time of .14 second. This was done in order to acquaint him with the altered types of auditory feedback, masking and DAF. The subject was next given a copy of the "Rainbow Passage" and these instructions.

In one minute I will point to you to indicate that you are to begin talking in an impromptu fashion for 30 seconds about what you have done today. Speak at a comfortable rate and level. At the end of 30 seconds, I will signal you to stop. The next time I point to you read this paragraph. Stop when you complete the paragraph. You should begin reading the paragraph again each time I signal. At some time during the readings you will experience noise in the earphones or delayed auditory feedback. When this occurs, continue reading as before. Are there any questions?

After the impromptu speaking, the subject read the "Rainbow Passage" six times with approximately 10 seconds separating each reading. The experimental conditions occurred on the second, fourth, and sixth readings. The conditions, normal auditory feedback (NAF), delayed auditory feedback (DAF), and masking were presented in a counterbalanced order. The impromptu speaking and the readings were recorded on a tape recorder (Magnecord, Model 1022).

Instrumentation

The subject was seated in an audiometric test room (Industrial Acoustics Company, Inc., Model 403ATR). The experimenter was seated outside the test room and was able to observe the subject through a window. During the impromptu speaking and the readings of the paragraph, the subject

wore earphones (Telephonics, Model TDH-39) mounted on a standard headband. The experimenter wore identical headphones to monitor aurally the subject's speaking behavior.

The subject spoke into two microphones (Electro-Voice, Model 650, and Turner Dynamic, Model 999) that were positioned to maintain a distance of six inches from the mouth of the speaker. The output of the Turner Dynamic microphone was fed to an audio-signal delaying unit, custom made and designed by Marple and Morrill,³ that consisted of a magnetic tape

³N. B. Marple and S. N. Morrill, "A Device for the Production of Delayed Side-Tone" (Jt. Proj. No. NM 001 064 0156.08, Ohio State University Res. Found. and U. S. Navy Sch. Av. Med. Rept. No. 8, 1951).

recorder and reproducer in which the distance between the record head and the playback head could be adjusted to yield delay times of from .03- to .30-second. The amplification at the speaker's ears was set to yield a sound pressure level of 90 dB. The output of the Electro-Voice Microphone was transmitted to a tape recorder (Magnecord, Model 1022). During the masking condition white noise was produced by a noise generator (Grason Stadler Noise Generator, Model 455B) which was coupled to the headphones. A diagram of the instrumentation follows as Figure 1.

In order to calibrate the equipment, four normal speakers were, one at a time, asked to sustain the vowels /a/ and /i/ three times while maintaining a distance of six inches from a microphone (Turner Dynamic, Model 999) coupled to a sound level meter (General Radio, Model 1551-B) in a sound treated audiometric booth. The mean of the levels measured was 80 dB SPL. An oscillator (Bruel-Kjaer Beat Frequency Oscillator, Type 1014) feeding a speaker (Electro-Voice, Model SP8B) was adjusted to that 80 dB

FIGURE 1

SCHEMATIC DIAGRAM OF EQUIPMENT USED TO PRESENT THREE FEEDBACK CONDITIONS.

(1) Noise Generator, (2) Delay Unit, (3) Tape Recorder, (4) Earphones, and (5) Microphones.

level at 1,000 Hz and the tone was transmitted via the microphone through the delay unit to the earphones (Telephonics, Model TDH-39). A Bruel and Kjaer, Model 2204, sound level meter with its associated artificial ear and pressure microphone was used to measure the output from the earphones. The volume controls on the delay unit were adjusted so that the level at the earphones was 90 dB sound pressure level (SPL) which represents a gain of 10 dB. The SPL of the white noise in the headphones during the masking condition was measured at 90 dB SPL by the artificial ear.

Treatment of the Data

Each subject's reading of the sentence, "There is, according to a legend, a boiling pot of gold at one end," was excerpted from the recordings of the paragraphs made in each of the conditions of the feedback. The tape recording containing these 90 sentences which had been originally recorded on a Magnecord, Model 1022, tape recorder was played on another tape recorder (Uher Universal S) in order to slow the speed by a factor of eight. The output of the recorder was transmitted to the Mingograph 34. The Mingograph records oscillations of the recorded speech signal as did the earlier instruments of Metfessel (1926), Tiffin and Steer (1939), etc. in the form of relative intensity versus time. Representative excerpts from the Mingographic tracings are shown in Figure 2.

Each sentence was divided into $1/20$ second intervals, and the number of periodic waves within each interval counted. This number was multiplied by 20 to give a measure of fundamental frequency within an interval. Simon (1926) termed this method of pitch determination, the time line method. Most early investigators of long-term fundamental frequency characteristics, among them Metfessel (1926), Fairbanks (1955), and Black (1942), have used

FIGURE 2

REPRESENTATIVE EXCERPT FROM A MINGOGRAPHIC TRACING TO SHOW A) 1/20 SECOND INTERVAL IN WHICH PERIODIC WAVES DO NOT EXTEND THROUGHOUT THE ENTIRE SEGMENT AND B) 1/20 SECOND INTERVAL IN WHICH PERIODIC WAVES EXTEND THROUGHOUT THE ENTIRE SEGMENT.

this method. In this report the following modification of the time line method was used. If the wave forms did not extend throughout the $1/20$ second interval, the number in half the interval was counted. In computing the mean, the numbers of waves in two "half" intervals were added and counted as the number in one interval. In plotting, the number in the "half" interval was doubled and multiplied by 20 to obtain the fundamental frequency. This value was used to give a better estimate of the direction of the curve at the beginning or end of a period of phonation. If the wave forms did not extend throughout half the $1/20$ second interval, they were not counted. Example: If the number of wave forms in one interval was seven but the wave forms did not continue throughout the interval because they preceded or followed a pause, the number in half the interval, six, was multiplied by 2 and then by 20 to give a frequency of 240 Hz instead of 140 Hz which would have resulted if 7 had been used.

The values determined were plotted on graph paper which shows time on the abscissa and frequency on the ordinate. The horizontal lines are one tone apart. Representative graphs (melody curves) are shown as Figures 3 through 5. Various computations were applied to the data to get measures of the other fundamental frequency and durational characteristics, median fundamental frequency, functional pitch range, number of total, upward, and downward pitch shifts, average extent of upward and downward pitch shifts, number of total, upward, and downward inflections, average extent of upward and downward inflections, average rate of upward and downward inflections, total time, and percentage of vocalized time.

