AN ACOUSTICAL/TEMPORAL ANALYSIS OF EMOTIONAL STRESS IN SPEECH

By

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This dissertation is dedicated

to the memory of my parents

James and Evelina Hicks

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Abstract of Dissertation Presented to the Graduate Council of the University of Florida in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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The external manifestation of emotions has been of interest to researchers for many years. For example, as early as 1872 Charles Darwin discussed the use of facial and body movements as indicators of emotion in his book The Expression of the Emotions in Man and Animals. However, Darwin's text is only descriptive in nature. Subsequently, various physiological measures have been correlated to emotional states; among these measures have been (1) heart rate, (2) galvanic skin response (GSR), (3) electroencephalogram (EEG), (4) respiration and (5) blood pressure.

However, more recently scientists have investigated speech parameters as possible indicators of the emotional state of the speaker. There are many instances in which knowledge about the emotional state of an individual would be desirable. It also would be advantageous to obtain this

information without any direct, physical contact with the individual--as is currently required with the above mentioned physiological measures. A research thrust aimed at determining the acoustical/temporal speech parameters correlated to emotional stress should be useful to the area of speech communications. Most of the previous investigations have been limited in scope. For instance, many have analyzed only one parameter--primarily fundamental frequency (f_o)--and/or had very small subject populations.

The thrust of the current study focuses on an acoustical/temporal analysis of the effects of stress on speech. Included in the study were both laboratory induced stress and a "real" situational stress. The laboratory stress was induced via an electrical shock as the stressor. The situational stress environment consisted of a university level public speaking course in which the students were recorded while delivering speeches to an audience of their peers.

Included in the analysis were several characteristics within the intensity, fundamental frequency and temporal domains. The following parameters were analyzed within the intensity domain: (1) maximum, (2) mean and (3) mode of the intensity distribution. The mean and distribution of speaking fundamental frequency (SFF) were analyzed within the frequency domain. The temporal parameters included: (1) speech/pause ratio, (2) speech rate, (3) the time-energy distribution, (4) the number of speech bursts, (5) the number of pauses, and (6) speech time/total time ratio. In addition, the number of disfluencies in each speech sample also was measured. A comparison was made between speech samples produced normally and under stress. The comparison was based on the acoustical/temporal parameters analyzed.

The results of the data analysis indicate that measurable acoustical/temporal changes do occur in speech produced under stress as compared to normal, non-stress speech. However, the magnitude of these changes seems to be a function of the type of stress. For the situational stress experiment, 68.8% of the parameters differed significantly between the normal and stress speaking conditions, whereas only 18.8% changed significantly in the laboratory stress experiment.

It was found that for the laboratory stress paradigm all of the parameters increased for the stress speech, relative to normal. However, only the maximum intensity, time-energy distribution and the number of disfluencies increased significantly. That is, the stress induced by electro-shock did not alter the subjects' speech patterns to any great extent.

However, significant differences were found to exist between the normal and stress speech samples in the situational stress experiment. Specifically, significant decreases were found for the intensity measures as well as the number of speech bursts and pauses. Conversely, the mean SFF and temporal parameters (except for speech rate) were found to increase significantly. Based on these findings, the general effects of stress on speech seem to: (1) decrease intensity, (2) increase SFF, (3) slightly decrease speech rate, and (4) decrease the number of speech bursts and pauses, resulting in longer speech bursts. However, the variability in these parameters also increased indicating that the observed changes may not be uniformly consistent for all individuals. Therefore, baseline (normal) data may be required for an individual before the presence of stress in that individual can be detected.

CHAPTER I

INTRODUCTION

For some time scientists have searched for parameters within the speech signal that might reveal the emotional state of the talker (Bonner, 1943; Cohen, 1961; Friedhoff et al., 1964; Barland, 1973; Fairbanks & Hoaglin, 1941; Fairbanks & Provnost, 1939; Hecker et al., 1968; Kuroda et al., 1976; Silverman & Silverman, 1975; Simonov & Frolov, 1973, 1977; Williams & Stevens, 1969, 1972). A number of the cited experiments were conducted prior to current advances in technology; hence, some of the parameters these scientists may have preferred to study were not amenable to their research. However, recent developments of equipment and techniques for the acoustical analysis of speech permit the investigation of issues previously not possible.

It is well known that speech contains both linguistic and paralinguistic messages. That is, virtually any utterance conveys information on several levels--including that related to cultural background, regional dialect, country of origin, and possibly the general feeling about the statement being made by the speaker. Perhaps more important, a talker can transmit information via speech that reflects his current health and emotional state.

There are many instances in which knowledge about the emotional state of an individual would be desirable. Further, there are situations where it would be advantageous to obtain this information without any direct, physical contact with the person being evaluated--for example, in aerospace or diving operations. Indeed, research directed at determining the acoustical correlates of emotional stress should be useful to many of the sub-specialties within the speech communication area; among these specialties are Forensics, Aerospace and Diver Communications, as well as Psychology/Psychiatry.

Psychology/Psychiatry

Psychiatrists and psychologists appear to rely on the parallel encoding of linguistic and emotional information by their patients in order to treat these individuals (Friedhoff et al., 1964; Ostwald, 1963). For example, Ostwald states, "whenever direct expression involves sound making--emotive sound making--acoustics has something tangible to contribute to psychotherapy" (p. 85). Thus, it would appear that Ostwald recognized the contribution to be made to psychotherapy by paralinguistic information encoded within the speech signal. A substantial benefit would accrue to psychotherapy if objective methods of evaluating the emotional state of the patient could be developed and used to complement subjective observations of the psychologist/ psychiatrist. In short, if the therapist could identify the emotion (fear, anger, or anxiety, say) being expressed by the patient, he should be able to provide more effective treatment.

Forensic Communication

Knowledge of emotional stress in speech is important to the area of Forensic Communication. For example, when a criminal is recorded making a bomb threat, it is desirable to determine his emotional state: Is it one where there is a high probability that he will follow through with the threat? Another illustration: It is obvious that when a suspect lies during interrogation, he is under stress. Can the acoustic speech signal be used to determine the likelihood that the suspect is lying in such cases? In an effort to answer these questions, "detectors" of voice stress recently have been developed. They are purported to be effective as "lie detectors"; they include the Psychological Stress Analyzer (PSA), Mark II, Hagoth (Bennett, 1977), Psychological Stress Evaluator (PSE) and Voice Stress Analyzer (VSA) (Kubis, 1973; McGlone, 1975; Almeida et al., 1975). However, independent research has shown, for example, that at least two of these devices (the PSE and VSA) probably are not capable of the analysis claimed by their proponents (Barland, 1973; Kubis, 1973; McGlone, 1975). For example, the PSE reportedly evaluates stress by demodulating the inaudible, stress related.FM patterns known as "Muscle Micro Tremors (MMT)" (Almeida et al., 1975). However, Almeida et al. conclude "our results, however, do not confirm the theoretical basis of the PSE" (p. 4).

Speaker identification is another area within Forensic Communication that has been shown to be affected by stress (Hollien & Majewski, 1977; Doherty & Hollien, 1978). Hollien and Majewski found that the ability of the long-term speech spectra (LTS) technique to identify individuals was reduced somewhat under conditions of stress--induced by randomly applying electric shock to the subjects while they were speaking. When a fullband procedure (80-10,000 Hz) was used, the effect of stress was to decrease the identification scores by 8% over the unstressed (normal) speaking condition. Moreover, this difference (between the normal and stress identification scores) was greater (20%) when the samples were bandpassed (315-3150 Hz) to simulate a telephone transmission system. Therefore, it would appear that the presence of stress not only degrades the LTS speaker identification technique in a laboratory setting, but when "in-the-field" restrictions are imposed, this negative effect is magnified.

Doherty and Hollien (1978) examined a set of three speaker identification vectors in the presence of speaker and system distortions; these vectors consisted of long-term speech spectra (LTS), speaking fundamental frequency (SFF) and speaking time (ST). They used stress, induced by electric shock, as one of the speaker distortions; system distortion was produced by subjecting the LTS vector to transmission distortion--specifically, to a limited pass-band of 315-3150 Hz. Doherty and Hollien conclude that, "while the described approach functioned adequately for the normal speaking condition, no vector (singly or in combination) adequately differentiated talkers when speech was distorted" (p. 1).

It is assumed that, while committing a crime, the criminal is under stress and his speech may be altered.

Therefore, the changes that occur in the criminal's speech due to stress may influence the probability of making a correct identification. It would appear that knowledge about the effects of stress on speech is important to the area of Forensic Communication. Conversely, the development of, and attempts to use devices such as the PSE indicate the need for increased information about stress and its effect on speech.

Diver Communication

The relationship between stress and its effect on speech is also important to Diver Communication. Once the diver enters the water, he is in an alien environment that is dangerous and potentially fatal; thus, he is ipso facto in a stressful situation. Monitoring the diver's speech in order to determine his emotional state would add another safety feature to a diving operation. Moreover, knowledge of a diver's specific emotional state should be useful in anticipating and preventing diving accidents; in turn, a safer working environment should result.

Safety measures are even more important in the case of saturation diving. In addition to the dangers and stresses of "shallow water" diving, the saturated diver remains submerged for long periods at great depths and is unable to surface safely in case of an emergency. Furthermore, a saturated diver tends to be assigned a heavier work schedule and lives in the highly restricted confines of an underwater habitat which leads to more stress--at least, when the situation is compared to conventional diving.

Voice communication channels are usually available during most diving operations. The ability to use existing communications to monitor a diver's level of stress would add to the safety of diving operations without imposing additional burdens on the divers.

Aerospace Communications

The analysis of speech to determine emotional states also is important to Aerospace Communication. The emotional state of pilots and astronauts based on speech samples has been investigated by authors such as Williams and Stevens (1969), Simonov and Frolov (1973) and Kuroda et al. (1976). Williams and Stevens (1969) analyzed speech samples obtained during obviously (emotionally) stressful situations. Their recordings consisted of air-to-ground communications between pilots and control tower operators during emergency (i.e., stressful) situations, plus a recording of the radio announcer describing the Hindenburg disaster. These authors obtained fundamental frequency (f_o) contours of the stressed speech using narrow-band sound spectrograms sampled at 0.15 sec intervals. They found differences in f_o contours of the speech samples recorded during the emergency situation as compared to samples before the emergency. The normal (nonstressed) samples were characterized by smooth, slow, and continuous changes in fundamental frequency as a function of time; the stress contours exhibited fluctuations that often were neither smooth nor continuous. Williams and Stevens state that when emotional stress is experienced, the speech of the individual may exhibit "sudden changes or jumps in fundamental frequency from one syllable to the next, and rapid up-and-down fluctuations may appear in the contour" (p. 1372). Furthermore, they found an increase in the mean f_o for the stressful condition as compared to normal speech--and the range of f_o was greater for stress. Williams and Stevens conclude that measurement of the median f_o and range of f_o may serve to classify whether an individual is undergoing emotional stress, providing, of course, his normal values are known.

Simonov and Frolov (1973) estimated the emotional stress experienced by two cosmonauts during several phases of the flight of "Voskhod 2" and during training in heat and pressure chambers. They used a one-third octave spectral analysis within the range of the first formant (300-1200 Hz) and compared these results to measures of heart rate (beats/minute). These authors were able to differentiate the degree of emotional stress in their subjects about 85% of the time by means of this method.

Kuroda _et al_. (1976) analyzed the communications of pilots in 14 actual aircraft accidents, eight of them fatal, using a measure of fundamental frequency; specifically, the vibration space shift rate (VSSR). VSSR is calculated by analyzing the spacing between the vertical striations on wideband sound spectrograms; specifically, the widest spacing between vertical striations during the normal phase of a flight is compared to the widest spacing encountered during an emergency situation. They found that the highest VSSR occurred during the initial phase of an emergency situation. Furthermore, when the emergency resulted in a fatality, Kuroda _et al_. found that a high VSSR had been maintained during the emergency. Therefore, Kuroda _et al_. (1976) conclude that "by analyzing the voice communications of a pilot involved in an emergency situation, we have a method of determining whether stress itself could have been a contributing factor in the outcome of that in-flight emergency" (p. 533).

As can be seen from the above discussion, research on the manifestation of stress via speech is indeed applicable to numerous areas of speech communication. Its application ranges from assisting law enforcement agencies in their investigations to avoiding a possible fatality in diving and/or aerospace operations. However, the research conducted to date has been limited in its scope, leaving many questions unanswered.

A Definition of Stress

If research is to be carried out on stress, it would appear that the first step would be to operationally define this psychological state. Many attempts at such a definition have been reported. For example, in _Psychological Stress: Issues in Research_, Appley and Trumbull (1967) state, "It is further evident from the definitions cited that another area in which separation of psychological from physical aspects is required is that of threat" (p. 36). They also quote E. A. Haggard who stated, "An individual experiences: emotional stress when his overall adjustment is threatened, when his adaptive mechanisms are severely taxed and tend to collapse" (p. 39). Therefore, it would appear that threat is a major variable in determining emotional (psychological) stress--at least of certain types. That is, an individual must perceive a threat to his ego, integrity, values or goals. Lazarus (1966) states that the individual must "anticipate a confrontation with a harmful condition of some sort" (p. 25); he goes on to say that "the strength of the stress response is determined by the strength of the intervening process, that is, by the degree of threat" (p. 26). Furthermore, emotional stress can be defined as a reaction to a stimulus condition; for example, Basowitz et al. (1955) concluded, "We should not consider stress as 'imposed' upon the organism, but as its 'response' to internal or external processes which reach those threshold levels that strain its physiological and psychological integrative capacities close to or beyond their limits" (pp. 288-289). Further, Appley and Trumbull (1967) suggest that stress "is a response state and that its induction depends on the mediation of some appraising, perceived, or interpreting mechanism" (p. 46). Therefore, it would appear that, in part, emotional stress is a mediated reaction to a threat to an individual.

Often the terms stress and emotion are used interchangeable, but, are they synonymous? A given stressful situation may produce dissimilar emotions in different people as well as diverse emotions in the same individual at different times. Some emotions (grief, fear, anger) are invariably connected with stress, but that does not necessarily equate stress and emotion. "There are many emotions that have nothing to do with stress (love, joy, delight)" (Arnold, 1967, p. 50). Arnold has called the emotions accompanying psychological stress "contending emotions"; they are primarily anger and fear and their combinations. Therefore, as stated by Levitt (1967), stress "appears to be a kind of operator word which is applied in connection with emotion-evoking situations and reactions" (p. 15). Based on the above discussion, it would appear that a reasonable definition of stress is that it is a psychological state that is a response to a perceived threat and it will be accompanied by specific emotions.

Laboratory Induced Stress

Stress can be operationally defined in the laboratory; that is, as long as the definition meets the above criteria. Further, the definition can be based on, or related to, the use of a particular stressor of either physiological or psychological origin. For example, physiological stressors are usually employed to induce physical discomforts; they include electric shock (Farr & Seaver, 1975; Doherty & Hollien, 1978; Hollien & Majewski, 1977; Silverman & Silverman, 1975) as well as olfactory stressors (Ostwald, 1963; Farr & Seaver, 1975). On the other hand, procedures to induce psychological stress include having subjects (1) give a five-minute speech to a group of peers or (2) sit in a small room for ten minutes with the object they are afraid of most (Farr & Seaver, 1975). Finally, it is important that the laboratory task be realistic compared to the task the subject will ultimately have to perform under real stress (as distinguished from laboratory stress). In this case, the investigator's conclusions of subjects' behavior under real stress will be more valid.

Situational Stress

In this case, the experimenter has not induced the stress; rather, the situation is normally stressful to the subjects. In situational stress, the consequences often are more severe than, for example, they would be if the subjects received a mild electrical shock. In this case, their lives might be threatened--as in the case of pilots or astronants in emergency situations (Kuroda et al., 1976; Simonov & Frolov, 1973 and 1977; Williams & Stevens, 1969). In addition, the subjects may not have the option of avoiding the stressor. However, situational stress need not be life threatening; for example, students taking an oral examination or giving a public address might experience a high level of stress even though their life is not in danger. In this case the stress is of a psychological nature since the subjects are not being physically threatened.

Therefore, the investigator can either create and induce stress in the laboratory or utilize the stress produced by a specific situation. In addition, he can use any of several measures to describe the effects of the stress. These measures can range from physiological to subjective/ perceptual.

Measures of Stress

Physiological Measures

The external manifestation of emotions has been of interest to researchers for many years. For example, Charles

Darwin (1872) discussed the use of facial and body movements as well as postures in his book _The Expression of the Emotions in Man and Animals_. However, Darwin's text is only descriptive in nature. Various methods subsequently have been used in an effort to measure the physiological correlates of emotional stress; these include (1) heart rate (Deane, 1961; Bowers, 1971; Bankart & Elliot, 1974); (2) galvanic skin response (GSR) (Bowers, 1971; Bankart & Elliot, 1974); (3) electroencephalogram (EEG) (Itil _et al_., 1976); (4) respiration (Sovijarvi, 1974); and (5) blood pressure (Brod _et al_., 1959; Blair _et al_., 1959).

While these measures have resulted in relatively accurate indicators of stress, they can introduce problems when used "in-the-field." For example, physical contact with the subjects is required to obtain any of these measures. Such contact does not create serious problems in clinical or laboratory applications but prolonged monitoring (of astronauts or divers, for example) can result in severe complications. Despite attempts to eliminate the problem, such as design improvements in the sensors and the use of creams or jellies at the placement site, extended attachment of sensors may lead to skin irritations and other undesirable consequences. For this reason, it has been recommended that GSR, respiratory rate, EEG and other physiological measures be recorded only intermittently and the sensors removed after each recording. In addition, subjects' physical activity is restricted while the sensors are attached and he "becomes an observed subject who is by no means indifferent to the experiment in which he is involved" (Simonov & Frolov, 1977, p. 23)--a condition that possibly can affect the resultant measures.

Furthermore, attachment of electrodes or measuring equipment tends to distress a patient under psychiatric treatment. However, the therapist could easily tape record the therapy sessions as a standard procedure. The use of a tape recorder during therapy would disrupt the session minimally. The patient would simply accept the recording process as part of the psychiatric environment. Tape recording the therapy session would provide a permanent account of the session for later evaluation by the therapist. In addition, the recordings could be used as feedback for the patient, which can be important in psychiatric treatment.

Acoustical/Temporal Measures of Stress

Analysis of the speech signal as an index of emotional stress is becoming a viable approach to research due to advances in the state-of-the-science of acoustic phonetic analysis equipment and techniques. However, the parameters of the speech signal, which are critical to the identification of stress, as yet have not been determined. Moreover, previous investigations have focused primarily on the frequency domain of these signals (e.g., fundamental frequency, range of fundamental frequency and formant structure) and have neglected intensity and temporal parameters. It would appear necessary that the parameters of each of these domains be investigated as possible indicators of emotional stress.

Intensity

Although it is a totally different type of stress, the study of research on linguistic stress (emphasis) can be of aid to the Acoustic Phonetician. Linguistic stress has been found to influence the intensity of a stressed word. In a 1937 study by Tiffin and Steer, it was found that the average intensity of the stressed production of a word was 9.3 dB higher when compared to its unstressed production. Further, the stressed words were more intense than the unstressed about 71% of the time. On the syllabic level, Ortleb (1937) found that when compared to unstressed syllables, the emphasized syllables were more intense in both emotional and unemotional material; however, the intensity increase was more pronounced in the emotional material. Further, Schramm (1937) observed that the intensity of accented syllables was greater than the unaccented syllables in 78% of the words studied. Therefore, it would appear that intensity changes are important indicators of linguistic stress.

When intensity features related to emotional stress have been studied, the relationship between intensity and stress has not been found to be obvious. For example, when studying emotional stress, Hecker *et al.* (1968) did not find consistent intensity differences between their control (nonstress) and stress conditions. Six of their ten subjects exhibited small and inconsistent differences in intensity between the two conditions. Of the remaining four subjects, only one showed an increased intensity for the stress condition while the remaining three subjects *lowered* their intensity level under stress. In a study by Friedhoff *et al.* (1964), subjects were instructed to respond no to a series of questions even though the correct response to some of the questions should have been yes; this technique was utilized to establish a mildly stressful lying situation. These authors report that average intensity increased under the condition of lying; however, variability was large, i.e., "some individuals give a consistently louder and some a consistently softer response when lying." Friedhoff et al. also measured the intensity of the response two-six-nine under normal (nonstress) and stressed conditions, using electric shock as the stressor. They found that maximum intensity shifted from the last word (nine) for the normal condition to the first word (two) for the stress condition. However, it is not clear from their study whether they are reporting a trend across subjects or the results from only one subject. Therefore, it would seem that the manner in which intensity manifests emotional stress is not as well defined as it is for linguistic stress. However, intensity variability and the amount of intensity change might prove to be important indicators of emotional stress.