Duplicate tracings of three of the sentences were analyzed a month after the original analysis in order to determine reliability of the

FIGURE 3

MELODY CURVES OF A TYPICAL STUTTERER AND A NONSTUTTERER SPEAKING IN THE PRESENCE OF NORMAL AUDITORY FEEDBACK.

9a

Stutterer

2

3

4

Time (seconds)

Nonstutterer

2

3

4

FIGURE 4

MELODY CURVES OF A TYPICAL STUTTERER AND A NONSTUTTERER SPEAKING IN THE PRESENCE OF DELAYED AUDITORY FEEDBACK.

Stutterer

ime (seconds)

Nonstutterer

FIGURE 5

MELODY CURVES OF A TYPICAL STUTTERER AND A NONSTUTTERER SPEAKING IN THE PRESENCE OF MASKING.

Stutterer

Nonstutterer

investigator. There was agreement for 98% of the measurements when compared interval by interval.

Definitions of Terms

The definitions used were those summarized by Fairbanks.

1. Inflection is frequency modulation, either upward or downward, without interruption of phonation. Frequency changes of less than a semitone were arbitrarily ignored.
2. Rate of pitch change is a measure of the rapidity with which frequency was modulated per unit of time during inflections, i.e., the relative "steepness" of the inflections. For any inflection this was determined by dividing its extent in semitones by its duration in seconds.
3. Functional pitch range is the middle 90% of the total pitch range.
4. Pitch shift is a change in frequency that occurs in the interval between the end of one phonation and the beginning of the next.
5. Mingograph is a writing recorder developed by Elquist that records the oscillations of a signal, in this case from a tape recorder. The electromagnetic vibrations from the tape recorder were transmitted to a galvanometer which in turn converted the electrical energy into mechanical energy and drove an ink filled stylus. The stylus recorded the oscillations on paper that was divided into uniform squares and that moved at a constant rate (1000 mm. per second) past the stylus. The plot produced by the stylus was in the form of amplitude versus time.

Hypotheses Which Were Tested

Two hypotheses regarding measures of fundamental frequency and duration of stutterers and nonstutterers were tested.

1. There are no differences in measures of fundamental frequency and duration between stutterers and nonstutterers while reading.

2. There are no differences in measures of fundamental frequency and duration made during reading in three conditions of auditory feedback (NAF, DAF, and masking).

Experimental Design and Statistical Analysis

The repeated measures for two groups of subjects that were collected fitted an analysis of variance, two-factor mixed design, Type I (Lindquist, 1953). This design permits simultaneous a) comparison between the groups (nonstutterers and stutterers), b) comparisons among the types of auditory feedback (NAF, DAF, and masking), and c) evaluation of the interaction between the groups and feedback conditions. Values at the .05 level of confidence were accepted as indicating statistically significant differences.

When the results of the analysis indicated that there were significant differences among the feedback conditions, the location of the significant difference was determined by applying a measure of critical difference to the differences among the means for the types of auditory feedback. When the results of the analysis indicated that there was significant groups-by-feedback interaction, the measures for the stutterers and nonstutterers were tested separately by a subjects-by-treatments analysis of variance (Lindquist, 1953). Using the mean square error term determined in the subjects-by-treatment analysis, the critical difference was computed and applied to the differences among the means for the types of auditory feedback within each group (stutterers and nonstutterers).

Summary

Fifteen stutterers and fifteen nonstutterers read a sentence under three conditions of auditory feedback (NAF, DAF, and masking). Fifteen characteristics of fundamental frequency and two characteristics of duration were measured. The means of each set of measures were analyzed via 15 separate analyses of variance. The results of the statistical analyses are reported in Chapter IV.

CHAPTER IV

RESULTS OF THE STATISTICAL ANALYSES

Fifteen characteristics of fundamental frequency and two characteristics of duration were measured in sentences which were excerpted from repeated readings of a paragraph by stutterers and nonstutterers under NAF, DAF, and masking. The characteristics of fundamental frequency included those used by Fairbanks in summarizing his related work and that of his students, i.e. mean and median fundamental frequency; functional pitch range; number of total, upward, and downward inflections; average extent of upward and downward inflections; average rate of upward and downward inflections; number of total, upward, and downward pitch shifts; and average extent of upward and downward pitch shifts. Durational characteristics included total time and percentage of vocalized time.

Measures of the 15 characteristics were treated separately by 15 analyses of variance (Lindquist, 1953). Number of downward pitch shifts and extent of downward pitch shifts were not treated statistically because the measures included too many instances of nonoccurrence. Each analysis of variance permitted the simultaneous testing of differences and interactions between the two groups of subjects, stutterers and nonstutterers, and among the three types of auditory feedback: NAF, DAF, and masking.

Fifteen stutterers and 15 nonstutterers read a sentence under counterbalanced conditions of NAF, DAF, and masking. Hypotheses under test related to a) differences between groups of speaker and b) differences among the three types of auditory feedback.

Presentation of the Results

The values of the measurements of fundamental frequency and duration for each subject are included in the Appendix in Tables 8 through 10. Results of the analyses of the measurements of fundamental frequency and duration are presented separately. In each instance there are two tables, a summary of the analysis of variance and a table of the associated mean values. In the instance of measures of fundamental frequency the analyses of variance are in 13 designated columns of Table 1 and the associated mean values are in 13 designated rows of Table 2. Successive treatments of the 13 topics follow topical subheadings. Each subheading includes references to the related columns of Table 1 and the related rows of Table 2. A similar organization is followed in presenting the results of the analyses of measures of duration.

Mean Fundamental Frequency (Column 1, Table 1; Row 1, Table 2.)

Mean fundamental frequency did not differentiate stutterers from nonstutterers. Subjects read with significantly different mean fundamental frequencies in the NAF condition than in the DAF or masking modes. The mean fundamental frequency values produced during masking and DAF were not significantly different from each other. These facts as reflected by the results of the analysis of variance are shown in Column 1 of Table 1. A comparison of the mean values is depicted in Row 1 of Table 2.

Travis (1926) and Adams (1932) reported that stutterers and nonstutterers were not significantly different in the average pitch at which a sentence was read.

Fairbanks (1955) and Soderberg (1959) concluded that DAF was associated with an increase in mean fundamental frequency over the NAF condition.

TABLE 1

SUMMARY OF THE ANALYSES OF VARIANCE OF THE MEAN FUNDAMENTAL FREQUENCY VALUES OF NORMAL SPEAKERS AND STUTTERERS READING UNDER THE INFLUENCE OF NORMAL AUDITORY FEEDBACK, DELAYED AUDITORY FEEDBACK, AND MASKING.

Source of Variation		Mean Square						
		1	2	3	4	5	6	7
	df	Mean Fundamental Frequency	Median Fundamental Frequency	Functional Range	Number Total Pitch Shifts	Number Upward Pitch Shifts	Average Extent Upward Shifts	Number Total Inflections
Groups (G)	1	1648.7	1813.5	1.9	5.4	1.4	0	86.1***
Error	28	520.1	596.1	21.0	3.3	3.4	3.3	16.2
Feedback (F)	2	1302.4*	1019.2*	23.0	4.9	7.5**	1.7	67.1***
F x G	2	92.2	16.1	.7	1.5	1.1	1.2	16.4
Error	56	181.7	152.3	157.3	3.6	2.7	3.3	13.5

* Significant at the .005 level of confidence.

** Significant at the .05 level of confidence.

*** Significant at the .01 level of confidence.

TABLE 1 (CONTINUED)

Source of Variation	df	Mean Square					
		8	9	10	11	12	13
		Upward Inflections	Downward Inflections	Average Extent Upward Inflections	Average Extent Downward Inflections	Average Rate Upward Inflections	Average Rate Downward Inflections
Groups (G)	1	10.0	57.3****	4.3	0	.6	251.0
Error	28	6.2	6.2	4.8	4.6	556.3	307.2
Feedback (F)	2	11.8**	22.6***	3.3	.8	1126.0**	400.6***
F x G	2	5.6	3.4	3.7	4.4	144.7	94.9
Error	56	3.6	4.8	3.4	1.9	334.5	75.6

** Significant at the .05 level of confidence.

*** Significant at the .01 level of confidence.

**** Significant at the .0025 level of confidence.

MEAN VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY PRODUCED BY NORMAL SPEAKERS AND STUTTERERS (IN PARENTHESES) WHILE READING UNDER NORMAL AUDITORY FEEDBACK, DELAYED AUDITORY FEEDBACK, AND MASKING.

Characteristics of Fundamental Frequency	NAF	DAF	Masking	
1. Mean Fundamental Frequency (cycles per second)	106.2 (112.5)	112.4 (125.1)	118.8 (125.4)	
	109.4	118.7	122.1	Total
2. Median Fundamental Frequency (cycles per second)	106.8 (115.1)	114.8 (125.5)	117.7 (125.7)	
	110.9	120.1	121.7	Total
3. Functional Range (semitones)	9.3 (9.3)	7.4 (7.8)	8.7 (9.2)	
	9.3	7.6	8.9	Total
4. Number Total Pitch Shifts	5.7 (6.7)	6.8 (7.1)	6.6 (6.7)	
	6.2	7.0	6.7	Total
5. Number Upward Pitch Shifts	3.4 (3.8)	4.3 (4.9)	4.1 (3.9)	
	3.6	4.6	4.0	Total
6. Average Extent Upward Pitch Shifts (semitones)	3.1 (3.3)	3.9 (3.4)	3.5 (3.7)	
	3.2	3.6	3.6	Total
7. Number Total Inflections	13.4 (14.1)	14.7 (18.3)	13.4 (14.9)	
	13.8	16.5	14.2	Total
8. Number Upward Inflections	5.9 (5.7)	6.1 (7.7)	5.5 (6.2)	
	5.8	6.9	5.9	Total
9. Number Downward Inflections	7.5 (8.5)	8.6 (10.7)	7.9 (8.7)	
	8.0	9.6	8.3	Total
10. Average Extent Upward Inflections (semitones)	3.9 (4.4)	3.2 (4.3)	4.5 (4.2)	
	4.2	3.7	4.4	Total
11. Average Extent Downward Inflections (semitones)	4.5 (3.7)	3.7 (4.4)	4.3 (4.4)	
	4.1	4.0	4.4	Total
12. Average Rate Upward In- flections (semitones/sec.)	42.0 (38.6)	23.2 (33.3)	42.7 (41.6)	
	40.3	30.7	42.2	Total
13. Average Rate Downward In- flections (semitones/sec.)	32.7 (32.8)	22.1 (29.3)	29.6 (32.4)	
	32.7	25.7	31.0	Total

Any difference between two total means in number 1 of 6.8, in number 2 of 6.4, in number 5 of .8, in number 7 of 1.8, in number 8 of .9, in number 9 of 1.1, in number 12 of 9.4, and in number 13 of 4.5 is significant.

Fairbanks' subjects were normal speakers; Soderberg's were stutterers. Fairbanks' reported an increase of 3.5 semitones (from 109.5 to 130.5 cps); there was an increase of one semitone (from 106.2 to 112.4 cps) according to present computations for normal speakers. Soderberg found that his stutterers increased their mean fundamental frequency one semitone from NAF to DAF conditions.

The increase in mean fundamental frequency in the presence of masking noise might have been predicted from consideration of the reports of Black (1950) and Atkinson (1952) who found that the pitch of a response increased as the loudness level of a stimulus tone increased.

Median Fundamental Frequency (Column 2, Table 1; Row 2, Table 2)

The difference between the median fundamental frequencies of the stutterers and nonstutterers was not significant. As were the values of mean fundamental frequency, the median fundamental frequency values for the DAF and masking conditions were significantly higher than the value for the NAF condition, but were not significantly different from each other. These results are summarized in Column 2, Table 1 and the mean values are shown relative to each other in Row 2, Table 2.

Functional Range (Column 3, Table 1; Row 3, Table 2)

There were no significant differences in functional range between groups (stutterers or nonstutterers) or among feedback conditions. A resume of the statistical analysis is displayed in Column 3 of Table 1, and comparisons of the means are shown in Row 3 of Table 2.

Travis (1926) concluded that stutterers use a smaller range in pitch than nonstutterers when each group made an habitual statement. This tendency was reversed when each group spoke under mental effort or in the

presence of threatened injury. Adams (1932) found that stutterers had a smaller range than nonstutterers and the difference in range between stutterers and nonstutterers reached significance when stutterers were compared with good and trained speakers.

Total Number of Pitch Shifts (Column 4, Table 1; Row 4, Table 2)

Stutterers and nonstutterers did not differ significantly in the total number of pitch shifts produced during the readings of a sentence. There were no differences among the feedback conditions in the total number of pitch shifts. A summary of the statistical analysis is shown in Column 4, Table 1. The mean values are shown in Row 4, Table 2.