Fundamental Frequency (f_o)

The f_o of speech also may be a parameter which is influenced by stress. For example, Fairbanks and Provonost

(1939) studied the pitch characteristics of six actors, reading the same test passage and expressing five emotions: contempt, anger, fear, grief, and indifference. They measured (1) pitch contours,[1] (2) pitch level, (3) pitch range, (4) rate of pitch change, (5) extent of pitch shifts, and (6) the number of changes in the direction of pitch movement per second. These authors report that they could distinguish among the five emotions they studied solely on the basis of the f_o measures. For example, they found that fear was identified as having the (1) highest median pitch level, (2) widest total pitch range, (3) largest excursion of all pitch shifts (together with anger) and of upward shifts within phrases, (4) largest change in pitch level between phrases, (5) fewest pauses during which no pitch change occurred, and (6) highest number of pitch changes per second of speaking time. Therefore, it would appear that fundamental frequency characteristics serve to differentiate among emotions.

In an investigation of the affects of task-induced stress on speech, Hecker <u>et al.</u> (1968) required ten subjects to read six meters and report the sum of the readings together with a test phrase. In this experiment they could

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[1]Fairbanks and Provnost used the term pitch interchangeably with f_o.

vary the level of stress induced in the subjects by controlling the duration of the meter display. The results of this study indicated inconsistent changes in f_o across subjects. That is, some of the subjects raised their fundamental frequency while others lowered it as a function of increased stress. These authors point out that those subjects who lowered their fundamental frequency also spoke at a lower intensity level--as apparently these parameters were interrelated.

Somewhat different results have been reported by Williams and Stevens (1969) who conducted their study using the air-to-ground communications between pilots and control tower operators during known stressful (i.e., emergency) situations. In an analysis of both pilots' and control tower operators' voices (for indications of stress), they obtained the level and range of f_o and f_o contours (from narrow band spectrograms). They found that under increased levels of stress the pilots and air traffic controllers raised their f_o and showed "irregularities and discontinuities" in f_o contours. Williams and Stevens (1969) also studied f_o usage in the voice of the announcer who described the Hindenburg zeppelin crash--both before and after this disaster. In addition to an increase in f_o

after the crash, they found that the announcer greatly reduced his inflectional pattern (variations in f_o) during the period he was under high stress.

In 1972 Williams and Stevens investigated the acoustical correlates of several emotions (anger, fear and sorrow) as portrayed by actors. In their analysis of these simulated emotions, they observed differences in mean f_o and range of f_o. They conclude that measurement of the median f_o and range of f_o for a speech sample serves to differentiate among emotions--assuming that the normal f_o and range of f_o for the talker are known.

On the basis of these experiments, it would appear that a speaker's emotional state can be determined by analyzing the acoustic speech signal. However, it can be seen that disagreement remains as to the affect of stress on f_o as Hecker et al. (1968) report intersubject variability while Williams and Stevens (1972) indicate that f_o is raised when subjects undergo emotional stress. Some discrepancies also can be found in the data contrasting emotions based on f_o measures (Fairbanks & Provnost, 1939; Williams & Stevens, 1972). Finally, when reporting changes in f_o, authors often describe: irregularities in f_o (rapid fluctuations) or irregular "bumps" in f_o

contours, "irregular bumps in the contour, which might be interpreted as a kind of tremor" (Williams & Stevens, 1972) and "vibration of the vocal folds was too irregular" (Hecker et al., 1968). While the statements above are descriptive and observational in nature, analysis of these rapid fluctuations in f_o may prove useful in the detection of emotional stress. Thus, it would appear that the relationship between stress and its affect on speaking fundamental frequency requires further investigation.

Temporal Measures

The temporal characteristics of speech have also been suggested as potential indicators of both emotional and linguistic stress. For example, increased duration of both words and syllables was found to be a major correlate of linguistic stress (Ortleb, 1937; Schramm, 1937; Tiffin & Steer, 1937). Further, Fairbanks and Hoaglin (1941) found that simulated emotions (anger, fear, indifference, contempt and grief) could be differentiated to some extent on the basis of speaking rate, speech to pause-time ratio, and durations of speech and pauses. However, they report that the five emotions could be divided into two groups based on these temporal measures, with anger, fear, and indifference in one group and contempt and grief in the other. All three of the first group of emotions are characterized by rapid speaking rate and shortened durations of phonation and pauses, but did not differ significantly from each other. Contempt and grief, on the other hand, could be differentiated both from each other and from the other emotions. Although they were both characterized by a slow rate, the rates (in simulating contempt) are produced by increasing the duration of both speech segments and pauses. On the other hand, the slow rate for grief results almost entirely from prolonged pauses, particularly those between phrases.

Disfluency

An additional parameter that may serve as an indicator of stress is speech fluency/disfluency. For example, Silverman and Silverman (1975) have defined this characteristic (disfluency) as follows: "repeating part of a word or an entire word, repeating a phrase, inserting extra sounds between words (ah, um), changing the wording of a sentence, prolonging the sounds of a word, or breaking-up the sounds of a word." In their study, Silverman and Silverman informed their subjects that an electric shock would be administered for each instance of disfluency during the reading of a 330 word passage. They found that under this stressful condition, normal speakers tended to become more fluent. That is, under stress the normal speakers were more accurate in their speech production as compared to the nonstress speaking condition. In short, it would appear that this feature may serve as an indicator of a speaker's emotional state.

Subjective Judgements of Stress

Stress can be quantified in other ways. These approaches include subjective measures such as aural/perceptual identification of stress by listeners and self-ratings by the subjects themselves of the level of stress they experienced.

Aural perception

It is generally agreed that the stress an individual experiences can often be detected merely by listening to his speech. Although aural/perceptual procedures are not as objective and analytical as the physiological, acoustical and temporal measures previously discussed, they remain valid dimensions for determining a speaker's emotional state. For example, Fairbanks and Provnost (1939) obtained correct aural perceptual identification of five emotions ranging from 66% to 88%. Therefore, they conclude that "emotions expressed by the voice alone are readily identifiable" (p. 104). Furthermore, Hecker et al. (1968) used an aural/perceptual procedure in their study and found that listeners were able to correctly identify stressful responses from 66% to 83% of the time.

An aural/perceptual evaluation is of major importance in any study using simulated emotions as speech material in order to verify the subjects' accuracy in affecting the emotions under investigation. Furthermore, the acoustical/temporal parameters critical to the perception of stress could be determined by comparing speech samples judged to be normal and those produced under stress.

Self-rating by subjects

In addition to the measures previously cited (physiological, acoustical, temporal and aural/perceptual), self-ratings by the subjects themselves are valuable in determining the level of stress they have experienced (Acker & Reynolds, 1966; Zuckerman et al., 1964). Indeed, this technique can be utilized to obtain an index of both levels of stress and possible intersubject differences in level. That is, what may be stressful to one subject may not stress another individual. Merely assuming that all the subjects had experienced a significant (or equal) level of stress could lead to erroneous conclusions based on the obtained data. For example, Farr and Seaver (1975) found that subjects rated various experimental protocols differently based on the level of stress produced. Therefore, self-rating by the subjects is important in order to insure that the subjects perceived a stress producing threat and to be able to quantify the level of perceived stress.

Objectives

The thrust of the current study is focused on an acoustical/temporal analysis of the effects of stress on speech. Included in the research protocol were both laboratory induced stress and nonlaboratory, or situational, stress. The laboratory stress was induced using a mild electric shock as the stressor. The situational stress condition consisted of speeches given by students enrolled in a university level public speaking course.

It is possible that, with further research, the emotional and stress states of an individual could be determined by an analysis of speech features. With this objective in mind, the current study consisted of an analysis of several acoustical and temporal speech parameters produced under emotional stress. Included in the acoustical analyses are intensity and fundamental frequency. Furthermore, several characteristics of each acoustical parameter were analyzed. For example, the following characteristics within the intensity domain were measured: (1) maximum intensity, (2) mean intensity, (3) the mode of the intensity distribution, and (4) the intensity distribution itself. Similarly, several characteristics within the temporal domain also were analyzed. The temporal characteristics included: (1) speech/pause ratio, (2) speech rate, (3) the time-energy distribution, (4) the number of speech bursts, (5) the number of pauses, and (6) speech time/total time ratio. In addition, the number of disfluencies in the two-minute speech sample also were measured.

A comparison was made between normal speech and speech produced under stress. The comparison of these two speaking conditions was based on the acoustical/temporal parameters analyzed. The ultimate goal of the present study is to add to the corpus of knowledge concerning the effects of stress on speech.

However, the specific goals of this research may be stated in the form of several questions. They are as follows:

1. Which of the many selected acoustical/temporal parameters, found within the speech signal, might serve as indicators of emotional stress?

2. Will stressful speaking conditions significantly increase or decrease the levels of the measured parameters?

3. Is the resultant change due to stress in a specific parameter consistent for all speakers?

CHAPTER II

METHOD

The objective of this investigation is to compare speech produced under stress to nonstressed (normal) speech. The analyses carried out included both acoustical and temporal measures as well as the level of disfluency observed and a self-rating (by the subjects) of the stress they experienced. The acoustical analysis consisted of several measures based on (1) speech intensity (SI) and (2) speaking fundamental frequency (SFF). The temporal measures analyzed were (1) speech/pause ratio (SPR), (2) speech rate (SR), (3) the time-energy distribution (TED), (4) the number of speech bursts, (5) the number of pauses, and (6) speech time/total time ratio (ST/TT). In addition, the number of disfluencies was determined for both speaking conditions (stress and nonstress); two minute speech samples were used for all the analyses. The self-rating by the subjects obviously was based on each subject's overall reaction to the experimental procedure and was a criterion for subject inclusion.

The analyses utilized were common to two experiments, i.e., stress induced by either (1) electroshock or (2) public speaking was examined. Therefore, the types of analysis carried out will be discussed first; these descriptions will be followed by reviews of the procedure used for each experiment.

Acoustical Analyses

Included among the acoustical analyses were several parameters within the domains of speech intensity and speaking fundamental frequency. They are as follows.

Speech Intensity (SI)

First among the intensity characteristics to be analyzed was mean intensity (MI). In addition to the mean, the maximum intensity (MAXI) also was analyzed. MAXI is defined as the highest intensity produced by each subject for the entire two minute speech sample. The mode of the intensity distribution (MODI) defined as the intensity level most frequently produced, also was determined for each speech sample. Additionally, the entire intensity distribution (ID) for each speech condition was analyzed for differences between the normal and stress speech samples.

A computer aided procedure was used to obtain the various intensity measures; a Digital Equipment Corporation (DEC) PDP-8i minicomputer and analog-digital (A/D) converter were used for this purpose. First, the envelope of the speech signal was obtained using a rectifier/integrator circuit. The speech envelope was negative dc shifted in order to make full use of the A/D range (-1.0 to 1.0 V). The computer software (ADCNV), controlling the A/D converter, allowed the computer operator to specify the parameters of sampling rate and the length of the speech sample. The sampling rate used was 50 samples per second and the sample length was 120 sec (2 min). This rate was determined by testing numerous different rates in order to obtain the lowest sampling rate that would accurately represent the speech envelope. The output of the A/D converter was then stored on magnetic tape (DECTAPE) and the analysis program (INTANA) was implemented. INTANA was written to give the operator substantial control over several program parameters. The first parameter the program requires the operator to enter is the A/D value of the dc shift (AD ZERO) used during the inputting of the data. Next, the operator specifies the A/D value of a dc calibration voltage (AD CAL). This calibration value is used by INTANA to convert A/D units to dB values of intensity. The next parameter requested by INTANA defines the calibration voltage as a multiple (MULT) of the dB reference level selected by the operator. This input was followed by a dB adjustment (DB ADJ) used to compensate for any amplification or attenuation of the original signal. That is, if the signal had been amplified at the time it was recorded, the operator would enter the negative value of the amplification level (in dB). If, on the other hand, the signal had been attenuated, the value of DB ADJ would be positive--in order to add back the amount of the original attenuation. Following the DB ADJ, the program requested a dB cutoff (DB CUTOFF). Any signal level below DB CUTOFF was considered to be either noise or a pause and was not included in the computation of the various intensity measures. The intensity analysis was then begun using the A/D equivalent of DB CUTOFF as well as the previous operator specified parameters.

The INTANA output included the A/D values of the minimum (AD MIN) and maximum (AD MAX) levels of the stored data, as well as the actual number of sample points for AD MIN and AD MAX and the corresponding percentage of the total data for each. The total number of valid (i.e., speech) and rejected (i.e., noise or pauses) data points and their corresponding percentages were indicated by the output of INTANA as were the maximum (DB MAX), range (RANGE), mean (DB MEAN), and standard deviation (STD DEV) of intensity (in dB). Next, a distribution table of intensity levels was printed; it listed the dB value, the number of sample points at each level, and the corresponding percentages. The final output was a histogram of the intensity values.

In summary, the intensity measures used are the mean (MI), maximum (MAXI), the mode of the distribution (MODI), and the overall distribution (ID). As stated, these intensity measures were utilized in comparing speech produced under stress and nonstress conditions. The rationale for using so many intensity measures is that it remains to be determined which speech intensity measures are critical to detecting the presence of stress. Therefore, it was judged that as many intensity parameters as possible should be investigated and the critical measures identified.

Speaking Fundamental Frequency (SFF)

Speaking fundamental frequency (SFF) is a measure of the rate of opening and closing of the vocal folds. In the present study the SFF measures of interest, i.e., mean SFF and the SFF distribution, were compared as a function of the stress and normal speaking conditions.

The specified SFF measures were obtained using the Fundamental Frequency Indicator (FFI) available at the Institute for Advanced Study of the Communication Processes (IASCP). FFI is a digital fundamental frequency tracking device consisting of low-pass filters with cutoffs at half-octave intervals coupled with high-speed switching circuits. FFI produces a series of pulses, coinciding with the fundamental period of a complex speech waveform. These pulses are then processed by a DEC PDP-8i minicomputer using an internal clock to mark the time interval between pulses and this data is processed to yield the geometrical mean frequency and standard deviation of the fundamental frequency distribution. In addition, FFI produces a SFF distribution table and a plot of the SFF distribution. The distribution table produced by FFI lists the following data: SFF in (1) semitone (ST), (2) absolute frequency (Hz), (3) the number of occurrences of each value of SFF, and (4) the per cent of the total phonation time each measure of SFF was produced. The value of SFF in Hz and ST and the per cent of occurrence were the values used from the SFF distribution table.

The mean SFF, both within and across sexes, was compared between speech samples produced under normal and stressed conditions. In addition, the SFF distribution for each subject was used to compute a composite SFF distribution for each sex. That is, a composite distribution was determined for the males and one for the females and each used to compare the two speaking conditions within sexes.

Temporal Analyses

In addition to the acoustical parameters discussed above, temporal aspects of speech also were investigated as possible indicators of emotional stress. The temporal characteristics analyzed consisted of (1) speech rate (SR), (2) a time-energy distribution (TED), (3) speech/pause ratio (SPR), (4) the number of speech bursts, (5) the number of pauses, and (6) speech time/total time ratio (ST/TT).

Speech Rate (SR)

Speech rate (SR) is defined as the number of syllables produced per second. This temporal feature was measured at the syllabic level due to varying word lengths; obviously, polysyllabic words will take longer to produce than monosyllabic words. Therefore, using word boundaries would result in misleading data. The syllabic level of measurement will become most important for the stress speech samples obtained in the public speaking experiment (to be discussed later) because the intersubject speech samples will be different; i.e., they are not the same samples.

The obtained two minute samples were divided into 15 sec segments and SR calculated for each segment by dividing the number of syllables in each segment by 15 sec. Finally, the mean and standard deviation of SR for the two minute samples were calculated.

Time-Energy Distribution (TED)

The time-energy distribution (TED) parameter originally was developed in 1978 by Johnson for a speaker identification study. "In general terms, TED reflects the total time a talker's speech intensity remains at a specific energy level (relative to his peak amplitude). It also provides indication of the speaker's speech pattern with respect to speech bursts and pause periods" (Johnson, 1978, p. 39). In the present study, TED was added to the other measurements in an attempt to discriminate between stress and normal speech.

TED was obtained utilizing a PDP-8i minicomputer and A/D converter. Initially, the envelope of the speech sample was generated using a rectifier/integrator circuit. The speech envelope then was digitized (A/D) and analyzed in real time using software developed by Johnson (1978). This software segments the speech signal into ten equal intensity levels relative to the maximum intensity produced by the speaker. Based on this segmentation, the TED program computes: (1) the number of speech bursts, (2) speech bursts per sec, (3) time in sec, (4) per cent of the total time, (5) mean time in millisec, and (6) standard deviation in millisec of each speech burst for each of the ten intensity levels. The mean pause periods and the number of pauses were the direct reciprocals of the speech bursts. In this manner, TED determines the distribution of both the speech bursts as well as the pause periods. The speech burst distribution was used in order to analyze differences between speech samples produced under the two speaking conditions (stress and no stress). In addition, the TED output also was used to determine the speech/pause ratio (SPR), the number of speech bursts, the number of pauses, and the speech time/total time (ST/TT) ratio (see below).

Speech/Pause Ratio (SPR)

The speech/pause ratio (SPR) is the ratio of the per cent of speaking time to the per cent of pause time. A pause is defined as that period of time during which an individual is not producing any audible sound. SPR can be readily obtained using the TED printout; that is, SPR can be calculated by using the percent of speech time and pauses for intensity level one, the lowest level.

Each two minute speech sample was divided into eight 15 sec segments and SPR was calculated for every other segment beginning with the first segment. This approach allowed the investigation of those SPR changes within each sample that may have been "averaged out" by examining the entire two minute sample. Furthermore, this segmentation permitted the calculation of the mean and standard deviation of SPR for the entire sample.

Speech Bursts and Pauses

In addition to SPR, specific speech bursts and pauses were counted in order to determine possible differences between normal (nonstress) speech and speech produced under stress. The rationale for this analysis was as follows: a reliance only on SPR would result in certain confusions. That is, one speech burst of 20 sec and four bursts of five sec each would both result in a SPR of 0.5 for a 40 sec sample, when in fact, the two samples are different. The number of speech bursts and pauses were obtained from the lowest TED intensity level. This intensity level distinguishes between portions of the total sample that include vocalizations and those that do not (i. e., pauses).

Speech Time/Total Time (ST/TT) Ratio

The speech time/total time ratio (ST/TT) is the ratio of the amount of time in which speech occurred to the total time of the speech sample. This measure compares the speech time of a given sample to the total time of that sample. The ST/TT ratio was calculated utilizing the TED output. Both the ST and TT of each speech sample were obtained from level one of the TED.

The same segmentation of the total sample used to calculate SPR and SR applies to ST/TT. That is, each sample was divided into eight 15 sec sub-samples and starting with the first sub-sample, alternate sub-samples were used to calculate the mean and standard deviation of ST/TT.

Disfluency

The final parameter analyzed was speech disfluency. This parameter is neither an acoustical measure nor entirely a temporal measure. While disfluency does relate to the temporal domain, in the present study it was not measured as a function of time. Instead, each occurrence of a disfluency was merely counted. Therefore, this parameter will be discussed separately from the acoustical and temporal parameters.

The definition of disfluency used in the present study is: "repeating part of a word or an entire word, repeating a phrase, inserting extra sounds between words (ah, um), changing the wording of a sentence, prolonging the sounds of a word, or breaking-up the sounds of a word" (Silverman, & Silverman, 1975, p. 353). The present author and a speech pathologist listened to each two minute sample and counted each time the speaker was disfluent. Included among the types of disfluencies measured were "audible pauses"; that is, sounds inserted between words (e.g., ah and um). These audible pauses would have been measured as speech in the SPR measure discussed above. Inclusion of audible pauses in the SPR would have artificially increased the SPR. This possibility would have been obscured without separately examining disfluencies. In addition, although the experimental paradigm was different from the present study, in their study Silverman and Silverman found that disfluency and the threat of electric shock are correlated. Therefore, it would seem that the number of disfluencies may serve as an indicator of stress.

Subjects' Self-Rating Stress

The individuals in both experiments rated the amount of stress they experienced in order to select subjects for inclusion in each experiment. This self-rating was accomplished using the Multiple Affect Adjective Check List (MAACL) (Zuckerman et al., 1964). The MAACL has three scales in order to measure: (1) anxiety, (2) hostility, and (3) depression. However, only the anxiety score was used for subject selection in the present study. The MAACL has a maximum anxiety score of 21, with normal (nonstressed) subject groups scoring 4-7 and individuals under stress averaging scores of about 15. Each subject completed the MAACL response form prior to the initiation of the speaking task under the stress condition. Only those individuals with scores of 13 or greater were included in the experimental population in order to insure that subjects had achieved a significant level of stress. A sample of the MAACL may be found in Appendix A.

Recording Procedure

The recording procedure will be discussed separately from the experimental descriptions since it was common to both experiments. Specifically, a FM wireless microphone/ transmitter was used to record the speech samples as can be seen in Figure 1. A special headset was designed and fabricated in order to position the microphone in constant relationship to the speaker. This headset with the microphone in place can be seen in Figure 2. The rationale for controlling the relationship between the microphone and the subject was to eliminate intensity variations resulting from

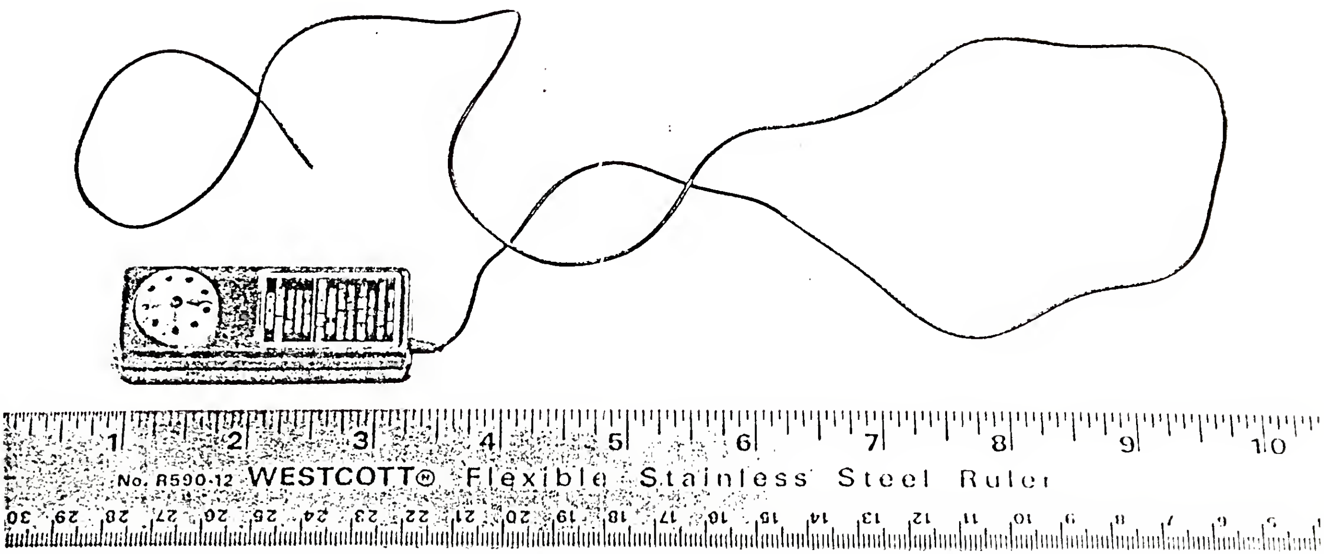

Figure 1. FM Wireless Microphone/Transmitter Used in Recording Process.

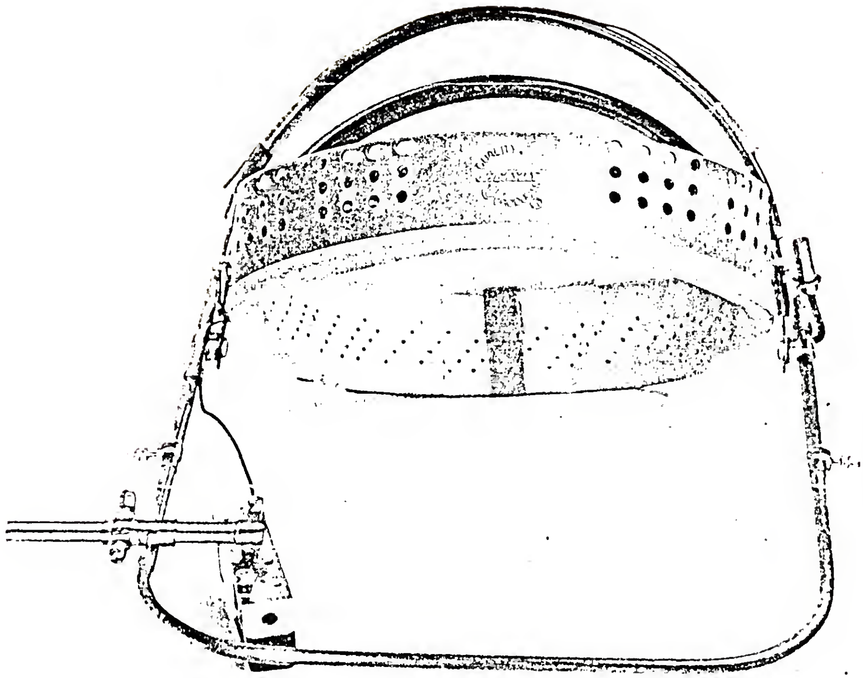

Figure 2. Specially Designed Headset Used to Hold FM Microphone/Transmitter (Shown in Place) in a Fixed Position Relative to Speaker.

head movement. The speech signal from the microphone/transmitter was received on a FM tuner which was coupled to a Sony TC-353D tape deck via a Hewlett-Packard 350D variable attenuator. The output of the FM tuner and the input to the tape deck were maintained at fixed levels such that attenuation was required in order to not overdrive the input to the tape deck. Therefore, the recording level was controlled with the attenuator, which facilitated maintenance of a constant gain in the recording system for both the normal and stress speech conditions for a given subject. Maintaining a constant gain between speaking conditions permitted intensity comparisons between conditions. Additionally, this recording technique was chosen in order to minimize the affect of the recording procedure on a subject's level of stress--particularly in the situation stress experiment. Furthermore, it was judged that it allowed the subjects freedom of movement not possible with conventional recording techniques while maintaining experimental control.

Experiment I: Laboratory Stress

In a laboratory setting the experimenter has greater control over the stressing environment as compared to "real" or situational stress. Furthermore, it would seem reasonable to first test a new procedure under highly controlled conditions before advancing to nonlaboratory, in-the-field environments. Therefore, the first experiment in this study was conducted in a laboratory environment.

Laboratory stress, as used in this experiment, is defined as a deliberately contrived stress induced in a laboratory environment. In this particular case an electric shock was used as the stressor.

Population

The subjects utilized in this experiment were recruited from members of the Institute for Advanced Study of the Communication Processes (IASCP) and the Speech Department of the University of Florida. They ranged in age from 20 to 31 years, with a mean age of 23.9 years. The total population included 7 males and 5 females; none exhibited any speech/voice abnormalities. All subjects scored 13 or above on the MAACL anxiety scale under the stress condition.

Speech Materials

Speech materials consisted of two readings of a modernization of R. L. Stevenson's "An Apology for Idlers." First the subjects read the passage with no electric shock administered (i.e., no stress induced). This reading constituted their normal speech sample. Next, the subjects randomly received an electric shock while reading the standard passage, and this was used as their stressed speech sample. "An Apology for Idlers" was selected as reading material based on the time required to read the passage; approximately 3-3.5 minutes. A passage of this length was needed in order to extract the two minute speech sample used in this experiment (see Appendix C).

Experimental Procedure

Recordings for this experiment were obtained by utilization of the procedures described above; subjects were recorded in an Industrial Acoustics Company (IAC) sound treated room. Only the FM receiver was placed in the IAC room with the subject, while the remainder of the recording equipment was operated outside the room and coupled to the receiver via the IAC room's patch panel.

The subjects' first task was to read "An Apology for Idlers" with no stress being induced (i.e., no shock was administered) in order to obtain a normal speech sample. At this juncture, the electroshock procedure was explained and the electrodes were placed on the index and ring fingers of the subject's hand. Once the electrodes were in place, the subject was asked to sign a Subject Informed Consent Form (see Appendix B) and complete the MAACL test.

The subject was told that the number of shocks (one to seven) and when they would occur had been randomly assigned, but that at least one shock would be administered. In fact, all subjects received seven shocks given on the same pre-selected words during the reading.

A Grason-Stadler Psychogalvanometer, Model 4, constant current shocking device was used to administer the electrical stressor. A current level of 2.5 ma was delivered manually. Of course, this procedure did not harm the subjects; it only caused enough discomfort and threat to induce stress. In addition, the subjects were free to terminate the experiment at any time, as stated in the written and verbal instructions provided them (see Appendix C). However, all the subjects read the entire passage; successfully completing the experiment.

Experiment II: Situational Stress

Situational stress can be defined as occurring when an individual is exposed to a particular setting that is normally stressful. For example, a student taking an oral examination ordinarily would be expected to experience a form of situational stress. In this case, then, the stress is caused by the particular act of taking the oral examination. Another example of situational stress is that perceived by a dental patient awaiting treatment. Under these cited conditions, individuals are threatened by the situation; it is thereby that stress is induced. In the case of the student, the threat may be the possibility of not passing the examination and having to confront the consequences of failure. Fear or anxiety resulting from the perceived threat of potential pain may be the cause of the stress in the dental patient. In both cases, the circumstances create a threat that results in the situation being stressful to the individual.

Population

Subjects for this experiment were chosen from students enrolled in a public speaking course taught in the Speech Department of the University of Florida. All students in the class were recorded; however, only the 17 with MAACL scores of 13 or above were included in the analysis; none exhibited any speech/voice abnormalities. Subjects ranged in age from 19 to 26 years with a mean age of 20.7 years; there were 10 males and 7 females.

Speech Materials

Two types of speech materials were obtained for this experiment. The stress material consisted of recordings of the actual speeches delivered by the students to an audience of fellow students in the public speaking class. The normal sample consisted of a reading of a modernization of R. L. Stevenson's "An Apology for Idlers" obtained from only those students with MAACL scores exceeding 12 for the stress condition. The normal samples were recorded at IASCP in an IAC sound treated room.

Experimental Procedure

The specially designed headset that would be used to record the speeches was demonstrated to the students several days prior to the actual recording date. This demonstration was done in order to explain the use of the device and reduce any special anxiety that might be caused by using the headset; however, the students were not told the actual purpose of the experiment. The students wore the headset on two occasions--first, while delivering a brief introductory speech. The purpose of this procedure was to accustom them to wearing the headset and to further reduce any anxiety they might feel which was associated solely with using the headset. Therefore, it can be argued that the stress experienced by the students during the recording process would be the result of the public speaking situation rather than the experimental procedure. Of course, the students also wore the headset while their speeches were recorded for the experiment.

Statistical Analysis

The statistical technique used in the data analysis was a matched-pairs t test. This procedure was selected because the normal and stress speaking conditions were not independent. In this instance, the two sample populations consisted of the same individuals.

Since the samples were deliberately matched, if each pair of measures is treated as a single case, statistical tests can be made legitimately. Instead of making a difference-of-means test, a direct pair-by-pair comparison can be made by obtaining a difference score--in this case, stress minus normal. Therefore, the null hypothesis is that there is no difference between the stress and normal speaking conditions and it can be hypothesized that the mean of the pair-by-pair difference in the population μ_d is zero.

The problem then reduces to a single-sample test of the hypothesis that $\mu_d = 0$.

The difference between the normal and stress speaking conditions was calculated for each of the measures obtained. The mean $\bar{x}_d$ and standard deviation s_d were calculated for the distribution of the differences, where

$$\bar{x}_d = \frac{\sum_{1}^{n} x_{di}}{N_d} \quad \text{and}$$

$$s_d = \frac{\sqrt{\sum_{1}^{n} (x_d - \bar{x}_d)^2}}{N_d}$$

The t test statistic is then calculated as

$$t_d = \frac{\bar{x}_d - \mu_d}{s_d / \sqrt{N - 1}}$$

with N - 1 degrees of freedom (df). Since the null hypothesis was $\mu_d = 0$, the test statistic reduces to

$$t_d = \frac{\bar{x}_d}{s_d / \sqrt{N - 1}}$$

A significance (alpha) level of 0.05 was chosen for the test statistic due to the exploratory nature of this study. In addition, a two-tailed test was used in order to test for the direction of the shift in the parameter under analysis. If the calculated value of t_d is greater than t_c, where t_c is the critical value of t at the 0.05 level with df = N - 1, the null hypothesis $\mu_d = 0$ is rejected. Furthermore, noting the sign of t_d ($\pm$) it can be determined whether the parameter increased (+) or decreased (-) for the stress condition compared to the normal. For a detailed discussion of matched-pairs t-tests see Blalock (1972).

CHAPTER III

RESULTS OF LABORATORY STRESS EXPERIMENTS

This first study was conducted in order to compare speech produced under stress to normal (nonstress) stress in a highly controlled laboratory environment. The thrust of the research is focused on an acoustical/temporal analysis of speech produced under the two specified conditions. Specifically, the acoustical analyses carried out consisted of various speech intensity (SI) and speaking fundamental frequency (SFF) measurements--including the maximum, mode, mean and distribution of SI and the mean and distribution of SFF. The measures within the time domain consisted of the mean and standard deviation of speech rate (SR), speech/pause ratio (SPR), speech time/total time ratio (ST/TT), the time-energy distribution (TED), and determination of the number of speech bursts and pauses. In addition, the number of disfluencies occurring in the stress and nonstress speech samples also was calculated.

A matched-pairs $\underline{t}$ test was used in the statistical analysis of the obtained data. For the matched-pairs $\underline{t}$ test, the mean ($\overline{x}_d$) and standard deviation (S_d) of the differences between the normal and stress speaking conditions--for each subject--are used in computing the test statistic $\underline{t}_d$. An alpha significance level of 0.05 was used for all $\underline{t}$ tests. That is, if the significance level of $\underline{t}_d$ is 0.05 or less, the test statistic is considered significant for the purposes of this experiment. The 0.05 alpha level was chosen because the present study is exploratory in nature and seeks to determine which speech parameter(s) might be the vocal cue(s) to stress.

Speech Intensity (SI)

The first intensity characteristic analyzed as a possible vocal indicator of stress was the relative mean intensity (MI) level. The results of the MI analyses are shown in Table 1-A. As can be seen, the overall MI was slightly greater for the stress condition than for the normal condition. That is, the mean difference between the speaking conditions is 0.5 dB with a standard deviation of 0.8 dB. The calculated $\underline{t}$ score for the difference between speaking conditions was found to be 2.07 (df = 11) which is not significant at the 0.05 level. Although nonsignificant, the positive t_d value probably indicates a trend for MI to increase for speech produced under stress. Similar results

Table 1. Results of the Speech Intensity (SI) Analyses for the Laboratory Stress Experiment; All Values are Expressed in dB Re: 1mv. Values in Parentheses are the Standard Deviation (SD) and Degrees of Freedom (df) for the t Scores.

	Speaking Condition Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d (df)
A. Mean Intensity (MI)				
Males (N=7)	67.3(1.7)	68.1(2.4)	0.8(0.7)	2.80(6)*
Females (N=5)	65.9(3.3)	65.9(3.1)	0.0(0.8)	0.00(4)
Overall (N=12)	66.7(2.5)	67.2(2.8)	0.5(0.8)	2.07(11)
B. Maximum Intensity (MAXI)				
Males (N=7)	79.1(3.6)	79.6(3.3)	0.4(0.5)	1.96(6)
Females (N=5)	78.4(2.9)	78.8(2.9)	0.4(0.5)	1.60(4)
Overall (N=12)	78.8(3.2)	79.3(3.0)	0.4(0.5)	2.65(11)*
C. Mode of Distribution (MODI)				
Males (N=7)	73.3(3.8)	76.0(3.6)	2.7(3.0)	2.20(6)
Females (N=5)	71.8(6.5)	72.0(6.5)	0.2(1.1)	0.36(4)
Overall (N=12)	72.7(4.9)	74.3(5.2)	1.7(2.6)	2.17(11)

*Significant at the 0.05 level.

$t_{.05} = 2.447$, df = 6

$t_{.05} = 2.776$, df = 4

$t_{.05} = 2.201$, df = 11

were found for the males alone, the difference of 0.8 dB was found to be significant (t_d = 2.80, df = 6). Conversely, analysis of the female subjects showed no difference between the normal and stress speaking conditions. It would appear that under the present experimental conditions MI was not a robust indicator of stress.

The results of the analyses of the maximum intensity (MAXI) level are shown in Table 1-B. Analysis of the overall results indicates a statistically significant increase (0.4 dB) in MAXI for the stress condition when it was compared to the normal speaking condition. The maximum intensity produced under the stress condition was 79.3 dB, compared to 78.8 dB for the normal condition. The difference in MAXI between the two conditions was found to be nonsignificant when controlled for the subjects' sex. However, the positive t_d values indicate at least a slight tendency for MAXI to be greater for speaking under stress than for normal speech.

The mode of the intensity distribution (MODI) also was analyzed. The results of these analyses may be found in Table 1-C. The 1.7 dB mean difference between the speaking conditions was not found to be significant. Moreover, the difference values were found to be 2.7 dB for the males and 0.2 dB for the females, neither of which were significant at the 0.05 level. In each of the analyses MODI was negligibly greater for the stressed speech than for normal speech. Therefore, the tendency--although slight--is for MODI to increase in stressed speech.

Finally, the entire intensity distribution (ID) was analyzed for differences between speech produced under stress and normally. The results of these analyses are shown graphically in Figures 3-5.* The distributions were first analyzed by sex, then the data were combined in order to obtain the overall distribution. However, no statistically significant differences were found. Indeed, the general shape of the two distributions (normal and stress) remained fairly constant across conditions. Therefore, analyzing the entire intensity distribution did not discriminate between normal speech and speech produced under stress.

In fact, MAXI was found to be the most powerful stress indicator. The MAXI for the overall data was significantly greater for the stressed speech samples relative to normal speech. The only other significant result was found in MI

*The tabulated values for the distributions may be found in Appendix D.

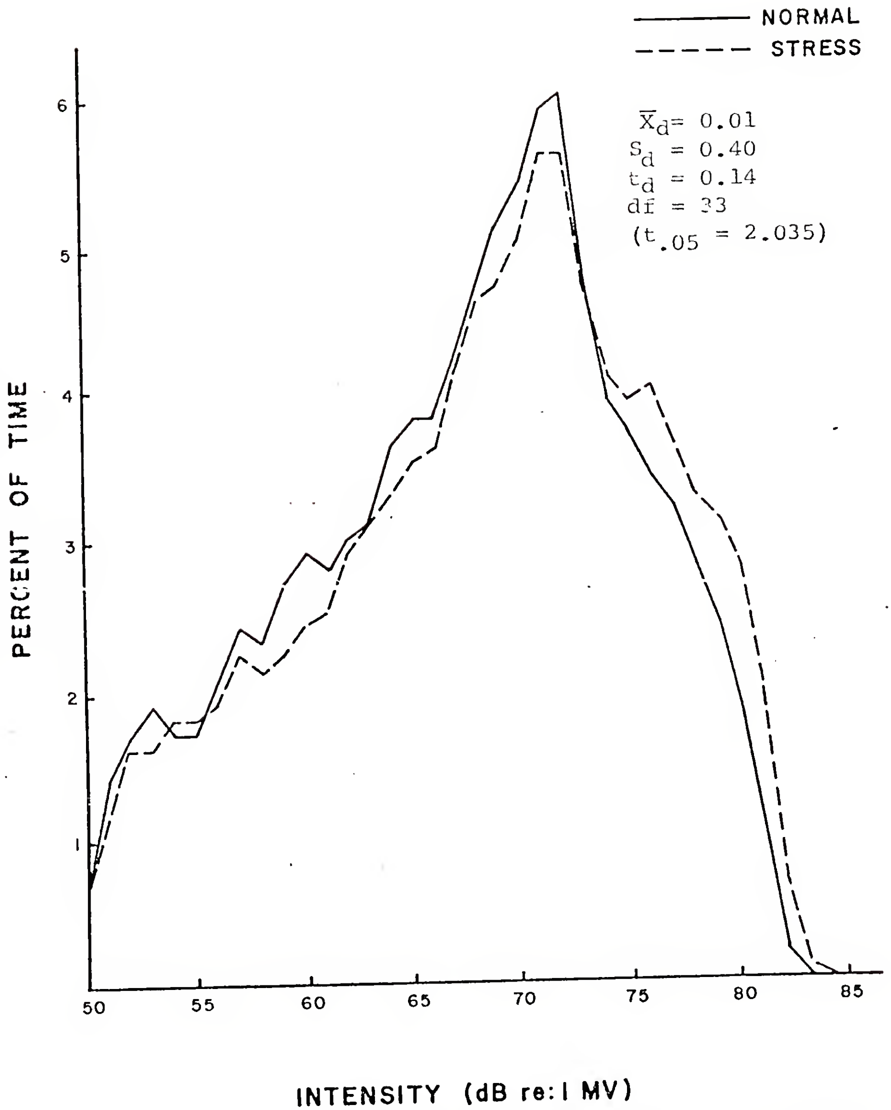

Figure 3. Intensity Distribution for the Male Subjects in the Laboratory Stress Experiment.