Number of Upward Pitch Shifts (Column 5, Table 1; Row 5, Table 2)

The difference between the number of upward pitch shifts produced by stutterers and the number produced by nonstutterers did not differ. While reading in the presence of DAF, subjects made significantly more upward pitch shifts than while reading in the presence of NAF. The number of upward pitch shifts produced in masking did not differ significantly from the number made in DAF or NAF. The conclusions of the statistical analysis are shown in Column 5 of Table 1. The means are contrasted in Row 5 of Table 2.

Average Extent of Upward Pitch Shifts (Column 6, Table 1; Row 6, Table 2)

There were no differences which reached significance between groups or among conditions in the average extent of upward pitch shifts. The statistical analysis is summarized in Column 6, Table 1. The mean values are presented for comparison in Row 6, Table 2.

Total Number of Inflections (Column 7, Table 1; Row 7, Table 2)

Nonstutterers read a sentence with significantly fewer total inflections than did stutterers. Both groups made significantly more inflections in the DAF mode than in the NAF or masking modes. The number of inflections produced during masking was not significantly different from the number produced under NAF. The results of the statistical analysis are shown in Column 7 of Table 1, and the means are shown for comparison in Row 7 of Table 2.

Number of Upward Inflections (Column 8, Table 1; Row 8, Table 2)

The groups did not differ significantly in the number of upward inflections. The number of upward inflections produced under DAF was significantly higher than the number produced under NAF or masking. The numbers of upward inflections produced in the latter two conditions were not significantly different from each other. Table 1 presents a summary of the statistical analysis, while Table 2 enumerates the means.

Number of Downward Inflections (Column 9, Table 1; Row 9, Table 2)

Stutterers read a sentence with significantly more downward inflections than did nonstutterers. DAF effected a significant increase in the number of downward inflections over the NAF and masking conditions for both groups. The number of downward inflections produced under masking was not significantly different from the number produced in NAF. The outcome of the statistical analysis is displayed in Column 9, Table 1. The mean values are exhibited for comparison in Row 9, Table 2.

Average Extent of Upward Inflections (Column 10, Table 1; Row 10, Table 2)

The stuttering and nonstuttering groups did not differ significantly

in measures of average extent of upward inflections. The three different auditory feedback conditions did not effect changes in extent of upward inflections. A summary of the statistical analysis is presented in Column 10 of Table 1. The means are tabulated in Row 10 of Table 2.

Average Extent of Downward Inflections (Column 11, Table 1 ; Row 11, Table 2)

Neither groups nor conditions were associated with significant changes in the average extent of downward inflections. A summary of the statistical analysis and a comparison of the mean values are shown respectively in Column 11, Table 1 and Row 11, Table 2.

Average Rate of Upward Inflections (Column 12, Table 1; Row 12, Table 2)

The experimental groups had statistically equivalent average rates of upward inflections. In the DAF condition subjects inflected significantly slower than in the NAF or masking conditions. The average rates of inflection for NAF and masking conditions were not significantly different. Table 1 presents a summary of the statistical analysis in Column 12; Table 2 presents the means for comparison in Row 12.

Average Rate of Downward Inflections (Column 13, Table 1; Row 13 Table 2)

Average rates of downward inflections were similar for stutterers and nonstutterers. Speakers produced downward inflections in the DAF mode at a rate of 25.7 semitones per second which was significantly slower than the rates in the NAF or masking modes. Statistically, the average rates of downward inflections were not different in the NAF and masking modes. The results of the statistical analysis is depicted in Column 13 of Table 1. The mean values are shown in Row 13 of Table 2.

The mean values of fundamental frequency characteristics of non-stutterers and stutterers reading in the presence of NAF that were determined in the present investigation are presented in Table 3 for comparison with the mean values of these same characteristics found by some earlier researchers, Travis (1926), Adams (1932), Snidecor (1943), Hanley (1951), Fairbanks (1955), and Hollien and Shipp (1972). Adams used a strobograph, and her mean for nonstutterers is the combined mean for good, poor, and trained speakers. Snidecor's subjects were superior speakers; Hanley's subjects were General American speakers. The mean attributed to Hollien and Shipp represents a combination of their means for two age groups from 20-29 and 30-39 years of age. Hollien and Shipp used the FFI to obtain their measures. Hecker worked from oscillograms.

Total Time (Column 1, Table 4; Row 2, Table 5)

Stutterers took significantly longer than nonstutterers to read a sentence. The scores of one stutterer were not included in the computations of the mean total time because he took approximately 20 times longer than the other stutterers to read the paragraphs. The scores of a non-stutterer chosen at random were also omitted in order to equalize the numbers in each group. It was necessary to determine the effects of the feedback conditions for each group of speakers separately since a significant interaction was found. As a result it was concluded that both groups of speakers responded to the feedback conditions in the same way but with different levels of confidence. Subjects took significantly longer total time to read a sentence under DAF than under NAF or masking. NAF and masking were associated with similar total time scores. The statistical analysis of total time scores is summarized in Column 1, Table 4. A comparison of

TABLE 3

MEAN VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY OF NORMAL SPEAKERS AND STUTTERERS (IN PARENTHESES) READING UNDER NORMAL AUDITORY FEEDBACK.

Characteristics of Fundamental Frequency	Lechner (1976)	Travis (1926)	Adams (1932)	Snidecor (1943)	Hanley (1951)	Fairbanks (1955)	Hecker (1970)	Hollien (1972)
Mean Fundamental Frequency (cycles per second)	106.2 (112.5)	110 (123)	134.7 (127.7)	132	119.4	109.5		116
Median Fundamental Frequency (cycles per second)	106.8 (115.1)			129	118.6		108.8	
Functional Range (semitones)	9.3 (9.3)			10.2	10.3		9.4	
Average Extent of Upward Pitch Shifts (semitones)	3.1 (3.3)			4.2	4.4			
Average Extent of Upward Inflections (semitones)	3.9 (4.4)			3.8	3.2			
Average Extent of Downward Inflections (semitones)	4.5 (3.7)			3.6	3.8			
Average Rate of Upward In- flections (semitones/sec.)	42.0 (38.6)			37.0	22.8			
Average Rate of Downward In- flections (semitones/sec.)	32.7 (32.8)			31.4				

the means may be made by reference to Row 2, Table 5.

Travis (1926) found no difference in time between stutterers and nonstutterers when each group spoke while relaxed or in the presence of threatened injury. Several previous reserachers, of which Soderberg (1959) was one, have reported that total reading time for stutterers in the presence of DAF was greater than total reading time in NAF. Nessel (1958) found no difference in total time for stutterers reading in the two conditions. A possible explanation for these conflicting reports may be discerned in the results of Naylor (1953) and Soderberg. Naylor concluded that as the rating of severity of stuttering increased the percentage change in reading time associated with DAF decreased. In other words, severe stutterers took longer to read in NAF while mild stutterers took longer in DAF. Soderberg found that severe stutterers took equal amounts of time in both conditions while mild stutterers took more time in DAF. Lotzmann (1961) found that optimum delay time coincided with maximal speech rate for stutterers. Delays less than or greater than optimum resulted in decreased word rate.