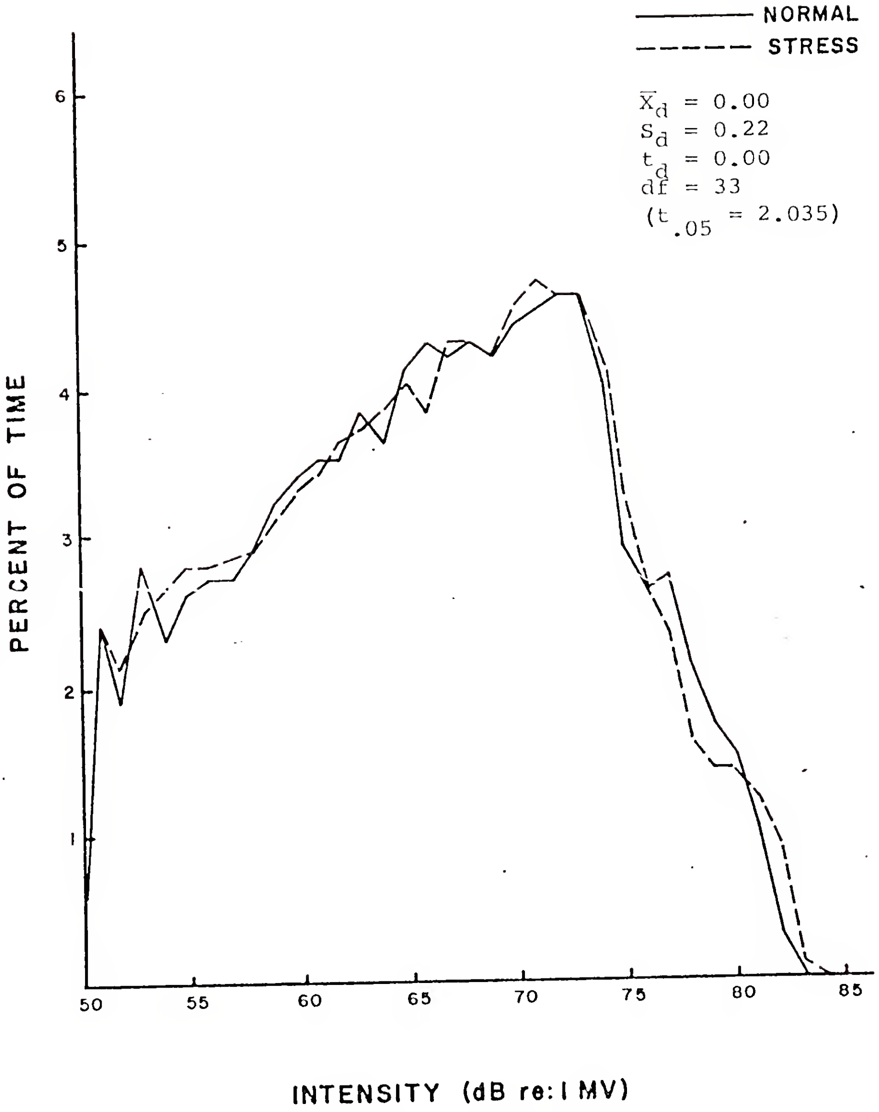

Figure 4. Intensity Distribution for the Female Subjects in the Laboratory Stress Experiment.

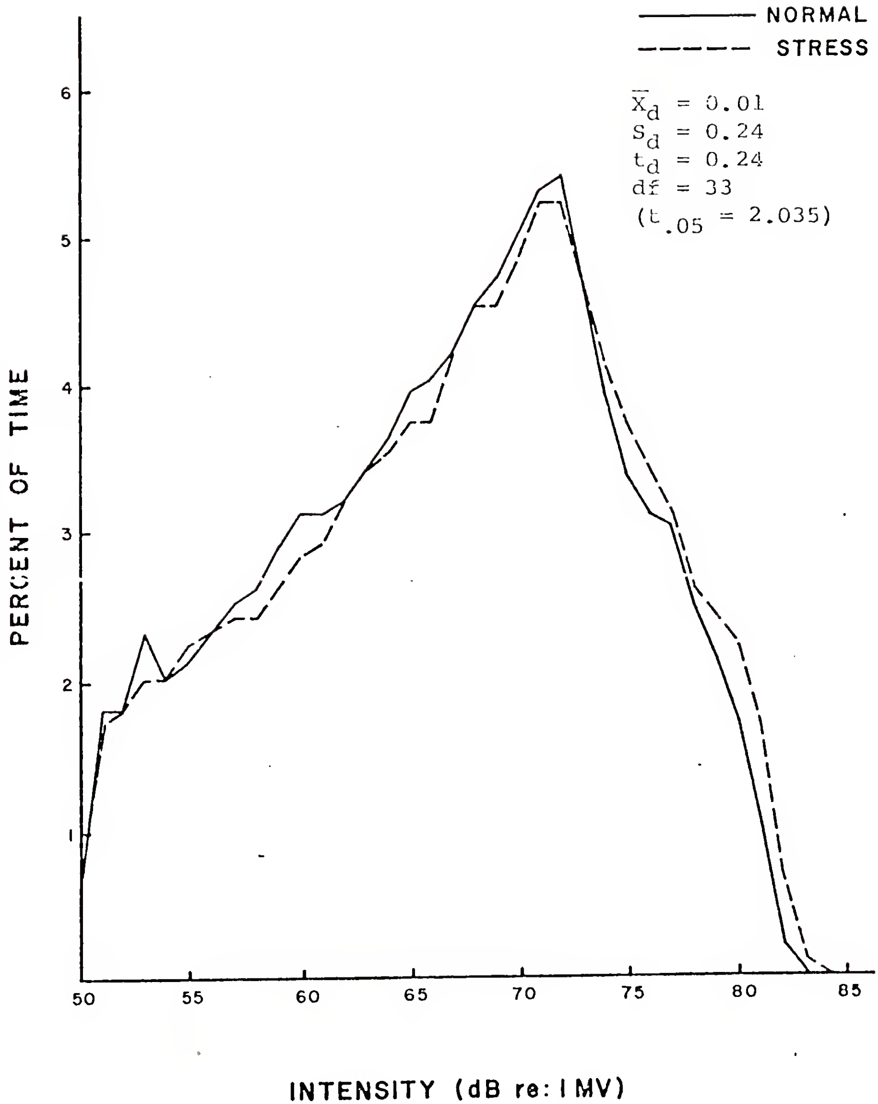

Figure 4. Overall Intensity Distribution for All Subjects in the Laboratory Stress Experiment.

for the males. Therefore, these intensity measures were not extremely indicative of stress--at least for this experiment.

Speaking Fundamental Frequency (SFF)

The other major acoustical parameter analyzed was speaking fundamental frequency (SFF). SFF is a measure of the rate of opening and closing of the vocal folds. The mean values of the obtained SFF can be seen in Table 2. The overall mean SFF increased from 166.7 Hz or 39.4 semitones (ST) for the normal speaking condition to 39.7 ST or 169.3 Hz for stress. However, the mean difference between the speaking conditions was not found to be significant. When analyzed by sex, the male subjects' SFF increased from 35.4 ST (127.4 Hz) for normal speech to 36.0 ST (132.0 Hz) for stress, with a mean difference of 0.6 ST (4.6 Hz). The difference for the male subjects was found to be nonsignificant at the 0.05 level. Therefore, SFF for males appears to increase slightly for the stress condition while the females exhibited no change at all in SFF. However, there was a slight tendency for SFF to be higher for speech produced under stress, although these increases were not statistically significant.

Table 2. Results of the Speaking Fundamental Frequency (SFF) Analyses for the Laboratory Stress Experiment; values Are Expressed in Both Semitones (ST) and Hertz (Hz); values in Parentheses Are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores.

	Speaking Conditions							
	Normal		Stress		Mean Difference		t_d	
	ST(SD)	Hz(SD)	ST(SD)	Hz(SD)	ST(SD)	Hz(SD)	ST(df)	Hz(df)
Males(N = 7)	35.4(2.3)	127.4(16.4)	36.0(2,8)	132.0(20.8)	0.6(0.8)	4.6(6.6)	1.84(6)	1.71(6)
Females(N = 5)	45.0(2.3)	221.7(30.0)	45.0(2.3)	221.6(30.0)	0.0(0.4)	-0.1(4.7)	0.00(4)	-0.04(4)
Overall(N = 12)	39.4(5.4)	166.7(53.2)	39.7(5.3)	169.3(51.9)	0.3(0.7)	2.7(6.2)	1.42(11)	1.44(11)

In addition to the mean SFF, the SFF distribution also was analyzed. The resulting relationships may be found in Figures 6-8.* The SFF distributions for the two speaking conditions were found to be very similar. The matched-pairs *t* test for the distributions substantiated this similarity. The distributions were first analyzed by sex, then the data were combined for the overall analysis. However, differences between the normal and stress speaking conditions were not found to be statistically significant. Therefore, the SFF distributions were not very discriminating between normal and stress speech.

Speech Rate (SR)

Speech rate (SR) was defined as the number of syllables produced per second. For the SR analysis the two minute speech samples were divided into eight 15-second subsamples and alternate subsamples utilized for the computation of the mean and standard deviation of SR. The results of the mean SR analysis may be found in Table 3. As can be seen, the mean value of SR increased from 4.41 syllables/sec

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*Also see Appendix E for the tabulated values for the SFF distributions.

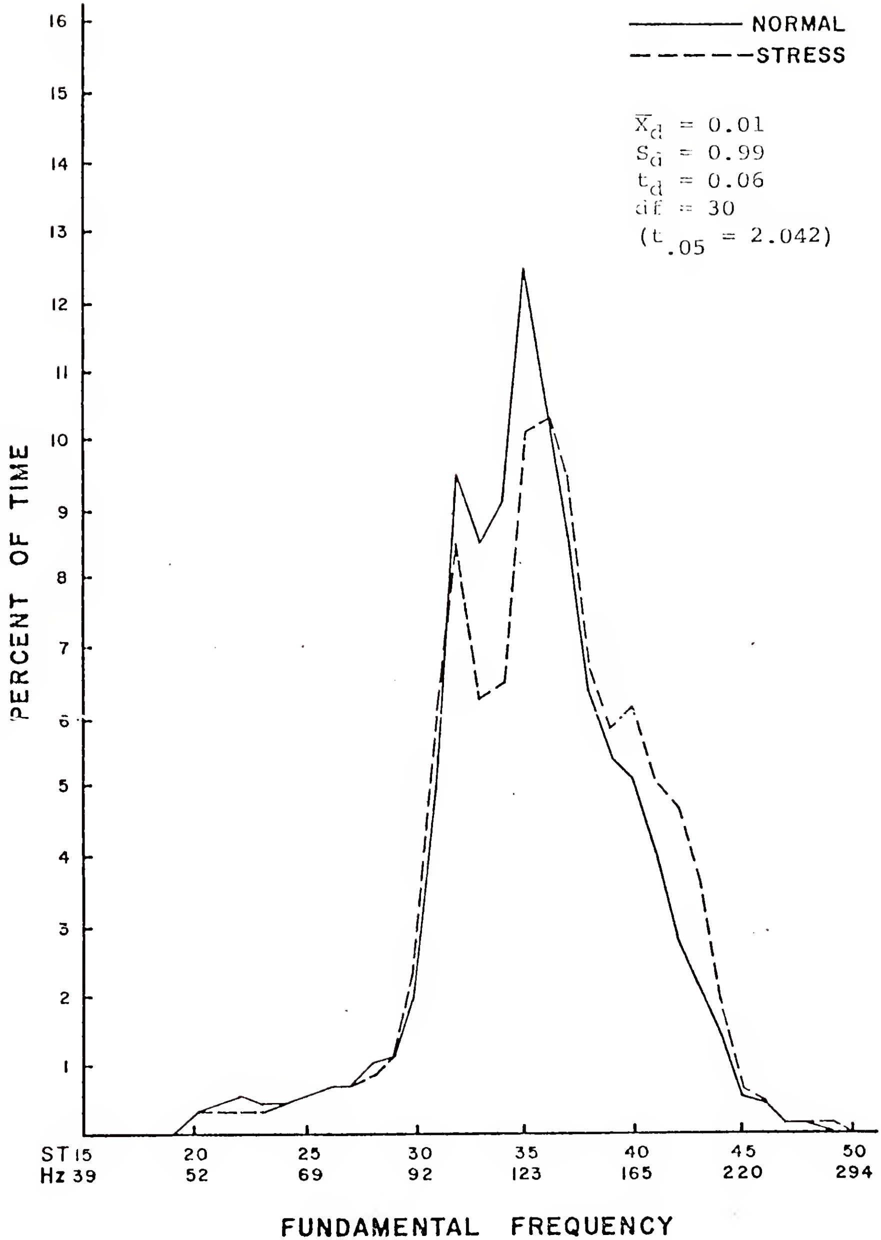

Figure 6. Speaking Fundamental Frequency (SFF) Distribution for the Male Subjects in the Laboratory Stress Experiment.

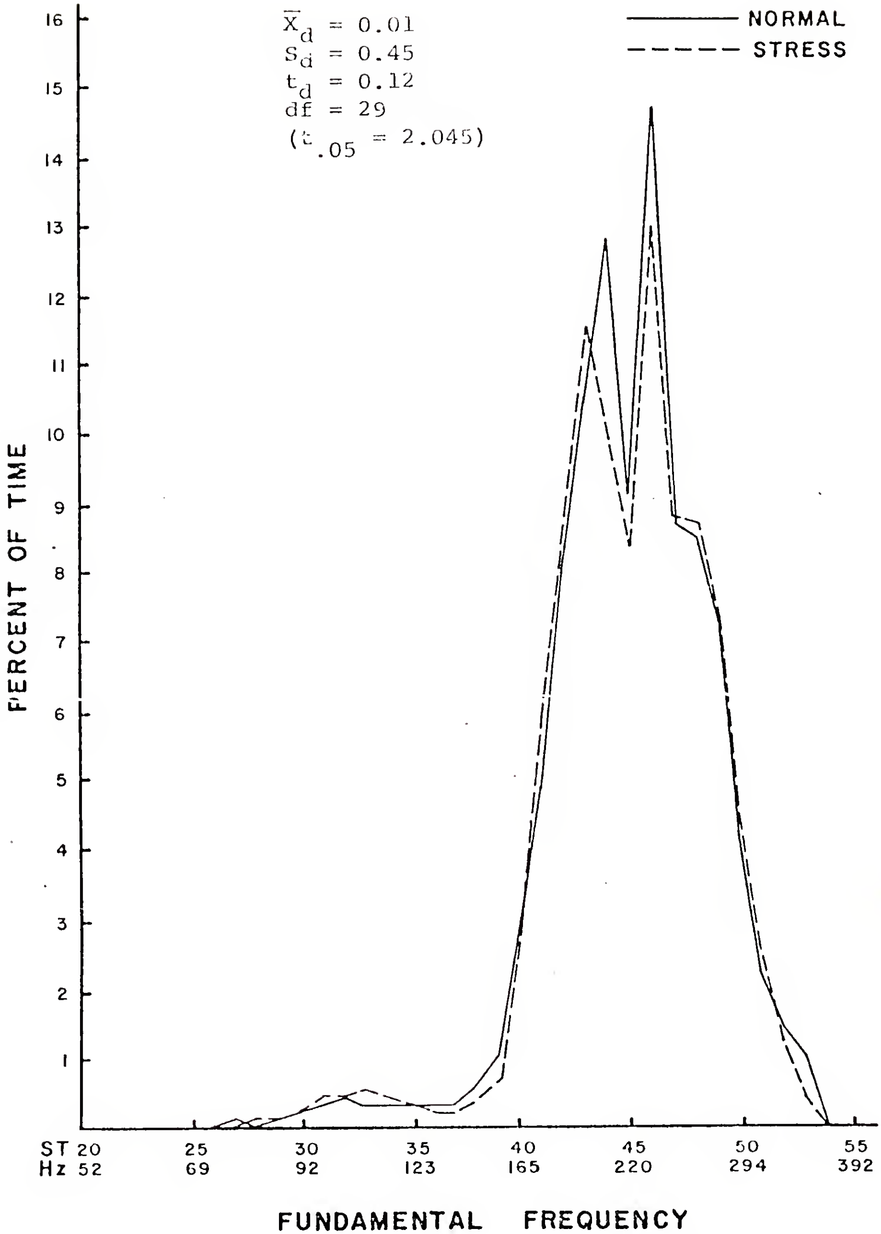

Figure 7. Speaking Fundamental Frequency (SFF) Distribution for the Female Subjects in the Laboratory Stress Experiment.

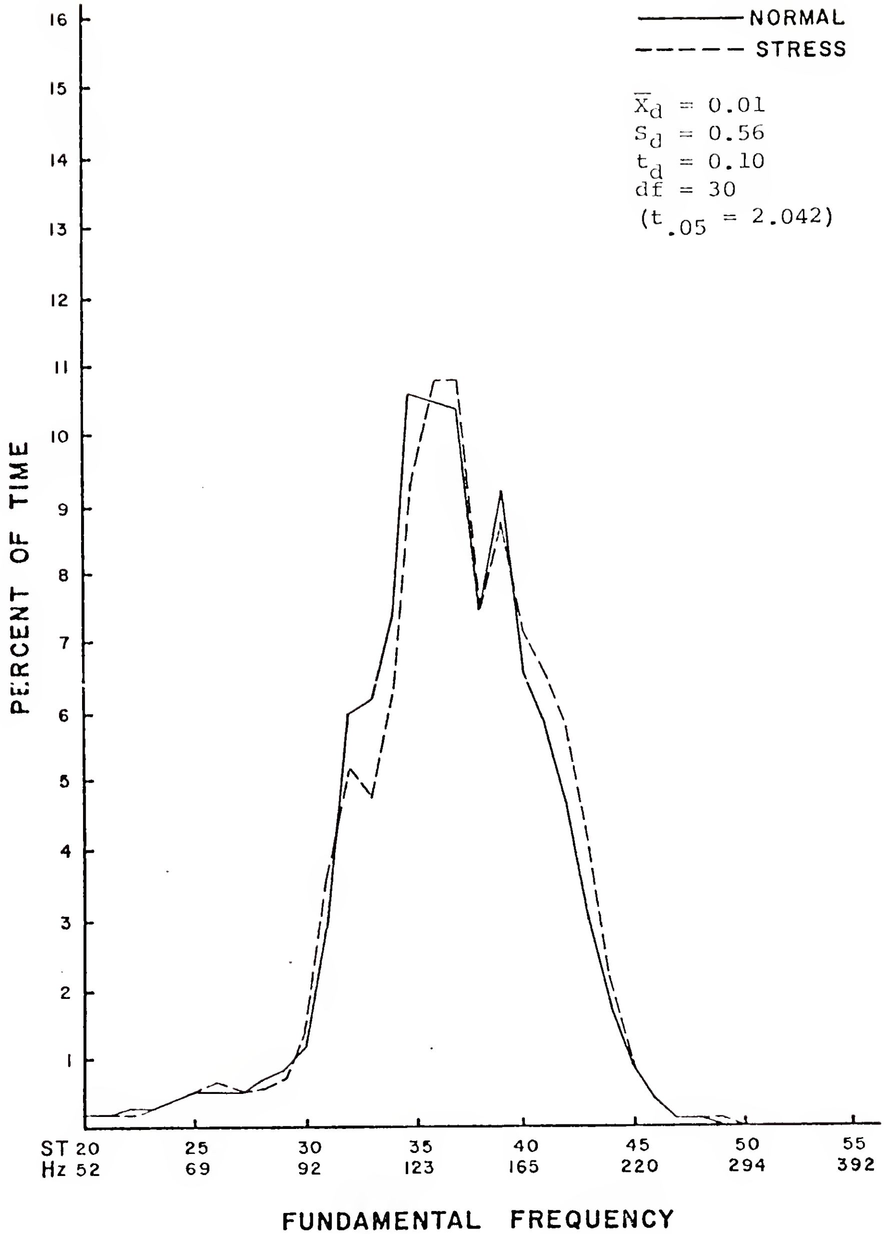

Figure 8. Overall Speaking Fundamental Frequency (SFF) Distribution for All Subjects in the Laboratory Stress Experiment.

Table 3. Results of the Speech Rate (SR) Analysis for the Laboratory Stress Experiment; SR Values are Expressed in Syllables Per Second; Values in Parentheses are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores (N = 12).

	Speaking Condition			
	Normal(SD)	Stress(SD)	Mean Difference(SD)	t_d(df)
Mean	4.41(0.24)	4.42(0.29)	0.01(0.20)	0.17(11)
Standard Deviation	0.25(0.15)	0.38(0.17)	0.13(0.21)	2.05(11)

for the normal speech samples to 4.42 syllables/sec for stress. However, this increase was not found to be statistically significant.

Similarly, the standard deviation of SR also was analyzed. The results may also be found in Table 3. The SR variability was found to increase for speech produced under stress although not significantly.

Although there was a slight tendency for both the SR mean and standard deviation to increase for the stressed speech samples, the increase was not sufficient to differentiate the normal and stress speech. Therefore, neither of the SR measures were very utilitarian in indicating the presence of stress.

Speech/Pause Ratio (SPR)

The speech/pause ratio (SPR) was the next temporal parameter analyzed. SPR is defined as the ratio of the per cent of speech time to the per cent of pause time. The same subsample segmentation used for SR was also utilized for the SPR analysis. That is, alternate 15 sec subsamples were used for the computation of the SPR mean and standard deviation. The results of these analyses may be found in Table 4. The analysis of the mean SPR resulted in a non-significant difference between speech produced under stress and normally.

Table 4. Results of the Speech/Pause Ratio (SPR) Analysis for the Laboratory Stress Experiment; Values in Parentheses are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores (N = 12).

	Speaking Condition			
	Normal(SD)	Stress(SD)	Mean Difference(SD)	t_d(df)
Mean	2.74(0.44)	2.90(0.46)	0.16(0.48)	1.11(11)
Standard Deviation	0.47(0.18)	0.58(0.24)	0.11(0.20)	1.82(11)

The results of the SPR standard deviation analysis are also shown in Table 4. Similar to the mean, the standard deviation of SPR increased for the stress speech although not significantly.

Therefore, SPR did not prove to be an adequate stress indicator. However, both the mean and standard deviation exhibited a slight tendency to increase in speech produced under stress.

Time-Energy Distribution (TED)

The time-energy distribution (TED) indicates the amount of time a speech signal remains at a particular energy level. An earlier investigation by Johnson (1978) indicated that the tenth (or highest) energy level does not contribute to the discrimination between waveforms. Therefore, in this study only the lower nine energy levels were utilized in the analysis. The TED values were obtained by segmenting the two minute sample into eight 15-second subsamples and computing the mean TED value for every other segment. A summary of the results may be found in Figures 9-11.*

Initially, the analyses were conducted by sex in order to examine possible differences due to sex; then the data

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*See Appendix F for tabulated values of TED.

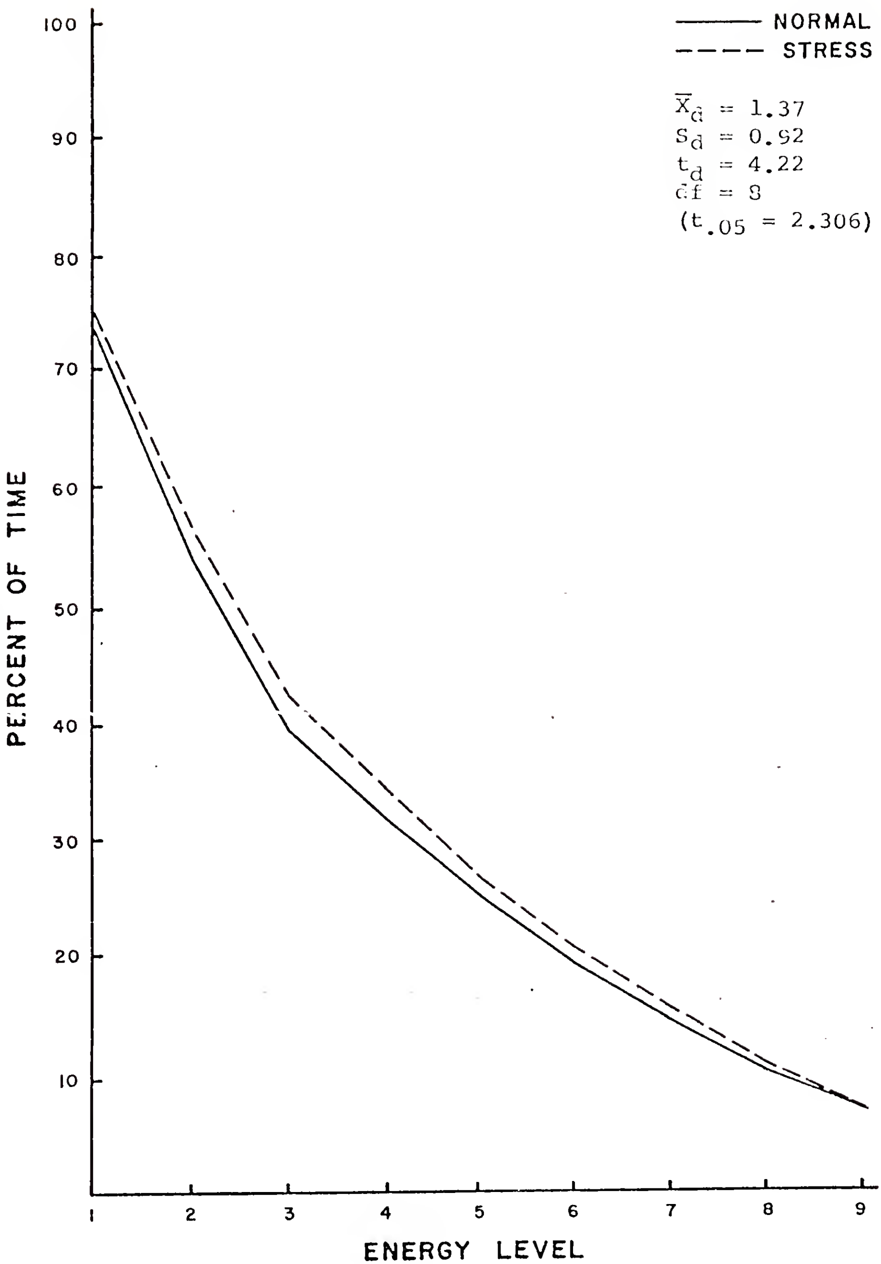

Figure 9. Time-Energy Distribution (TED) for the Male Subjects in the Laboratory Stress Experiment.

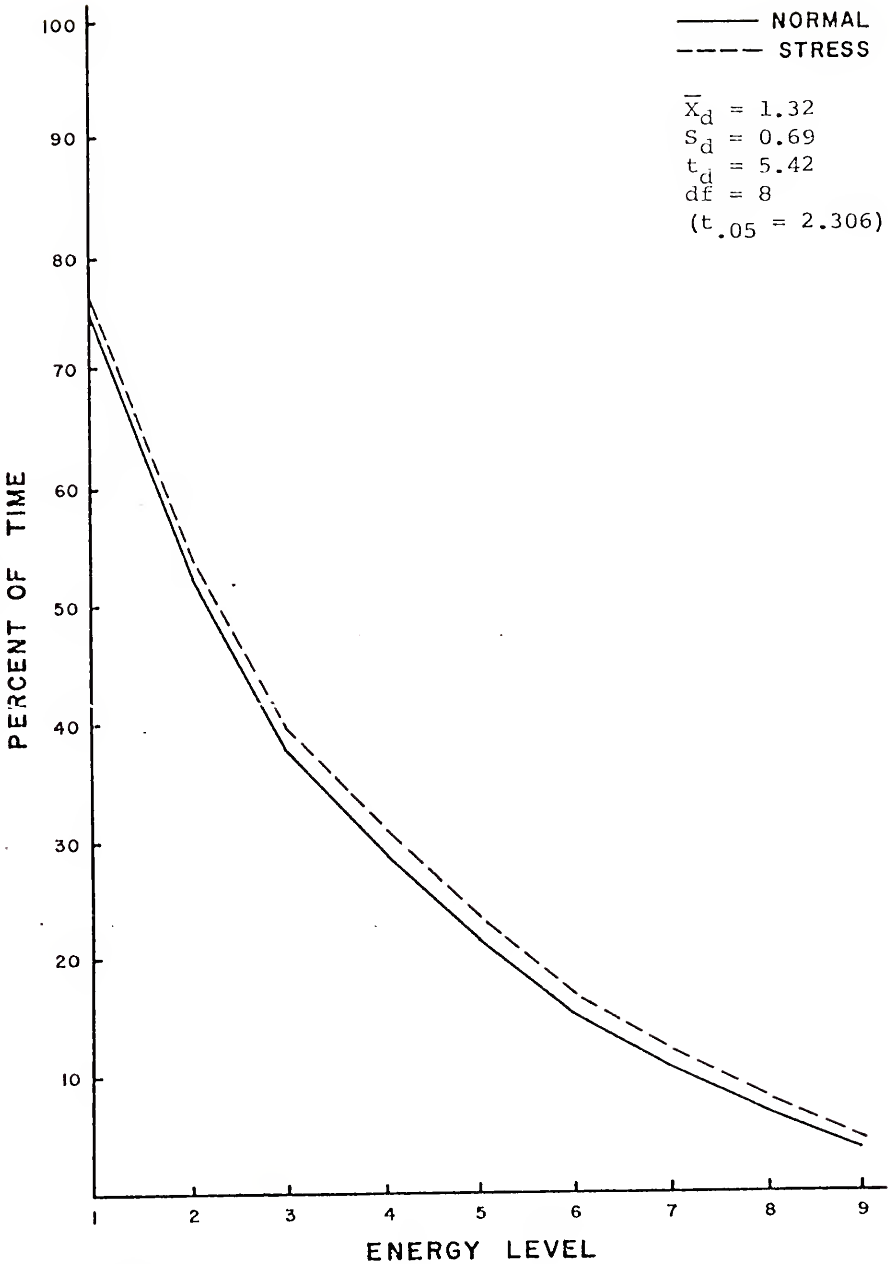

Figure 10. Time-Energy Distribution (TED) for the Female Subjects in the Laboratory Stress Experiment.

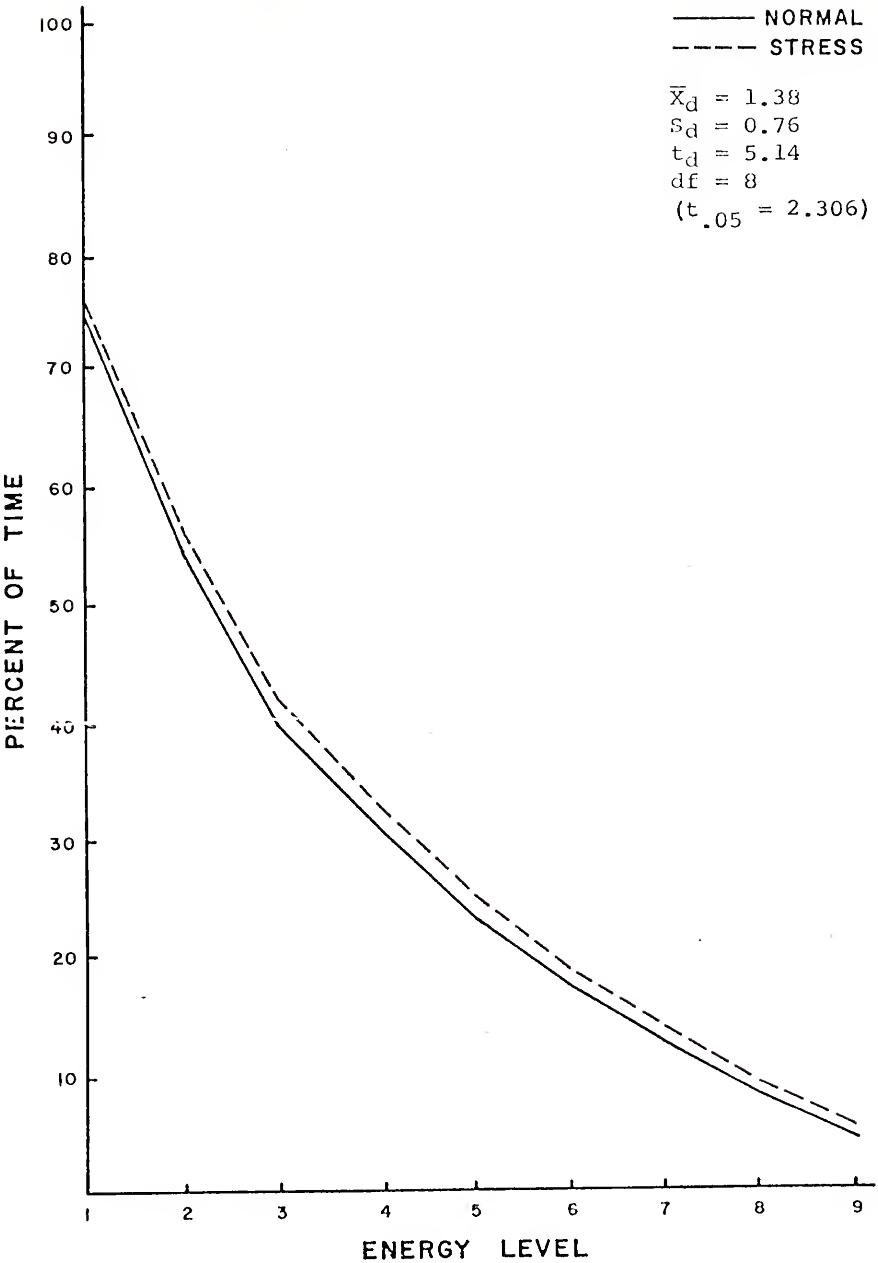

Figure 11. Overall Time-Energy Distribution (TED) for All Subjects in the Laboratory Stress Experiment.

were combined to obtain the overall results. As can be seen, the $\underline{t}$ scores were all positive and significant at the 0.05 alpha level. The $\underline{t}$ scores for the males is 4.22, 5.42 for the females and 5.14 for the overall data.

The indication is that under stress a speaker will maintain a higher intensity level for a greater portion of his speaking time. This is illustrated in Figures 9-11 by the fact that the stress distribution is elevated relative to the normal distribution.

Speech Time/Total Time Ratio (ST/TT)

In addition to SPR, the ratio of the speech time to the total sample time (ST/TT) also was analyzed. The ST/TT measure is the percentage of the total speech sample occupied by speech. The results of the ST/TT analyses are shown in Table 5. The analyses included the mean and standard deviation of ST/TT. The mean ST/TT was found to increase, although not significantly. The mean difference in ST/TT between the normal and stress speaking conditions was only 0.01. Similar results were found for the standard deviation (or variability) of ST/TT; that is, the small increase in variability for stressed speech was not significant.

Table 5. Results of the Speech Time/Total Time (ST/TT) Ratio Analysis for the Laboratory Stress Experiment; Values in Parentheses are the Standard Deviations (SD) and the Degree of Freedom (df) for the t Scores (N = 12).

	Speaking Condition			
	Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d (df)
Mean	0.73 (0.03)	0.75 (0.03)	0.01 (0.04)	0.83 (11)
Standard Deviation	0.03 (0.02)	0.04 (0.02)	0.01 (0.02)	1.66 (11)

In short, ST/TT was not found to be a very powerful indicator of stress in this experiment. However, there was a tendency for both the mean and standard deviation of ST/TT to increase slightly for speech produced under stress.

Speech Bursts and Pauses

Two other temporal measures obtained were the number of speech bursts and pauses. The results of these analyses may be found in Table 6. As can be seen, the number of speech bursts as well as the number of pauses was greater for the stress speech samples. However, the increase was inconsequential (0.1) for both measures and not statistically significant.

Disfluency

The final measure analyzed in this experiment was that of disfluency. This measure was obtained utilizing the total number of disfluences in the two minute speech samples. The mean values for the two speaking conditions are shown in Table 7. As can be seen, the number of disfluencies was greater for the stressed speech (7.7) than for the normal (5.2). In addition, the 2.5 increase was found to be statistically significant. Therefore, the affect of stress on

Table 6. Results of the Speech Bursts and Pause Analyses for the Laboratory Stress Experiment; Value in Parentheses is the Degrees of Freedom (df) for the t Scores (N = 12).

	Speaking Condition			
	Normal	Stress	Mean Difference	t_d(df)
A. Speech Bursts				
Mean	40.0	40.2	0.1	0.10(11)
Standard Deviation	5.7	6.6	3.2	
B. Pauses				
Mean	40.6	40.7	0.1	0.10(11)
Standard Deviation	5.7	6.6	3.4	

Table 7. Analysis Results of the Number of Disfluencies for the Laboratory Stress Experiment; Value in Parentheses is the Degrees of Freedom (df) for the t Score (N = 12).

	Speaking Condition			
	Normal	Stress	Mean Difference	t_d(df)
Mean	5.2	7.7	2.5	2.86(11)*
Standard Deviation	3.1	4.6	2.9	

*Significant at the 0.05 level.

the level of speech disfluency is substantial enough to suggest that this measure might be utilized as a vocal indicator of stress.

CHAPTER IV

RESULTS OF SITUATIONAL STRESS EXPERIMENT

The purpose for conducting the second experiment was to obtain information under conditions of a different and greater stress. In this experiment, the stress experienced by the subjects was induced by having them deliver a public speech to a group of their peers. For the majority of the subjects this was the first exposure they had experienced to a situation of this type and they naturally were anxious. Nevertheless, the behaviors of only those individuals scoring 13 or higher on the MAACL anxiety scale were studied.

The same values were obtained and analyzed in this experiment as in the previous investigation. That is, within the acoustic domain they included maximum, mean, mode and distribution of speech intensity (SI) as well as speaking fundamental frequency (SFF) mean and distribution. The measures within the temporal domain included mean and standard deviation of speech rate (SR), speech time/total time (ST/TT) ratio, and speech/pause ratio (SPR). Finally, also included were time-energy distribution (TED) measures and the mean number of speech bursts and pauses, as well as the number of disfluencies. As with the previous experiment, the statistical procedure utilized was a matched-pairs, two-tailed t test. It was used in order to test the null hypothesis--i.e., that there is no difference between the acoustical/temporal measures for speech produced under conditions of stress and for those produced when there is no stress.

Speech Intensity (SI)

Of the three intensity characteristics analyzed, the first to be reported will be mean intensity (MI) level; these results may be found in Table 8-A. It may be seen, MI was greater for normal speech than for speech produced under stress both by sex and for the subjects pooled. These relationships are indicated by the negative mean difference values. The reduction in MI for the stressed speech ranged from 3.3 dB for the females to 6.1 dB for the males. The trend was sufficiently consistent to produce significant t scores. The implication of these data is that, for conditions of situational stress, mean speech intensity will be reduced from the normal.

Table 8. Results of the Speech Intensity (SI) Analyses for the Situational Stress Experiment; All Values are Expressed in dB Re: 1mv. Values in Parentheses are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores.

	Speaking Condition			
	Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d(df)
A. Mean Intensity (MI)				
Males (N=10)	68.4(2.5)	62.3(4.0)	-6.1(3.5)	-5.23(9)*
Females (N=7)	67.6(1.8)	64.3(1.8)	-3.3(2.2)	-3.67(6)*
Overall (N=17)	68.1(2.2)	63.1(3.4)	-4.9(3.3)	-5.94(16)*
B. Maximum Intensity (MAXI)				
Males (N=10)	81.6(1.2)	73.7(3.1)	-7.9(2.7)	-8.78(9)*
Females (N=7)	81.4(1.1)	76.4(2.4)	-5.0(3.1)	-3.95(6)*
Overall (N=17)	81.5(1.1)	74.8(3.0)	-6.7(3.1)	-8.65(16)*
C. Mode of Distribution (MODI)				
Males (N=10)	74.6(4.9)	66.4(7.5)	-8.2(5.7)	-4.32(9)*
Females (N=7)	73.4(4.9)	70.0(3.6)	-3.4(4.6)	-1.81(6)
Overall (N=17)	74.1(4.8)	67.9(6.3)	-6.2(5.7)	-4.35(16)*

*Significant at the 0.05 level.

$t_{.05} = 2.262$, df = 9

$t_{.05} = 2.447$, df = 6

$t_{.05} = 2.120$, df = 16

The second intensity measure to be analyzed was maximum intensity (MAXI). The MAXI results also may be found in Table 8-B. MAXI was found to decrease by 7.9 dB for the males, 5.0 dB for the females and 6.7 dB for the combined results and all three differences between the two speaking conditions were found to be statistically significant. These results would appear to indicate that, under conditions of stress, the maximum speech intensity subjects produce tends to be somewhat less than it does when they are speaking under neutral conditions.

The third intensity metric studied was the mode of the intensity distribution (MODI). See Table 8-C for the results of this analysis. As with the previous measures, when compared to the normal MODI was found to decrease for speech produced under stress conditions. The males exhibited the greatest decrease (8.2 dB) and the females, the least (3.4 dB). The overall results, obtained by combining the results for the males and females, showed a decrease of 6.2 dB. However, only the results for the males and the overall analysis were found to be statistically significant. Nevertheless, the tendency for MODI was to decrease for stressed speech.

As a follow-up, the overall intensity distribution also was analyzed to provide more insight into these relationships. The results of these evaluations may be seen in Figures 12-14.* Here the data are presented by sex and also combining all the subjects. The statistical analyses of the distributions indicated little or no difference between the two speaking conditions (normal and stress). However, some weight can be obtained by consideration of these distributions. For example, the first impression is of a "shift" in the stress distribution (relative to the normal). It was found that for intensity levels less than approximately 65-75 dB the stress distribution was greater than the normal. Conversely, above the 65-75 dB level, the distribution for the stress condition is less than the normal distribution. However, the "shift" was such that the differences between the distributions at the lower intensities counter-balanced the differences at the higher intensities resulting in a nonsignificant mean difference between the stress and normal intensity distributions.

The cited results appear to indicate that the measures of the mean, maximum or mode of the intensity distribution

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*The tabulated values for the distributions may be found in Appendix D.