Atkinson (1952), Fairbanks (1955), and Black (1961), among others, found longer total reading times in DAF than in NAF for their nonstutterers. Fairbanks' subjects read the same sentence as subjects in the present study, and the mean total time scores of 3.2 seconds in NAF and 4.9 seconds in DAF that he found compare favorably with those found here, 3.3 and 5.1 seconds respectively.

Hanley and Steer (1949) concluded that as the intensity level of a masking noise was increased the number of words read per minute by normal speaking adult males decreased. The level of the masking noise they used was 10 - 35 dB greater than the level used in the present report and could

TABLE 4

SUMMARY OF THE ANALYSES OF VARIANCE OF THE DURATIONAL VALUES OF NORMAL SPEAKERS AND STUTTERERS READING UNDER THE INFLUENCE OF NORMAL AUDITORY FEEDBACK, DELAYED AUDITORY FEEDBACK, AND MASKING.

Source of Variation	df	Mean Square	
		1	2
		Total Time	Percentage Vocalized Time
Groups (G)	1	9.9**	32.2
Error	26	.5	91.9
Feedback (F)	2	29.6**	111.5*
F x G	2	.5**	109.4*
Error	52	.03	38.3

* Significant at the .05 level of confidence.

** Significant at the .001 level of confidence.

TABLE 5

MEAN VALUES OF THE CHARACTERISTICS OF DURATION OF NORMAL SPEAKERS AND STUTTERERS (IN PARENTHESES) READING IN THREE CONDITIONS OF FEEDBACK.

Characteristics of Duration	NAF	DAF	Masking
1. Percentage of Vocalized Time	a. 70.9 b. (65.3)	65.9 (67.9)	70.8 (70.8)
2. Total Time (seconds)	a. 3.3 b. (4.1)	5.1 (6.0)	3.6 (4.9)

1.a. Any difference between two means of 4.4 is significant.

2.a. Any difference between two means of .8 is significant.

2.b. Any difference between two means of .9 is significant.

account for the opposing results.

Conture (1974) found that stutterers produced more words per minute in noise as opposed to quiet. His subjects read for 10 minutes in each condition before the measurements were made. Adams and Hutchinson (1974) summarized the current view that severe stutterers take longer total time in NAF than in masking while for mild stutterers the reverse is true.

Percentage of Vocalized Time (Column 2, Table 4; Row 1, Table 5)

Stutterers and nonstutterers did not differ in percentage of vocalized time scores. As with the analysis of total time scores, there were only 14 subjects in each group, and the finding of a significant interaction necessitated a separate analysis of feedback effects for each type of speaker. Stutterers read with the same percentage of vocalized time in the three auditory feedback conditions. Fluent speakers read with a significantly smaller percentage of vocalized time in the presence of DAF than in the two other feedback conditions. Percentage of vocalized time scores did not differ in masking and NAF for the fluent speakers. Table 4 presents a summary of the results of the statistical analysis in Column 2; Table 5 presents the means for comparison in Row 1.

Fairbanks (1955) found an increase in percentage of vocalized time for his fluent speakers in the DAF condition, and his absolute values (85% in NAF; 89% in DAF) were higher than those reported here (70.9% in NAF; 65.9% in DAF). Spilka (1954) found that normal speakers had mean percentages of vocalized time of 43% for reading in the presence of NAF and 67% for reading in the presence of DAF, the reverse of the trends reported here and by Fairbanks. Both Fairbanks and Spilka may have computed vocalized time

in a manner that was different from that of the present investigator who defined vocalized time as those intervals in which periodicity was observed.

Summary

In this chapter the mean values for the 13 measures of fundamental frequency and the two measures of duration produced by stutterers and non-stutterers in three modes of auditory feedback were presented. The results of the statistical analyses of these mean values were discussed, and significant differences among the means were detailed. The mean values found here for the 15 measures were compared with the absolute and relative mean values reported by previous researchers.

CHAPTER V

SUMMARY AND CONCLUSIONS

An investigation of the effects of the fluency of the speaker and the type of auditory feedback on 15 characteristics of fundamental frequency and two characteristics of duration was conducted. Mean fundamental frequency; median fundamental frequency; number of total, upward, and downward pitch shifts; average extent of upward and downward pitch shifts; number of total, upward and downward inflections; average extent of upward and downward inflections; average rate of upward and downward inflections; total time; and percentage of vocalized time were measured in sentences excerpted from a paragraph read by stutterers and nonstutterers in NAF, DAF, and masking. Mingographic tracings of the 90 tape recorded sentences were divided into 1/20 second intervals, and the number of periodic waves within each interval counted. These values were subjected to various computations in order to get the measures of fundamental frequency and duration. The means of the measures were analyzed by separate analyses of variance. Fluency of the reader effected changes in two measures of fundamental frequency and one measure of duration. The delayed auditory feedback mode effected changes in eight measures of fundamental frequency and both measures of duration. The masking mode effected changes in the two measures of central tendency.

Effects of the Fluency of the Reader

The performances of stutterers and nonstutterers were significantly different in only three of the characteristics measured, total time, total inflections, and number of downward inflections. Since the number of upward inflections was not significantly different between the groups, the difference in the total number of inflections was just a reflection of the difference in number of downward inflections. Stutterers read with more downward inflections in greater total time than did nonstutterers. It was expected that stutterers would take longer to read a sentence because non-fluent speech is characterized by repetitions, prolongations, and hesitations. The implications of the increased number of downward inflections in the speech of stutterers are unknown.

Effects of Masking

Only two measures made in the masking condition were found to be different from those made in the NAF condition. Mean and median fundamental frequencies of subjects reading under masking were significantly higher than the mean and median of subjects reading under NAF. If masking has fluency-producing effects, the reasons for this effect lie outside the realm of this study or might be related to the change in fundamental frequency.

It was observed during the testing that almost every subject spoke louder while he was reading under masking than under NAF. (This increased loudness necessitated decreasing the gain control of the VU meter on the tape recorder). Though these adjustments weren't quantified, the observation seem to indicate that mean and median fundamental frequencies are

the only pitch characteristics of those measured that are changed when speech is produced with greater loudness.

If the stuttering subjects had been separated into mild and severe stutterers, significance may have been established for differences among durational characteristics.

Effects of DAF

Delayed auditory feedback is associated with similar changes in nine measures of fundamental frequency and duration for both stutterers and non-stutterers. The numbers of total, upward, and downward inflections and upward shifts increase under DAF while average rates of upward and downward inflections decrease. Mean and median fundamental frequencies and total time also increase in the DAF condition. DAF effects a decrease in the percentage of vocalized time for fluent speakers; there is no decrease in percentage of vocalized time for stutterers.

To restate, readers make more pitch changes and make them more slowly in DAF than in NAF. In the presence of DAF stutterers and non-stutterers use higher mean fundamental frequencies while reading a sentence. Fluent speakers take longer to read a sentence in DAF, but since this increase in time is accompanied by a decrease in percentage of vocalized time, most of the additional time is silence. Stutterers take longer to read a sentence in DAF than in NAF, but the percentage of vocalized time does not change. This demonstrates that stutterers prolong vocalizations and silence in the same proportions.

The finding that the measures of fundamental frequency characteristics of stutterers and nonstutterers change similarly from the NAF to the DAF condition was not predicted. However, it seems more than a coincidence that for seven of the measures of fundamental frequency--mean fundamental frequency, median fundamental frequency, numbers of total and upward pitch shifts, upward and downward inflections--the absolute values for the normal speakers under DAF were within .5 of the absolute values for the stutterers under NAF. Other investigators have concluded that the behavior of nonstutterers under DAF resembles the behavior of stutterers under NAF and vice versa.

Fairbanks (1955) found a similar increase in mean fundamental frequency from the NAF to the DAF condition. He did not find the changes in the other nine characteristics reported here.

When reading in the presence of DAF, stutterers and nonstutterers alike produced significantly more upward and downward inflections with significantly slower average rates in significantly more time than when reading in the presence of masking. Stutterers vocalized for equal percentages of time in both conditions; nonstutterers vocalized for a greater percentage of time in the masking condition.

Implications for Future Research

The present investigator observed that all but one of the stutterers were more fluent in the experimental conditions than in impromptu speaking and equally fluent in the experimental conditions, NAF, DAF, and masking. This observation was made of both severe and mild stutterers. The exceptional subject was very much more fluent in impromptu speaking and slightly more fluent in masking than in NAF or DAF. Measures of fluency should be

quantified in order to verify this impression.

The DAF condition was different from the NAF condition in nine characteristics of fundamental frequency and duration. If clinical use is to be made of these findings, another investigation using the same basic design with larger populations of stutterers is needed to validate the results of this report. Because hand measurement is horrendously time consuming, a reliable and valid computer program for the extraction of the parameters of this study is needed. Stutterers should be separated into a mild and a severe group to clarify the effects of masking and DAF on total time.

Following verification, a therapy regimen based on improving the vocal flexibility of stutterers should be tested to determine if increased flexibility will improve fluency. And, if such a regimen is more effective than a regimen based on prolongation.

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APPENDIX A

TABLE 6
AGES, HEIGHTS, AND WEIGHTS OF SUBJECTS .

NONSTUTTERERS			STUTTERERS		
Age (years)	Height (inches)	Weight (pounds)	Age (years)	Height (inches)	Weight (pounds)
5.* 21	73	160	22. 21	73	195
6. 19	70	158	23. 23	69	130
7. 28	72	269	24. 18	71	147
8. 22	72	235	26. 22	66	155
9. 20	74	180	28. 28	67	130
10. 22	71	157	29. 32	70	175
12. 24	68	180	30. 30	68	150
13. 22	71	167	31. 25	75	180
14. 18	69	145	33. 28	66	165
15. 21	68	135	34. 21	71	165
16. 19	75	175	35. 20	72	225
19. 19	74	175	36. 26	69	204
21. 21	67	115	37. 62	70	160
25. 29	68	140	40. 35	68	170
39. 22	72	165	41. 34	70	173

*Subjects were assigned consecutive numbers. Some subjects were not used because of technical or diagnostic difficulties.

TABLE 7

ORDER IN WHICH EXPERIMENTAL CONDITIONS WERE PRESENTED TO SUBJECTS.

Normal	Stutterers
5. Masking, NAF, DAF 6. Masking, DAF, NAF 7. DAF, Masking, NAF 8. DAF, NAF, Masking 9. NAF, DAF, Masking 10. NAF, Masking, DAF 12. DAF, Masking, NAF 13. DAF, NAF, Masking 14. NAF, DAF, Masking 15. NAF, Masking, DAF 16. Masking, NAF, DAF 19. DAF, NAF, Masking 21. NAF, Masking, DAF 25. Masking, NAF, DAF 39. Masking, DAF, NAF	22. NAF, Masking, DAF 23. Masking, NAF, DAF 24. Masking, DAF, NAF 26. DAF, Masking, NAF 28. NAF, DAF, Masking 29. NAF, Masking, DAF 30. Masking, NAF, DAF 31. Masking, DAF, NAF 33. DAF, NAF, Masking 34. NAF, DAF, Masking 35. NAF, Masking, DAF 36. Masking, NAF, DAF 37. Masking, DAF, NAF 40. DAF, NAF, Masking 41. NAF, DAF, Masking

APPENDIX B

TABLE 8

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION
PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE
INFLUENCE OF NORMAL AUDITORY FEEDBACK.

	Mean Fundamental Frequency (cycles per second)	Median Fundamental Frequency (cycles per second)	Functional Range (semitones)	Number Total Pitch Shifts	Number Upward Pitch Shifts	Number Downward Pitch Shifts	Average Extent Upward Pitch Shifts (semitones)	Average Extent Downward Pitch Shifts (semitones)	Number Total Inflections
5	99.7	96	5	6	4	2	2.2	1.5	14
6	83.5	84	5	6	4	2	3.2	1.5	19
7	110	108	9	6	4	2	2.4	5	14
8	120.3	122	5	5	3	2	3	6.7	17
9	103.7	108	9.5	6	3	3	1.8	6.7	11
10	112	114	15	9	5	4	9.2	5.9	16
12	109.7	112	19	6	3	3	4.5	4	19
13	116.8	118	14	5	3	2	1.7	4	12
14	99.3	100	16	5	3	2	2.7	2.2	12
15	117.2	116	9	8	5	3	3.5	2.5	10
16	108.1	112	8	3	3	0	2	-	9
19	106.8	106	7	3	1	2	2	7.2	10
21	118.4	118	4.5	5	3	2	2	7.7	12
25	99.1	100	6	5	4	1	2.7	2	12
39	89.1	88	8	7	3	4	3.3	2	14
22	91.4	98	5	7	3	2	5.7	6.5	10
23	112.7	120	8	9	7	2	2.4	12.2	14
24	96.6	100	17.5	9	5	4	8.6	7.9	16
26	148	150	6	7	5	2	3.2	1	10
28	108	114	13	7	2	5	4.5	3.6	18
29	107.6	110	5.5	8	5	3	2.3	6.7	17
30	111.5	120	12	8	2	6	2.7	3.1	18
31	111.8	116	8	5	2	3	4.5	6.7	13
33	126.2	126	11	6	5	1	2.4	3	14
34	108.3	108	7	8	6	2	3.2	1	12
35	93.2	98	16	7	3	4	2.7	1.1	16
36	122.1	120	8	6	3	3	3	2.7	10
37	126	122	6	6	5	1	1.3	3	14
40	110.1	110	8	3	3	0	1.8	-	16
41	114.6	114	8	4	1	3	2	4	14