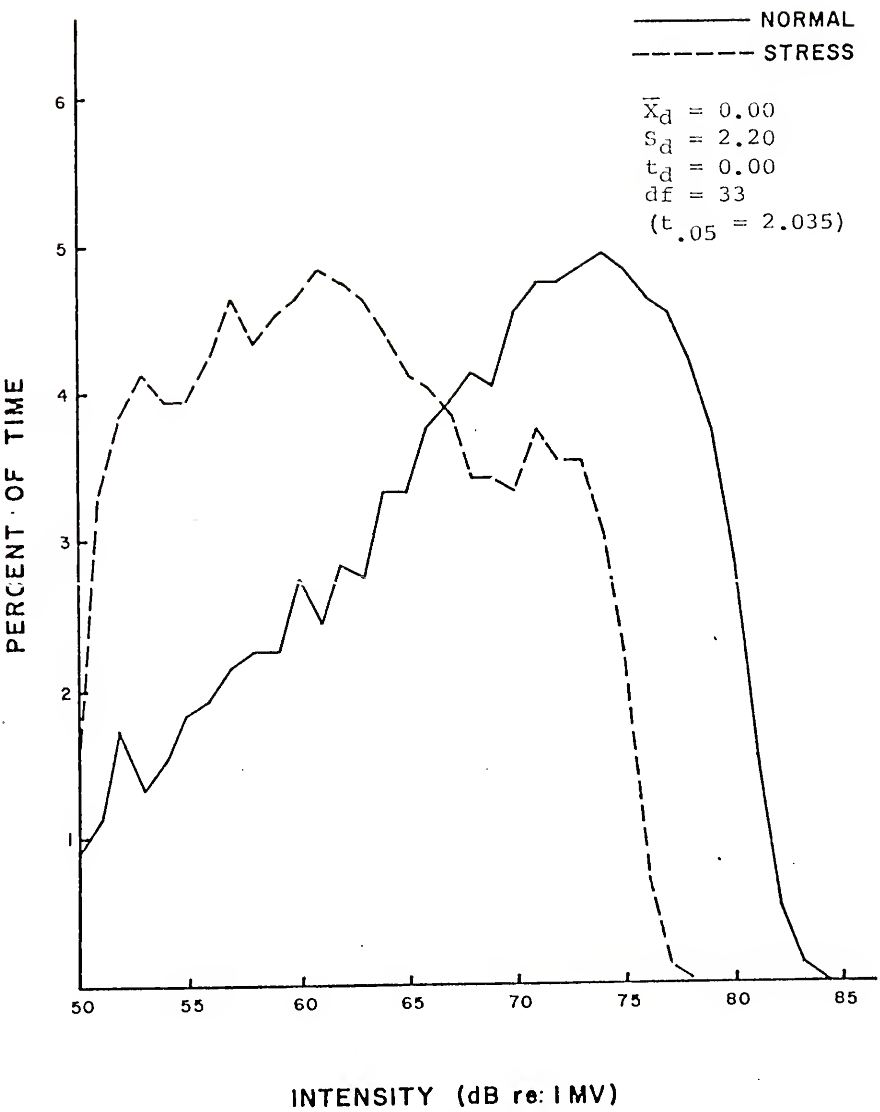

Figure 12. Intensity Distribution for the Male Subjects in the Situational Stress Experiment.

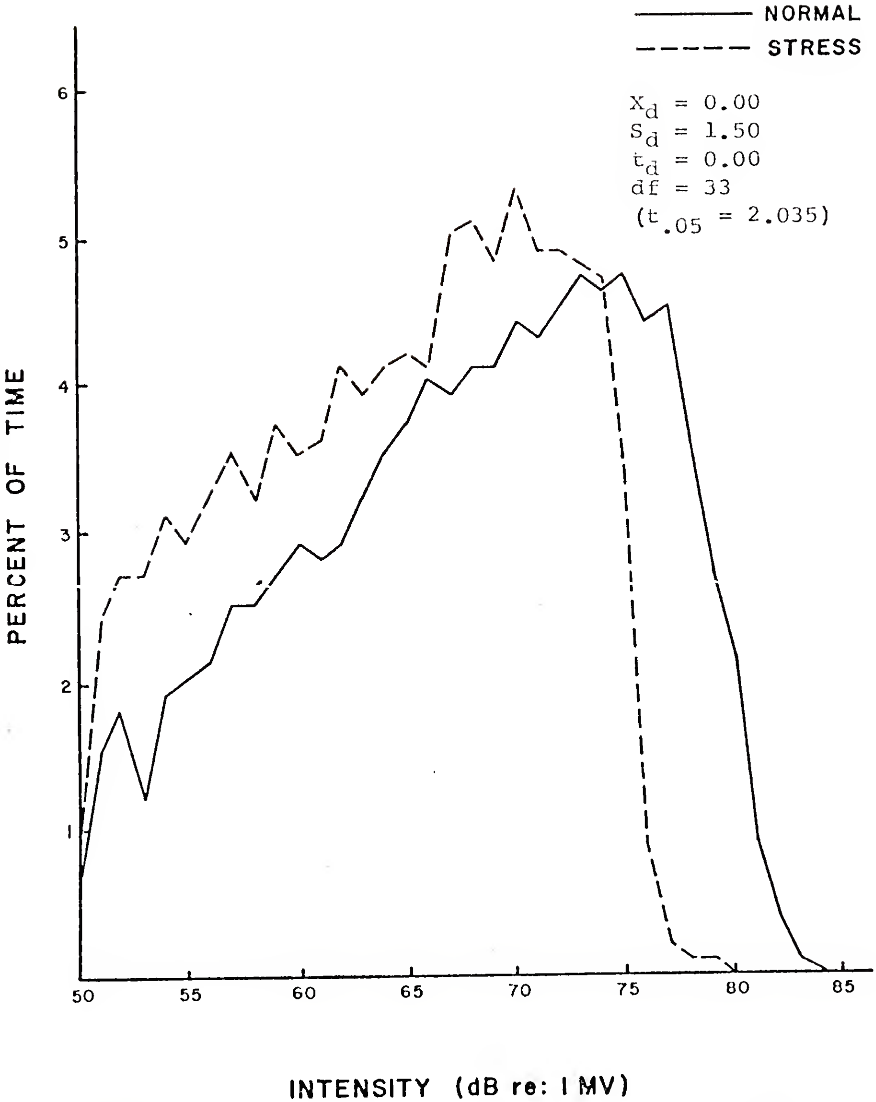

Figure 13. Intensity Distribution for the Female Subjects in the Situational Stress Experiment.

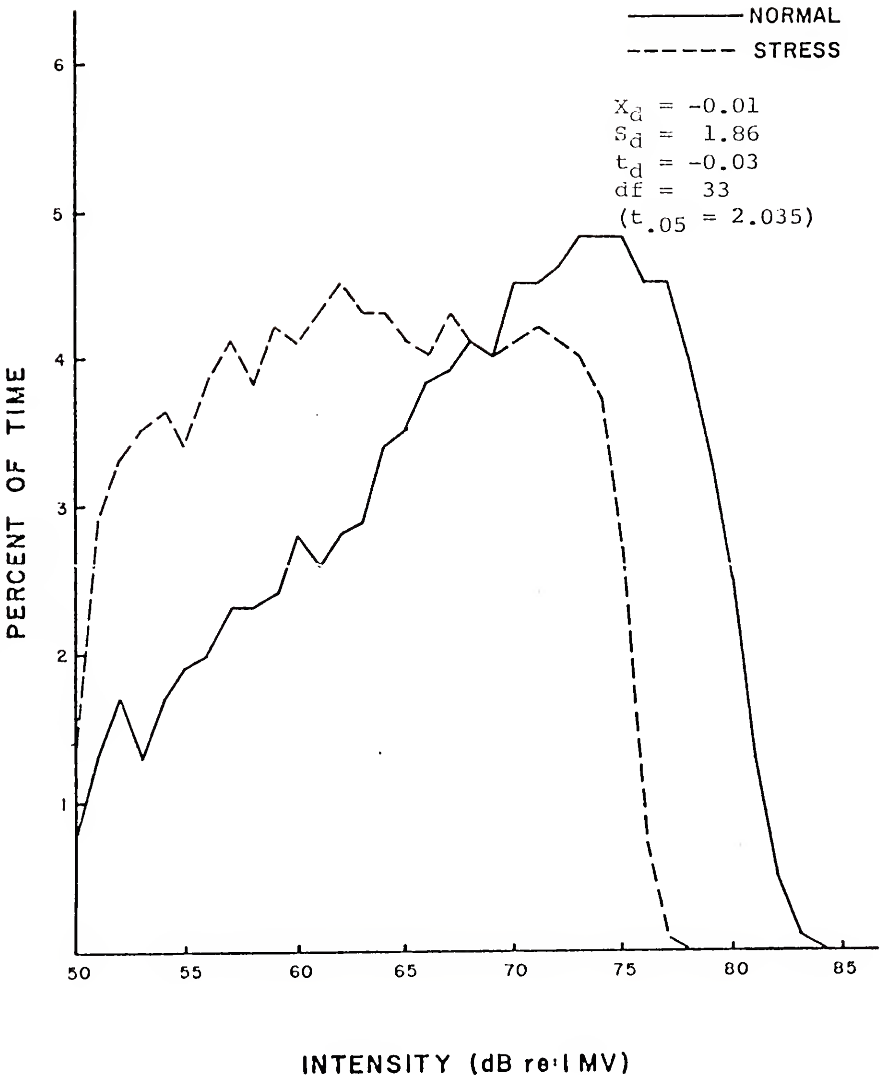

Figure 14. Overall Intensity Distribution for All Subjects in the Situational Stress Experiment.

would be better stress indicators than the entire distribution.

Speaking Fundamental Frequency (SFF)

As with the first experiment, the SFF parameters selected for analysis were the mean and SFF distribution. The results of these several SFF analyses may be found in Table 9. It should be noted that the data are tabulated in both semitones (ST) and hertz (Hz) but the analyses will be discussed only in terms of ST because of the geometric nature of SFF. As with the other measures, the data were analyzed first by sex then combined to obtain the overall results. Examination of the table will demonstrate that the males and the overall analyses showed significant increases in SFF for speech produced under stress. The females also showed an increase in f_o, although it was not significantly different. That is, the increase for the females was only 0.1 ST as compared to 1.3 ST for the males and the overall increase of 0.8 ST.

The SFF distribution also was analyzed for potential differences between speecn produced under neutral and stress conditions. As with the mean, these results are

Table 9. Results of the Speaking Fundamental Frequency (SFF) Analyses for the Situational Stress Experiment; Values Are Expressed in Both Semitones (ST) and Hertz (Hz); Values in Parentheses Are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores.

	Speaking Condition							
	Normal		Stress		Mean Difference		t_d	
	ST(SD)	Hz(SD)	ST(SD)	Hz(SD)	ST(SD)	Hz(SD)	ST(df)	Hz(df)
Males(N=10)	34.8(2.3)	122.8(16.1)	36.1(1.9)	132.1(36.1)	1.3(0.9)	9.3(6.2)	4.33(9)*	4.50(9)*
Females(N=7)	43.8(1.7)	206.6(20.7)	43.9(1.3)	206.6(15.1)	0.1(1.2)	0.0(15.2)	0.20(6)	0.00(6)
Overall(N=17)	38.5(5.0)	157.3(46.0)	39.3(4.3)	162.8(40.4)	0.8(1.2)	5.5(11.4)	2.67(16)*	1.93(16)

*Significant at the 0.05 level.

shown in Figures 15-17* As can be seen, no significant difference was found between the two distributions for any of the analyses. Indeed, in each case, the analysis resulted in a t score of 0.00 and the general shape of the distributions for the different speaking conditions appear to be very similar.

To summarize, the mean SFF was found to be more important than the SFF distribution for determining the presence of stress. The mean SFF was found to increase for both the males and the females although only the increase for the males was significant. Furthermore, the overall SFF was found to be significantly greater than normal for the stress condition. However, the SFF distributions for each sex as well as the males and females combined showed no difference between the two speaking conditions.

Speech Rate (SR)

As per the protocols utilized in the previous experiment, the two minute speech samples were divided into 15 second subsamples for speech rate (SR) analysis. The first, third, fifth and seventh subsamples were utilized to compute the mean and standard deviation of SR. Table 10

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*See Appendix E for the tabulated values for the SFF distributors.

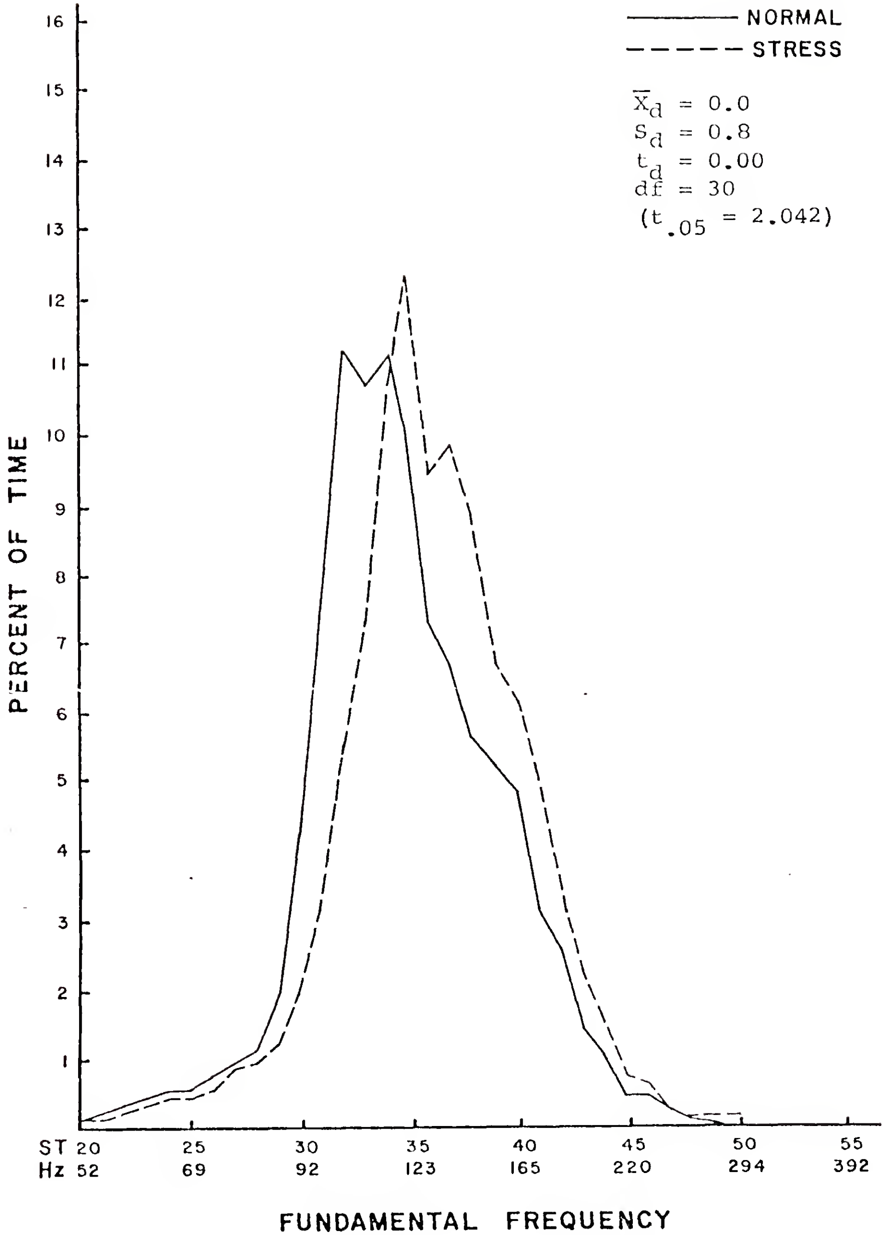

Figure 15. Speaking Fundamental Frequency (SFF) Distribution for the Male Subjects in the Situational Stress Experiment.

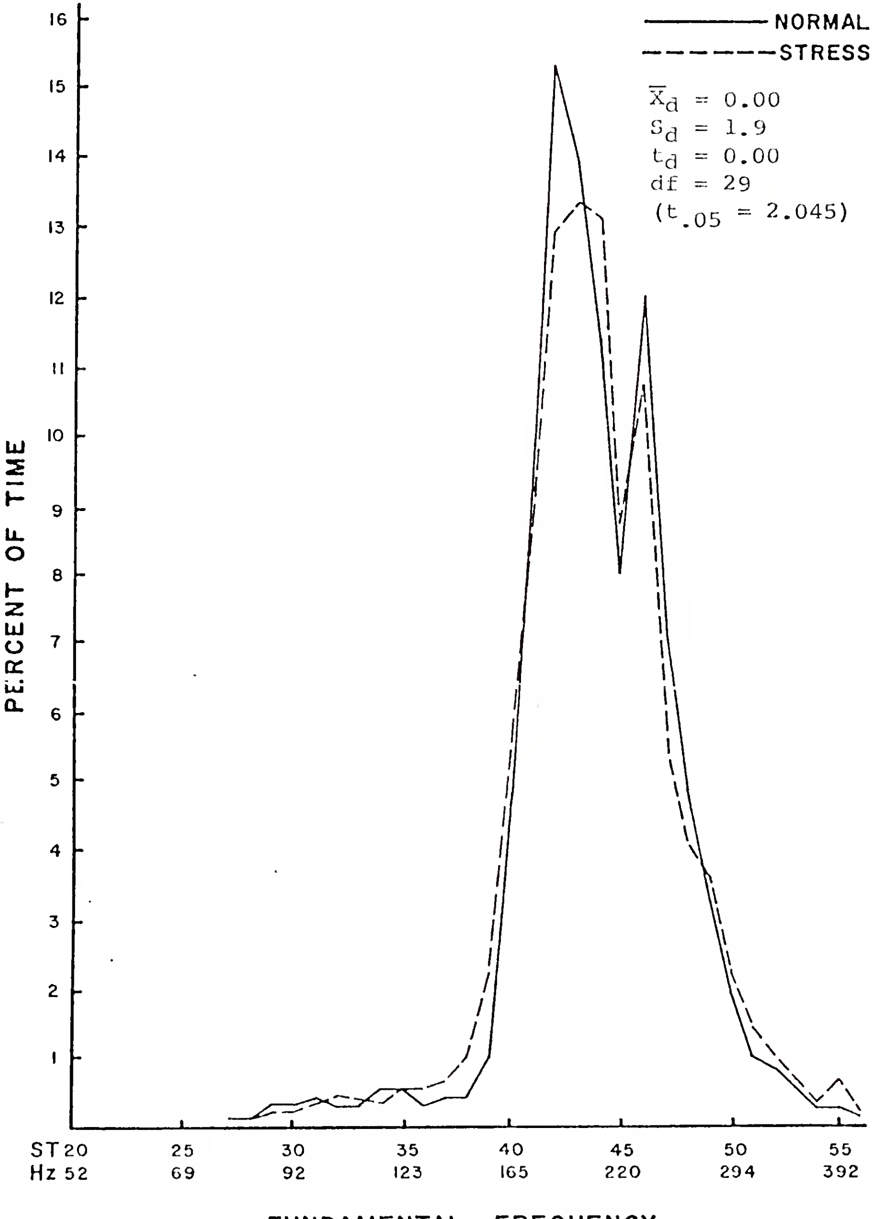

Figure 16. Speaking Fundamental Frequency (SFF) Distribution for the Female Subjects in the Situational Stress Experiment.

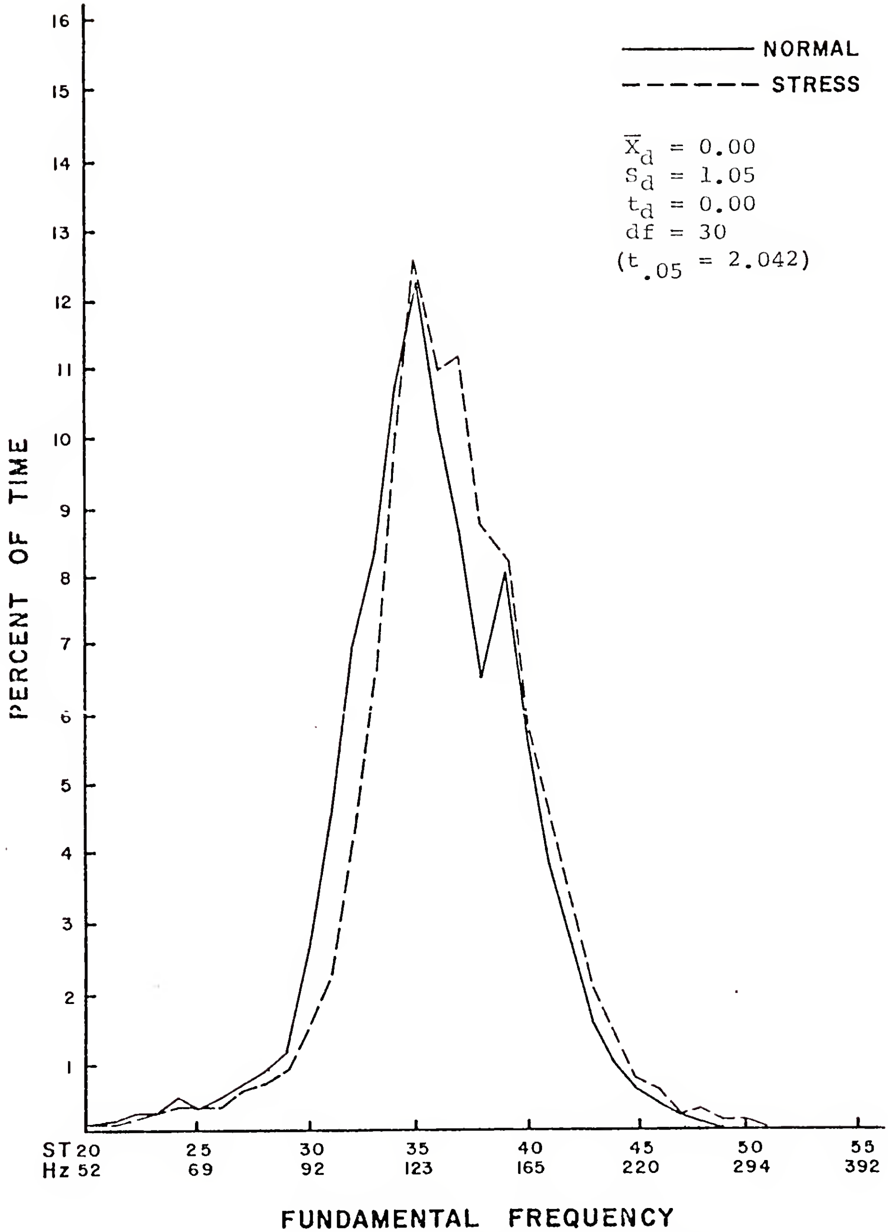

Figure 17. Overall Speaking Fundamental Frequency (SFF) Distribution for All Subjects in the Situational Stress Experiment.

Table 10. Results of the Speech Rate (SR) Analysis for the Situational Stress Experiment; SR Values Are Expressed in Syllables Per Second; Values in Parentheses Are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores (N = 17).

	Speaking Condition Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d(df)
Mean	4.5(0.5)	4.2(0.5)	-0.3(0.6)	-2.00(16)
Standard Deviation	0.3(0.2)	0.6(0.3)	0.3(0.2)	6.00(16)*

*Significant at the 0.05 level.

provides the mean values and standard deviations of SR under the two speaking conditions studied. It also provides the mean difference (stress minus normal) between these conditions. The SR was found to be less for the stressed speech (4.2) than the normal (4.5); however, the decrease was not enough to be statistically significant. The variability (as measured by the standard deviation) for the normal speaking condition was found to be 0.3 syllables/sec as compared to 0.6 syllables/sec for the stress samples. This difference of 0.3 resulted in a significant increase in the variability of SR for speech under stress conditions compared to normal.

In any case, no significant change was found for mean SR between the two speaking conditions. However, the data suggest that when stressed, individuals will vary their SR more than they will under normal circumstances. That is, under stress they fluctuate SR to greater extremes compared to normal, while maintaining the same mean SR.

Speech/Pause Ratio (SPR)

The speech/pause ratio (SPR) is defined as the ratio of total speech time to the pause time in the overall sample. As with speech rate, SPR was calculated using alternate 15 sec subsamples extracted from the two minute speech sample. The mean, standard deviation and mean difference in SPR for each speaking condition are shown in Table 11. Both the SPR mean and standard deviation can be seen to increase significantly for the stress speech samples; the mean by 1.32 and the standard deviation, 0.87.

In short, these data imply that, under conditions of stress, the average amount of speech for a given time period will increase relative to the amount of pause time. Furthermore, the variability of SPR also can be expected to increase.

Time-Energy Distribution (TED)

As has been stated, the time-energy distribution (TED) is a measure of the amount of time speech signal energy reaches a specified level. That is, the energy range of the signal is divided into ten equal levels and the percentage of the total sample time the signal remains in each level is determined. However, only the first nine levels are incorporated in the data analysis of the present study. The decision to eliminate the tenth level is based on earlier research by Johnson (1978). In his speaker identification study, Johnson found that the tenth energy level did not

Table 11. Results of the Speech/Pause Ratio (SPR) Analysis for the Situational Stress Experiment; Values in Parentheses are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores (N = 17).

	Speaking Condition Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d (df)
Mean	3.13 (0.96)	4.44 (1.53)	1.32 (1.06)	4.98 (16)*
Standard Deviation	0.61 (0.39)	1.48 (0.83)	0.87 (0.89)	3.91 (16)*

*Significant at the 0.05 level.

contribute to the discrimination of different speech samples. That is, once a discrimination level had been reached utilizing the first nine energy levels, the addition of the tenth level did not improve the ability of TED to differentiate speech samples.

The results of the TED analyses are presented in Figure 18-20.* A relatively strong and consistent relationship can be seen to exist between the speaking condition and TED. Specifically, the TED was found to increase significantly for speech produced under stress when the samples were contrasted to normal speech. This relationship held true for each of the sex subgroups as well as for the pooled groups.

These data indicate that, under conditions of stress, a speaker will produce speech at higher energy levels for a greater proportion of time than they would if they were speaking normally. Although, under stress, the higher intensity levels are produced a greater amount of the time, the overall intensity level is reduced from the normal (as reported earler in the speaking intensity section).

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*The tabulated values for the TED may be found in Appendix F.

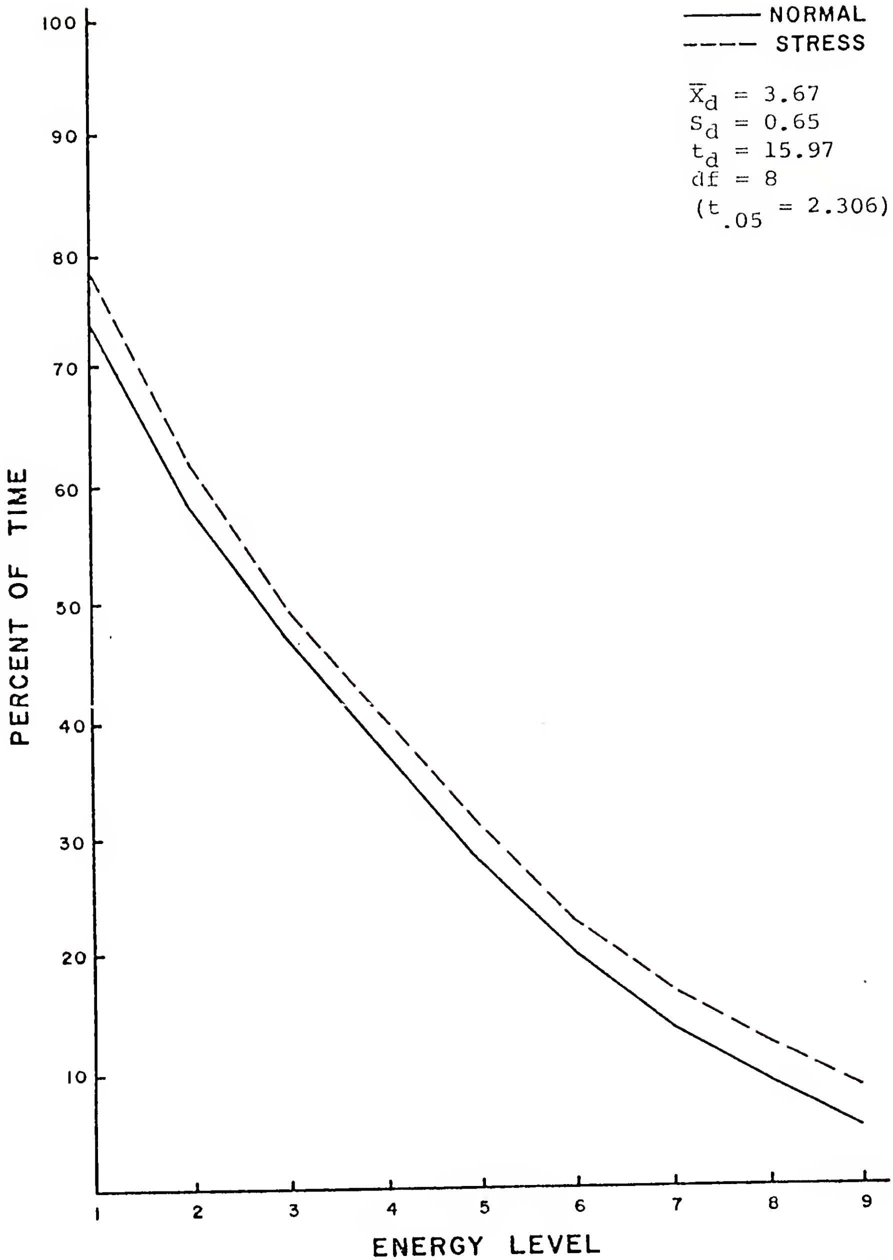

Figure 18. Time-Energy Distribution (TED) for the Male Subjects in the Situational Stress Experiment.

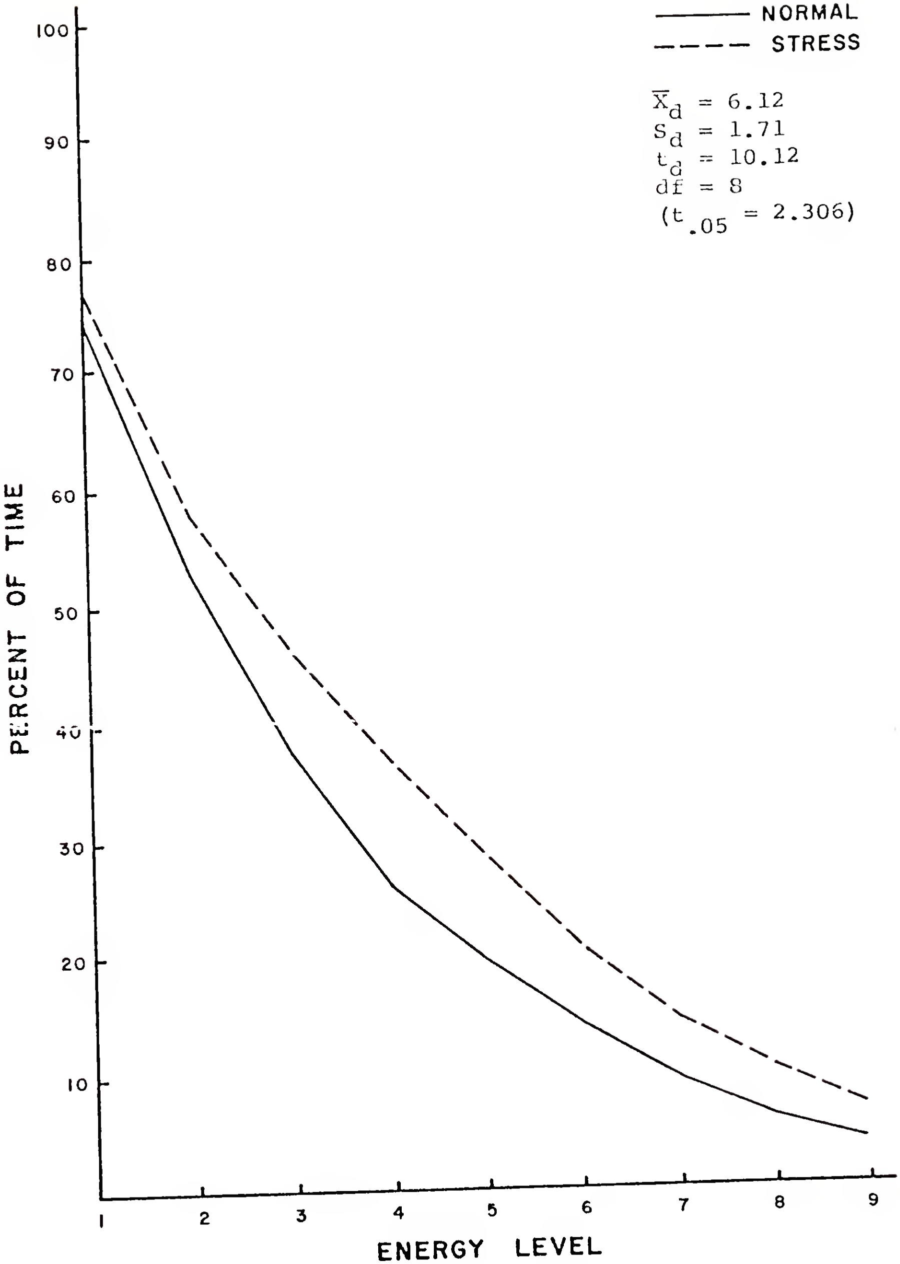

Figure 19. Time-Energy Distribution (TED) for the Female Subjects in the Situational Stress Experiment.

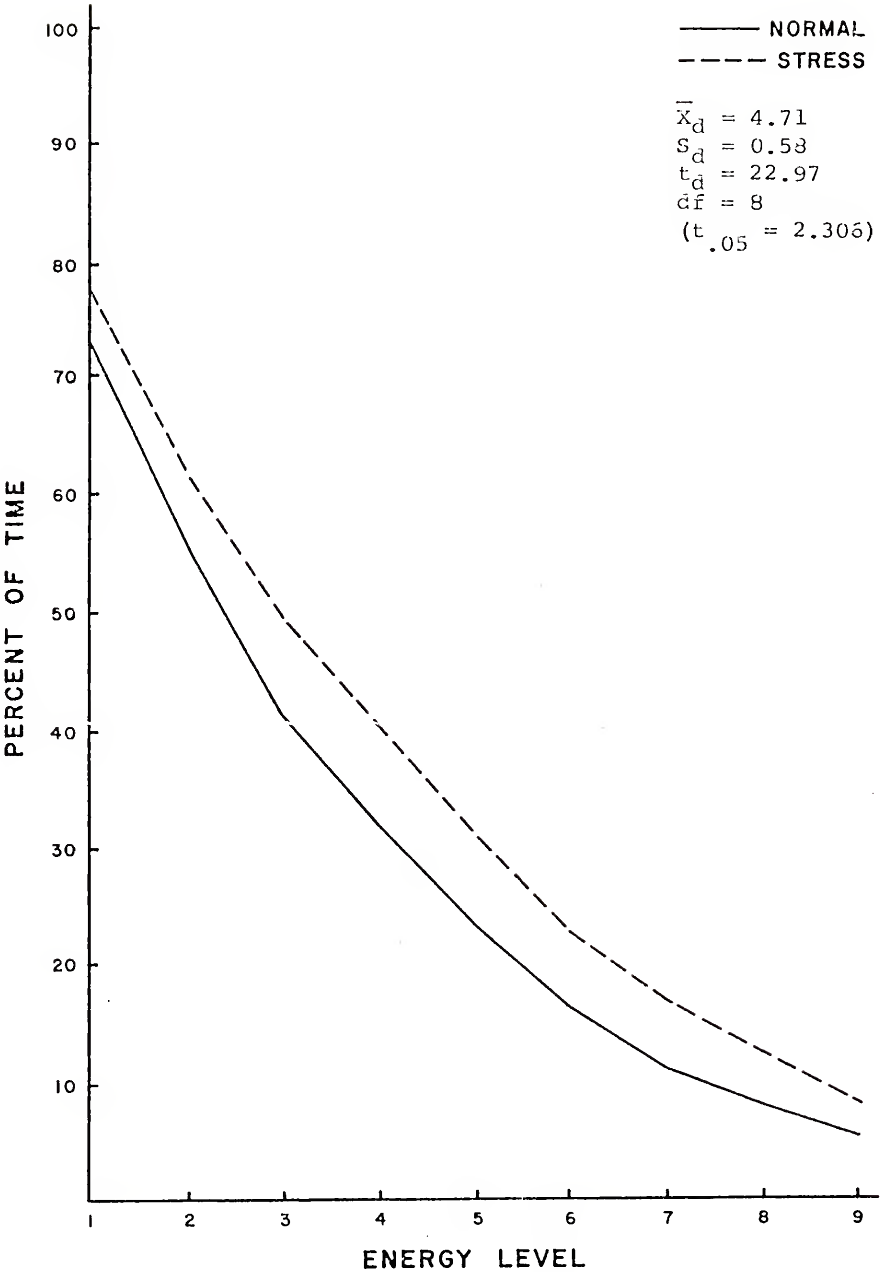

Figure 20. Overall Time-Energy Distribution (TED) for All Subjects in the Situational Stress Experiment.

Speech Time/Total Time Ratio (ST/TT)

Another temporal ratio analyzed was that of the speech time to the total time of the sample (ST/TT). Although this metric is related to the speech/pause ratio (SPR) they are different measures. SPR compares the speech time to the pause time whereas ST/TT contrasted the speech time to the total sample time. Both the mean and standard deviation of ST/TT were analyzed and the results may be found in Table 12.

As indicated in Table 12, the mean ST/TT was 0.05 greater for the stress speech samples than for the normal samples. Similarly, the standard deviation also increased, although by only 0.02. The increase in mean ST/TT was found to be statistically significant, while the slight increase in standard deviation was not significant. Therefore, it can be concluded that an individual speaking under stress will generally tend to spend a greater percentage of the total time speaking than he or she would normally. Furthermore, based on the SPR and ST/TT results, it can be seen that the speech time increases as compared to both the pauses and the total time of the speech samples.

Table 12. Results of the Speech Time/Total Time (ST/TT) Ratio Analysis for the Situational Stress Experiment; Values in Parentheses are the Standard Deviations (SD) and the Degrees of Freedom (df) for the t Scores (N = 17).

	Speaking Condition Normal (SD)	Stress (SD)	Mean Difference (SD)	t_d (df)
Mean	0.74 (0.05)	0.79 (0.06)	0.05 (0.05)	4.00 (16)*
Standard Deviation	0.04 (0.02)	0.06 (0.04)	0.02 (0.04)	2.00 (16)

*Significant at the 0.05 level.

Speech Bursts and Pauses

Two additional temporal parameters analyzed were the actual number of speech bursts and pauses. The results of these analyses may be found in Table 13. As would be expected, these measures are related to both SPR and ST/TT. Consideration of these data will reveal that when an individual is speaking under conditions that induce stress, his or her speech apparently reflects a reduced number of speech bursts and pauses. As can be seen in Table 13, both the bursts and the pauses decreased significantly for the stress samples as compared to the normal.

Combining these results with those for SPR and St/TT the speech pattern under stress might be described as follows. An individual will produce an extended utterance, pause briefly, then continue speaking in another extended speech segment. In this manner, the individual produces fewer speech bursts (of longer duration) and pauses in addition to increasing the speech time as compared to the pause time and total sample time.

Disfluency

The final measure analyzed in this experiment was that of disfluency. In this case, the number of times the

Table 13. Results of the Speech Bursts and Pause Analyses for the Situational Stress Experiment; Value in Parentheses is the Degrees of Freedom (df) for the t Scores (N = 17).

	Speaking Condition			
	Normal	Stress	Mean Difference	t_d(df)
A. Speech Bursts				
Mean	40.0	33.1	-6.9	-3.45(16)*
Standard Deviation	5.6	6.0	8.0	
B. Pauses				
Mean	40.4	33.5	-6.9	-3.49(16)*
Standard Deviation	5.5	5.9	7.9	

*Significant at the 0.05 level.

speaker was disfluent was counted for the entire two minute sample.

These data can be found in Table 14. The mean number of disfluencies was greater for speech produced under conditions of stress (10.2) than it was for the neutral sample (6.8). However, the difference between these conditions was not found to be significant.

These findings indicate that this measure of disfluency may not be as useful an indicator of stress as had been anticipated. However, the non-significance of the increase in disfluency may have been due to the speakers' familiarity with stress speech sample (i.e., their public speeches). Since the subjects had practiced the particular sample they tended to be more fluent than if they had not practiced. Therefore, disfluencies may not indicate stress when the speaker produces a prepared speech sample.

Table 14. Analysis Results of the Number of Disfluencies for the Situational Stress Experiment; Value in Parentheses is the Degrees of Freedom (df) for the t Score (N = 17).

	Speaking Condition			
	Normal	Stress	Mean Difference	t_d(df)
Mean	6.8	10.2	3.2	1.97(16)
Standard Deviation	5.1	5.5	6.5	

CHAPTER V

DISCUSSION

As would be expected, the results of the two current studies indicate that measurable acoustical/temporal changes do occur in speech produced under stress--that is, when it is compared to normal, nonstress speech. Based on the present data, however, some of the observed vocal changes were not in the direction that had been anticipated. Furthermore, the magnitude of the differences between the normal and stress speech samples appears to be a function of the type of stress. For example, more of the measures analyzed for the situational stress experiment showed significant change than did those in the laboratory experiment.

Laboratory Stress Experiment

A summary of the results of the laboratory stress experiment may be found in Table 15. These results are based on the overall mean values for each of the parameters analyzed. As can be seen from the table, the mean values

Table 15. Summary of Results for the Laboratory Stress Experiment Based on Overall Mean Values for Each Parameter.