Normal Speakers

Stutterers

TABLE 8 (CONTINUED)

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE INFLUENCE OF NORMAL AUDITORY FEEDBACK.

		Number Upward Inflections	Number Downward Inflections	Average Extent Upward Inflections (semitones)	Average Extent Downward Inflections (semitones)	Average Rate Upward Inflections (semitones/sec.)	Average Rate Downward Inflections (semitones/sec.)	Total Time (seconds)	Percentage Vocalized Time
5	7	7		1.6	3.1	28.7	27.5	3.3	70
6	8	11		2.4	2.9	23.6	31.5	3.2	76
7	5	9		3.3	2.8	34.7	27	2.7	78
8	7	10		4.9	3.3	71.6	27.3	3.3	75
9	6	5		7	7.1	62.2	38.4	3.5	71
10	6	10		4.7	6.0	39.3	50.4	3.9	67
12	9	10		7.4	8.9	81.2	69.8	3.8	75
13	5	7		6.1	4.1	42.1	30	2.7	83
14	5	7		3.1	7.1	31	45	3.2	74
15	3	7		2	3.8	60	25.8	3.5	59
16	3	6		4.3	5.5	22.6	35.7	2.5	77
19	5	5		4.5	3.7	40.9	16.1	3.3	70
21	7	5		2.9	2.7	50	21.6	3.7	53
25	5	7		2.2	3.3	19.1	20.9	4	65
39	7	7		2.1	3.4	23.1	23.4	3.8	63
22	4	6		4.9	3.1	35.4	24.7	3.4	73
23	6	8		7.5	5.2	43.9	38.2	4.6	70
24	7	9		4.3	4.2	38.7	49	3.7	53
26	3	7		1.3	3.2	11.4	13.8	5.3	49
28	6	12		5.9	2.7	52.2	24.6	4.5	72
29	7	10		4.7	2.5	44	21.7	3.7	71
30	9	9		5.3	4.4	50.5	51	3.4	76
31	8	5		4.7	5.4	51.7	56.8	3.8	63
33	4	10		7.1	4.9	95	38.8	4	67
34	3	9		3	3.5	30	25.1	4.5	58
35	6	10		6.0	6.1	41.1	45.2	4.2	69
36	3	7		3.3	2.5	23.5	21.2	4.8	52
37	6	8		2.3	2.4	13	29.2	3.7	80
40	6	10		3.1	3.1	26.4	25.3	-	-
41	7	7		2.9	2.2	21.6	27	4.2	61

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE INFLUENCE OF DELAYED AUDITORY FEEDBACK.

	Number Total Inflections	Average Extent Downward Pitch Shifts (semitones)	Average Extent Upward Pitch Shifts (semitones)	Number Downward Pitch Shifts	Number Upward Pitch Shifts	Number Total Pitch Shifts	Functional Range (semitones)	Median Fundamental Frequency (cycles per second)	Mean Fundamental Frequency (cycles per second)
Normal Speakers	11	-	4.9	0	5	5	5	104	103.5
	15	4	4.5	3	4	7	7	94	91.9
	12	-	2.5	0	6	6	5	118	118.1
	11	1	2.3	1	5	6	5	130	129.4
	11	2	1.3	2	3	5	7	114	113.4
	15	3.2	1.5	3	2	5	6	134	120.1
	21	2.5	4.5	3	5	8	13	128	126.4
	14	1.8	2	3	2	5	5	120	115
	11	1	1.8	1	5	6	7.5	100	100.1
	12	2.2	4.1	4	5	9	7	126	123.1
	25	5.1	5.6	5	7	12	9	120	115.5
	17	8.7	2.7	3	3	6	6.5	112	111.6
	11	11.7	10	3	2	5	14	120	115.1
	24	2.5	4.2	2	8	10	6.5	110	107.5
	11	2.6	6.2	4	3	7	8	92	90.1
Stutterers	8	-	2	0	4	4	6.5	104	108.7
	18	6	2.1	1	4	5	5.5	120	120.7
	19	-	2.9	0	9	9	7	100	99.2
	16	3	5.2	3	5	8	7	144	144.9
	16	2	3.5	2	2	4	5	114	112.9
	18	3.5	4.7	2	6	8	8	130	130.2
	17	9.2	6	5	5	10	14.5	110	111.3
	20	5	4	2	4	6	14	116	103.6
	20	7.2	8.3	3	3	6	7	130	131.8
	17	4	2.9	1	5	6	5	120	119.5
	16	7	2.4	1	5	6	12	100	99.6
	27	2	1.8	2	9	11	7	156	153.5
	16	2.1	2	5	1	6	5	204	202.4
	27	6.2	1.8	4	5	9	6	120	113.7
	20	2.5	1.7	3	6	9	8	114	114.5

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE INFLUENCE OF DELAYED AUDITORY FEEDBACK.

		Number Upward Inflections	Number Downward Inflections	Average Extent Upward Inflections (semitones)	Average Extent Downward Inflections (semitones)	Average Rate Upward Inflections (semitones/sec.)	Average Rate Downward Inflections (semitones/sec.)	Total Time (seconds)
								Percentage Vocalized Time
Normal Speakers	5	3	8	2.7	4.6	20	32.2	4
	6	7	8	1.9	2.5	19.3	15.4	4.8
	7	3	9	2.3	3.4	35	20.7	3.6
	8	4	7	1.4	3.3	14.7	17	4
	9	5	6	3.1	2.8	17.2	21.9	4.2
	10	7	8	2.9	3.4	22.8	13.2	6.6
	12	10	11	4	4.9	22.2	25.9	7.4
	13	6	8	4.4	3.7	31.2	22.3	4.7
	14	3	8	1.7	2.9	7.1	15.1	3.8
	15	4	8	2.5	3.6	15.4	20	5
	16	11	14	4.9	4.4	38.6	34.2	7.5
	19	9	8	4	3.2	52.1	20.4	4.2
	21	5	6	7.4	4.4	98.7	26.5	3.5
	25	9	15	2.8	3.7	20	27.4	8.3
	39	6	5	1.7	4.7	8.9	20	4.7
Stutterers	22	2	6	2	3.5	20	11.5	4.9
	23	7	11	4.5	3.5	36	22.6	4.9
	24	6	13	4.7	5.8	38.6	39.5	5.5
	26	6	10	3	4.2	22.5	20.2	6.5
	28	7	9	2.3	2.4	13.9	11.7	5.9
	29	8	10	4.9	6.5	44.6	30.8	6.2
	30	8	9	6.6	5.5	48.2	46	4.7
	31	8	12	6.1	6	55.4	52.4	5.5
	33	9	11	2.2	2.6	23.6	15.9	5.7
	34	6	11	2.5	2.8	28.6	21	5.7
	35	7	9	8	8	57.4	59.2	3.5
	36	12	15	2.4	3.3	17.1	13.2	13.2
	37	8	8	2.7	2.5	8.3	18.2	6.7
	40	13	14	5.1	3.8	34.1	27.4	-
	41	8	12	7.1	5.4	50.7	49.6	5.3

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE INFLUENCE OF MASKING.

	Number Total Inflections	Average Extent Downward Pitch Shifts (semitones)	Average Extent Upward Pitch Shifts (semitones)	Number Downward Pitch Shifts	Number Upward Pitch Shifts	Number Total Pitch Shifts	Functional Range (semitones)	Median Fundamental Frequency (cycles per second)	Mean Fundamental Frequency (cycles per second)	
Normal Speakers	5	103.3	104	7.5	9	7	2	2.7	3.2	10
	6	95.8	96	8	7	4	3	1.6	3.7	17
	7	124	128	11	5	5	0	5.3	-	17
	8	133.3	134	6	6	5	1	5.1	1.5	14
	9	109.9	108	11	7	4	3	5.5	5.8	12
	10	147.8	152	9	8	5	3	3.2	5.7	15
	12	129.5	128	11	9	4	5	2.6	1.6	18
	13	114.5	116	4.5	3	2	1	2.5	2.5	9
	14	105.2	108	10.5	5	3	2	1.7	6	10
	15	138.4	140	9	6	3	3	3.7	7	13
	16	139.8	120	9.5	5	4	1	3.4	2	13
	19	111.8	110	7	7	4	3	4.4	10.2	15
	21	123.3	124	10	7	5	2	6	4.2	15
	25	110.2	104	7	6	3	3	1.8	3.5	10
	39	94.8	94	9	9	4	5	3.1	3.4	13
Stutterers	22	108.2	106	7	8	6	2	2.8	2	13
	23	130.2	132	7	9	9	0	3	-	18
	24	105.6	104	10.5	7	4	3	4.2	1.7	14
	26	158.2	160	7	6	4	2	4.5	2.2	14
	28	120.5	122	13	8	4	4	2.9	6.1	17
	29	120	122	6	8	5	3	2.8	3.7	15
	30	109.2	110	14.5	8	3	5	2.2	7.4	23
	31	114.2	116	18	6	2	4	7.5	6.2	7
	33	138.7	130	7	9	6	3	5.2	4.3	15
	34	126.4	124	8	6	4	2	3.1	3.5	17
	35	96.6	100	13	4	3	1	4.3	7	21
	36	158.2	160	9	6	2	4	4	2	11
	37	148.3	152	6	7	4	3	1.9	2.3	15
	40	121.5	124	6	2	1	1	5	13	13
	41	125.9	124	6	7	2	5	2.5	4.6	11

TABLE 10 (CONTINUED)

VALUES OF THE CHARACTERISTICS OF FUNDAMENTAL FREQUENCY AND DURATION
PRODUCED BY NORMAL SPEAKERS AND STUTTERERS WHILE READING UNDER THE
INFLUENCE OF MASKING.

	Number Upward Inflections	Number Downward Inflections	Average Extent Upward Inflections (semitones)	Average Extent Downward Inflections (semitones)	Average Rate Upward Inflections (semitones/sec.)	Average Rate Downward Inflections (semitones/sec.)	Total Time (seconds)	Percentage Vocalized Time
5	3	7	5.5	5.1	44	33	3.5	71
6	7	10	3.9	2.7	37.2	25.6	3.5	79
7	5	12	6.5	4.8	50	34.8	4.9	60
8	6	8	1.4	4.9	15.4	39.5	3.5	73
9	6	6	3.7	4.9	27.3	30.3	3.3	74
10	8	7	3.2	4.7	30.9	25.9	4.4	63
12	8	10	4.6	4.3	49.3	36.2	3.9	73
13	4	5	5.1	5.3	51.2	28.6	2.6	75
14	4	6	6.1	4.6	37.7	22.4	3.7	74
15	4	9	6.7	2.7	98.2	20.8	3.8	62
16	4	9	2.9	3.3	17.7	30.8	2.7	82
19	8	7	4.7	3.9	60.1	25	3.5	79
21	7	8	2.1	5.2	25.2	31.3	4	64
25	3	7	5.8	2.6	46.7	20	3.9	63
39	6	7	5.8	5.4	50	39.5	4.1	64
22	4	9	1.2	2.8	16.7	16.7	3.9	72
23	7	11	2.5	4.7	23.3	32.2	5.9	58
24	6	8	2.5	4.6	24	36.1	4.2	60
26	4	10	2.2	2.3	22.5	22	3.5	71
28	8	9	5.4	4.2	62.1	27.3	4.2	79
29	6	9	5.5	4.7	52.8	26.2	3.7	79
30	9	14	6.9	3.2	61	45	3.6	79
31	4	3	11.7	13.5	89.5	55.9	4	65
33	4	11	4	3.9	45.7	29.5	3.9	71
34	7	10	2.3	2.6	32	22.5	3.3	79
35	10	11	4.4	6.1	74.2	57	3.2	77
36	4	7	2.1	2.9	26.1	14	4.3	68
37	7	8	1.9	2.4	18.6	18.1	4.4	70
40	6	7	6.7	4.5	40	35	-	-
41	7	4	4.1	3.6	35.6	48.3	4.2	63