Speech Parameter	Direction of Change (Stress re: Normal)
A. Acoustical	
Speech Intensity (SI)	+
Speaking Fundamental Frequency (SFF)	+
B. Temporal	
Speech Rate (SR)	+
Speech/Pause Ratio (SPR)	+
Time-Energy Distribution (TED)	+*
Speech Time/Total Time Ratio (ST/TT)	+
Speech Bursts	+
Pauses	+
C. Disfluency	+*

+ = Change in direction toward increase

− = Change in direction toward decrease

* = Statistically significant at the 0.05 level

for all the parameters analyzed in this experiment showed change--specifically increases--for the stressed speech when it was compared to the neutral condition. However, many of these changes were not statistically significant. For example, the maximum intensity (MAXI) was the only intensity measure to increase significantly, although the general trend was for all intensity measures, i.e., the maximum, mean, mode and distribution, to increase at least slightly. Similarly, the mean and distribution of speaking fundamental frequency (SFF) both increased slightly under stress conditions. However, these increases were not found to be of statistical significance either.

Examination of Table 15 also will reveal that, within the temporal domain, the only parameter to change significantly for the stress speech condition was the time-energy distribution (TED). The remaining temporal parameters of speech rate (SR), speech/pause ratio (SPR), speech time/total time ratio (ST/TT), speech bursts, and pauses were found to be greater than normal under conditions of stress, although not significantly so. Finally, the disfluency metric increased significantly when the speech samples were produced under stress.

In addition to increases in the mean values of those parameters studied, variability also increased. Quite often a large variability (as measured by the standard deviation) resulted in the differences between two means not being significant. That is, the measured changes in the acoustical/ temporal parameters included in this research turned out to be inconsistent across individuals. Moreover, the stressing effects of electro-shock, in this particular experiment, did not appear to alter the subjects' speech patterns to any significant degree. Therefore, few of the parameters appear to show compelling promise as potential indicators of stress.

On the other hand, it is possible that electric shock did not stress the subjects studied to a reasonably high degree and that application of other types of stressors would result in conditions that would lead to the uncovering of the anticipated relationships. For example, most of the trends observed in these two experiments were found to be consistent for both. To illustrate, speaking fundamental frequency, speech/pause ratio and the speech time/total time ratio were found to increase (and significantly) in the situational stress experiment. Thus, it would appear that the trends found in the laboratory stress experiment may be in the right direction, and that the stressor was not severe enough to move them to significant levels.

Situational Stress Experiment

The results of the situational stress experiment are summarized in Table 16. As can be seen, many of the relationships between speech and emotional stress were found to be significant. That is, subjects' speech was significantly modified under the stress of a public speaking task. Significant differences between the two speaking conditions (i.e., neutral/stress) were found both acoustically and temporally.

Certain of the results in the acoustic domain are of particular interest. For example, the results show a significant decrease in speaking intensity and an increase in mean speaking fundamental frequency. The decrease in intensity was consistent for the mean, maximum and mode.

Within the temporal domain, the speech/pause ratio, time-energy distribution and speech time/total time ratio all were found to be significantly greater for the stress speech samples than for the normal samples. Conversely, the results for speech rate, the number of bursts and pauses indicated a decrease relative to neutral speech. However, the decrease in speech rate was not significant.

In addition to these findings, it can be noted that the speech changes resulting from the public speaking situation

Table 16. Summary of Results for the Situational Stress Experiment Based on Overall Mean Values for Each Parameter.

Speech Parameter	Direction of Change (Stress re: Normal)
A. Acoustical	
Speech Intensity (SI)	-*
Speaking Fundamental Frequency (SFF)	+*
B. Temporal	
Speech Rate (SR)	-
Speech/Pause Ratio (SPR)	+*
Time-Energy Distribution (TED)	+*
Speech Time/Total Time Ratio (ST/TT)	+*
Speech Bursts	-*
Pauses	-*
C. Disfluency	+

+ = Change in direction toward increase

- = Change in direction toward decrease

* = Statistically significant at the 0.05 level

were more complex than that for laboratory stress. For example, speech intensity decreased with a simultaneous increase in SFF. This relationship, between intensity and SFF, is contrary to accepted theory that vocal intensity and SFF are positively correlated (Issihiki, 1959; Ladefoged and McKinney, 1963). However, in the present case, the differences are behaviorally based. Thus, it is quite possible that the behavioral effects were powerful enough to override the natural physiological relationships.

Further, it was found that the number of speech bursts decreased simultaneously with a significant increase in both the speech/pause and speech time/total time ratios. These particular temporal findings would suggest that the subjects spoke in extended utterances. That is, they appeared to produce fewer speech bursts and the overall duration for these bursts was greater in this case than for neutral speech. The number of pauses also were found to be fewer for speech produced under stress than for normal speech; a finding that is consistent with that for increases in speech/pause ratios.

In short, tasks based on situational stress resulted in speech that showed: (1) lower intensity, (2) higher speaking fundamental frequency, (3) slightly slower rates, (4) fewer (but longer) speech bursts, and (5) fewer pauses. However, as with the laboratory stress experiment, the large variability for several of the parameters suggests that the resultant parameter changes were not consistent for all the subjects.

It should be noted that, for the laboratory stress experiment, both speaking conditions were recorded in an IAC sound treated room and that the same speech materials ("An Apology for Idlers") were utilized. However, for the situational stress experiment, the stress samples were recorded in an open classroom and consisted of different semi-extemporaneous speech materials while the normal speech samples were recorded in the IAC room and consisted of a reading of "An Apology for Idlers." However, when the results of the two experiments are compared (see Tables 15 and 16), the general agreement (in direction usually) of the speech changes becomes obvious. The only disparities might be in speech intensity, number of speech bursts and pauses where these parameters decreased for the situational stress experiment and tended to increase for laboratory stress. However, the increases were only slight and were not found to be significant. Nevertheless, there are more similarities between the results of the two experiments than there are differences (see Table 17). It is on this basis that a kind of cross-verification of the results occurs. That is, the data from the first study cross-validate the second and the data from the second tend to give credence to the trends in the first (which, otherwise, are non-significant).

Comparison to Previous Studies: SFF

Prior to the present study, the acoustic parameter most frequently investigated as a potential correlate of stress effects on speech has been fundamental frequency (f_0) (Fairbanks and Pronovost, 1939; Bonner, 1943; Hecker et al., 1968; Williams and Stevens, 1969 and 1972). Although several of the previous studies utilized actors simulating various emotions, certain comparisons can be made between these investigations and the present data. For instance, Fairbanks and Pronovost (1939) found that for the emotions they studied (contempt, anger, fear, grief and indifference), fear was reflected by the highest SFF. Similar results were reported by Williams and Stevens (1972) using the emotions sorrow, fear, anger and a neutral speaking condition. Williams and Stevens found that fear had the second highest mean SFF, with anger being higher. In an earlier (1969) study, Williams and Stevens also found that pilots and

Table 17. Comparison of the Overall Results for the Laboratory and Situational Stress Experiments Based on Mean Values for Each Parameter.

Speech Parameter	Direction of Change (Stress re: Normal) Laboratory Stress	Situational Stress
A. Acoustic		
Speech Intensity (SI)	+	-*
Speaking Fundamental Frequency (SFF)	+	+*
B. Temporal		
Speech Rate (SR)	+	-
Speech/Pause Ratio (SPR)	+*	+*
Time-Energy Distribution (TED)	+	+*
Speech Time/Total Time Ratio (ST/TT)	+	+*
Speech Bursts	+	-*
Pauses	+	-*
C. Disfluency	+*	+

+ = Change in direction toward increase

- = Change in direction toward decrease

* = Statistically significant at the 0.05 level

control tower operators increased f_0 under stress conditions (presumably, fear). On the other hand, Hecker et al. (1968) reported inconsistent changes in f_0 for their subjects who were experiencing stress. For the present study, mean SFF was found to increase--for the stressed speech samples--in both experiments. When the results of the above studies are combined relative to the f_0 effects of fear/anxiety/stress, the pattern seems to indicate that a speaker's SFF will increase from the norm for conditions of stress.

Comparison to Previous Studies: Intensity

Two earlier groups of investigators (Friedhoff et al., 1964; Hecker et al., 1968) have examined the relationship between speaking intensity and stress. Friedhoff et al. found that average intensity increased when subjects lied (and presumably were speaking under stress). Hecker et al. reported small or inconsistent differences in intensity levels between their control and stress speaking conditions; however, one of their subjects did exhibit an increase of 2.0 dB for the stress condition. By comparison, the data from the current laboratory stress experiment show a slight, but nonsignificant, increase in intensity for stress related speech productions. However, for the situational stress experiment, these same measures manifest a significant _decrease_ in intensity for the stressed speech. The difference in these results may have been due to a difference in the types of stress applied to subjects in the two experiments. Furtheremore, the discrepancy between the present experiments and earlier studies may be explained by the fact that Friedhoff _et al_. (1964) analyzed only one word and Hecker _et al_. (1968) utilized "certain portions of the test phrase" (p. 995) whereas the entire speech sample was analyzed in the present case.

Comparison to Previous Studies: Temporal

Temporal analysis of speech--as it relates to emotions--was extensively studied by Fairbanks and Hoaglin (1941) and also by Williams and Stevens (1972). In addition, Hecker _et al_. (1968) refer to changes in the "duration of phonetic segments" (p. 1001) as potential articulatory manifestations of stress. Fairbanks and Hoaglin (1941) found that conditions of (emotional) fear resulted in the second highest mean overall rate of 202 words per minute, followed closely by anger. However, Williams and Stevens (1972) report that when compared to their neutral speaking condition, the fear condition resulted in a slower speech rate (i.e., 3.80 syllables per second). Fairbanks and Hoaglin (1941) also studied the mean number of phonations and pauses for the simulated emotions of contempt, anger, fear, grief and indifference. They report that fear had the second lowest number of phonations and pauses.

It is difficult to compare the rate measures obtained by Fairbanks and Hoaglin (1941) to those of Williams and Stevens (1972) due to their differential use of units of measure. Moreover, it is difficult also to compare the results from the present study to these experiments as the data here are obtained by different means; anyway the present results do not seem conclusive. For example, speech rate increased for the laboratory experiment, but decreased in the public speaking experiment, although neither change was found to be significant. However, the number of speech bursts and pauses were found to be significantly less for the situational stress speech than for the control (nonstress) speech, a finding which is in agreement with those of Fairbanks and Hoaglin. For the laboratory stress experiment, the number of speech bursts and pauses tended to increase for stressed speech; nevertheless, the increase was only slight and not found to be significant.

Conclusions

The findings of this research may be viewed yet differently; that is, they show that, of the acoustical/temporal measures analyzed, 68.8% changed significantly between the two speaking conditions in the situational stress experiment, whereas only 18.8% changed significantly in the laboratory stress experiment. These relationships may be explained, in part, by a differential subject response to the two stressors. Specifically, it will be remembered that the definition proposed in Chapter I was that stress is a psychological state that is a response to a perceived threat and will be accompanied by specific emotions (e.g., fear, anxiety, anger). The major difference between the two present experiments may have been embedded in the threat perceived by the subjects. In the laboratory experiment, the subjects had no emotional involvement with the speaking task; they were free to end the experiment at any time and the threat was primarily a physiological one. However, in the situational stress experiment, the subjects probably were under more emotional pressure and undoubtedly perceived a greater threat--i.e., the possibility of failure or not doing well in front of a peer group. Therefore, it can be argued that the subjects in the situational stress experiment perceived a substantially greater threat and the effects of this (greater) stressor were manifested in their speech. Thus, it would appear that the level/type of stress must be such that the perceived threat exceeds a particular threshold before the stress is reflected in an individual's speech.

Based on the results of the acoustical/temporal analyses conducted in the present study, certain conclusions can be drawn. These conclusions relate to the general speech/voice patterns of an individual who is experiencing stress. Specifically, his or her patterns might be characterized as exhibiting:

1. a generally decreased overall intensity,
2. a generally increased speaking fundamental frequency,
3. somewhat decreased speaking rates,
4. longer speech bursts within an utterance; that is, fewer (but longer) speech bursts and fewer pauses.

Although the above characteristics may describe the overall pattern for speech under stress, individual subject variability may be expected. That is, the speech changes that resulted from the effects of stress were not necessarily consistent for all subjects. For one person, an increase in a particular speech parameter might indicate the presence of stress, whereas in another person a decrease in the same parameter may be equally indicative. Therefore, "speaking stress" profiles may have to be established for an individual if attempts are to be made subsequently to determine if that person is experiencing stress and only speech samples are available as indicators.

APPENDICES

APPENDIX A

MULTIPLE AFFECT ADJECTIVE
CHECK LIST

MULTIPLE AFFECT
ADJECTIVE CHECK LIST

in general form

By Marvin Zuckerman
and
Bernard Lubin

Name________________________________Age __________ Sex________

Date__________________Highest grade completed in school_____

DIRECTIONS: On this sheet you will find words which describe different kinds of moods and feelings. Mark an /X/ in the boxes beside the words which describe how you generally feel. Some of the words may sound alike, but we want you to check all the words that describe your feelings. Work rapidly.

1 active
2 adventurous
3 affectionate
4 afraid
5 agitated
6 agreeable
7 aggressive
8 alive
9 alone
10 amiable
11 amused
12 angry
13 annoyed
14 awful
15 bashful
16 bitter
17 blue
18 bored
19 calm
20 cautious
21 cheerful
22 clean
23 complaining
24 contented
25 contrary
26 cool
27 cooperative
28 critical
29 cross
30 cruel
31 daring
32 desperate
33 destroyed
34 devoted
35 disagreeable
36 discontented
37 discouraged
38 disgusted
39 displeased
40 energetic
41 enraged
42 enthusiastic
43 fearful
44 fine
45 fit
46 forlorn
47 frank
48 free
49 friendly
50 frightened
51 furious
52 gay
53 gentle
54 glad
55 gloomy
56 good
57 good-natured
58 grim
59 happy
60 healthy
61 hopeless
62 hostile
63 impatient
64 incensed
65 indignant
66 inspired
67 interested
68 irritated
69 jealous
70 joyful
71 kindly
72 lonely
73 lost
74 loving
75 low
76 lucky
77 mad
78 mean
79 meek
80 merry
81 mild
82 miserable
83 nervous
84 obliging
85 offended
86 outraged
87 panicky
88 patient
89 peaceful
90 pleased
91 pleasant
92 polite
93 powerful
94 quiet
95 reckless
96 rejected
97 rough
98 sad
99 safe
100 satisfied
101 secure
102 shaky
103 shy
104 soothed
105 steady
106 stubborn
107 stormy
108 strong
109 suffering
110 sullen
111 sunk
112 sympathetic
113 tame
114 tender
115 tense
116 terrible
117 terrified
118 thoughtful
119 timid
120 tormented
121 understanding
122 unhappy
123 unsociable
124 upset
125 vexed
126 warm
127 whole
128 wild
129 willful
130 wilted
131 worrying
132 young

APPENDIX B

SUBJECT INFORMED CONSENT FORM

SUBJECT INFORMED CONSENT FORM
University of Florida

Department:

Name of Subject:

Address:

Title of Project:

Name of Investigator and Academic Title:

Project Number (assigned by the Departmental Committee):

I, the undersigned, after having read the attached instructions, do understand the general nature of the investigation entitled above. Also, the procedures to be followed have been described to me by the investigator whose name is signed below. I agree to participate in this study, or to have my minor child, or ward, whose name is ______________________ participate in this study. I have been informed of the right to withdraw at any stage of the project.

______________________________ ______________________________
(Subject's Signature) (Date)

______________________________ ______________________________
(Signature of parent or guardian, if subject is a minor (where applicable)) (Date)

I, the undersigned, have described to the volunteer, whose signature is given above, the general nature of this study and the procedures to be followed.

______________________________ ______________________________
(Investigator's Signature) (Date)

______________________________ ______________________________
(Witness) (Date)

Written instructions to the subject are attached.

APPENDIX C

INSTRUCTIONS TO SUBJECTS

INSTRUCTIONS TO SUBJECTS

Please read the attached prose passage to familiarize yourself with its contents. After you have gone over it you will be asked to read it twice. First in a normal conversational style; secondly, you will be subjected to stress by a random presentation of mild electric shock to your index finger. The entire procedure should take approximately twenty minutes.

If at anytime, during the experiment, you wish to terminate, please feel free to do so by informing the experimenter. The shock level used will cause minimal discomfort. Stress will actually be induced by the randomness of presentation.

No monetary compensations will be made for participation in this experiment. Feel free to ask any questions you may have.

Adapted from: AN APOLOGY FOR IDLERS
By Robert Louis Stevenson

If you look back on your own education, I am sure it will not be the full, vivid, hours of truancy that you regret. You would rather cancel out some of the lack-luster periods between sleep and waking that you experienced in school. For my own part, I have attended a good many lectures in my time--I still remember that the spinning of a top is a case of kinetic stability. But though I would not willingly part with such scraps of science, I do not set the same store in them as by certain other odds and ends that I came upon in the open street while I was playing truant.

Extreme busyness, whether at school or college, church or market, is a symptom of deficient vitality. A faculty for idleness implies a catholic appetite and a strong sense of personal identity. There are a sort of dead-alive, hackneyed people about, who are scarcely conscious of living except in the exercise of some conventional occupation. Bring these fellows into the country, or set them on board ship, and you will see how they pine for their desk or their study. They have no curiosity; they cannot give themselves over to random provocations nor do they take pleasure in the exercise of their faculties for its own sake. Unless necessity lays about them with a stick, they will even stand still. It is no good speaking to such folk. They cannot be idle; their nature is not generous enough. They pass those hours, which are not dedicated to furious toiling in the gold-mill, in a sort of coma. When they do not require to go to the office, when they are not hungry or have no mind to drink, the whole breathing world is a blank to them. If they have to wait an hour or so for a train, they fall into a stupid trance with their eyes open. To see them you would suppose there was nothing to look at and no one to speak with. You would imagine they were hypnotized or frozen. Yet, very possibly they are hard workers in their own way, and have good eyesight for a flaw in a deed or a turn of the market. They have been to school and college, but during all that time they had their eye only on their grades. They have gone about in the world and mixed with clever people, but all the time they were thinking only of their own affairs. As if a man's soul were not too small to begin with, they have dwarfed and narrowed theirs by a life of all work and no play. Here they are forty, with a listless attention, a mind vacant of all material of amusement, and not one thought to rub against another while they wait for that train. Before he grew up he might have clambered on boxes. When he was twenty he would have stared at the girls. But now the pipe is smoked out, the snuff-box empty, and my gentleman sits bolt upright upon a bench, with vacant eyes. This does not appeal to me as being a "Success in Life."

But it is not only the person himself who suffers from his busy habits, but his wife and children, his friends and relations, and even the very people he sits with in a railway carriage or a bus. Perpetual devotion to what a man calls his "business" is only to be sustained by perpetual neglect of many other things. In fact, it is not by any means certain that a man's "business" is the most important thing he has to do.

APPENDIX D

TABULATED VALUES FOR THE INTENSITY DISTRIBUTIONS

Table D-1. Intensity Distribution Values for the Male Subjects in the Laboratory Stress Experiment; Intensity Values are Expressed in dB re:1mv.

Intensity (dB)	Speaking Condition Normal	Stress	Difference
50	0.7%	0.7%	0.0%
51	1.4	1.2	-0.2
52	1.7	1.6	-0.1
53	1.9	1.6	-0.3
54	1.7	1.8	0.1
55	1.7	1.8	0.1
56	2.0	1.9	-0.1
57	2.4	2.2	-0.2
58	2.3	2.1	-0.2
59	2.7	2.2	-0.5
60	2.9	2.4	-0.5
61	2.8	2.5	-0.3
62	3.0	2.9	-0.1
63	3.1	3.1	0.0
64	3.6	3.3	-0.3
65	3.8	3.5	-0.3
66	3.8	3.6	-0.2
67	4.2	4.1	-0.1
68	4.7	4.6	-0.1
69	5.1	4.7	-0.4
70	5.4	5.0	-0.4
71	5.9	5.6	-0.3
72	6.0	5.6	-0.4
73	4.7	4.7	0.0
74	3.9	4.1	0.2
75	3.7	3.9	0.2
76	3.4	4.0	0.6
77	3.2	3.6	0.4
78	2.8	3.3	0.5
79	2.4	3.1	0.7
80	1.8	2.8	1.0
81	1.0	2.0	1.0
82	0.2	0.7	0.5
83	0.0	0.1	0.1
		Mean	0.01
		S.D.	0.40

$t_d = 0.14$, df = 33 ($t_{.05} = 2.035$)

Table D-2. Intensity Distribution Values for the Female Subjects in the Laboratory Stress Experiment; Intensity Values are Expressed in dB re:lmv.

	Speaking Condition		
Intensity (dB)	Normal	Stress	Difference
50	0.6%	0.6%	0.0%
51	2.4	2.4	0.0
52	1.9	2.1	0.2
53	2.8	2.5	-0.3
54	2.3	2.3	0.0
55	2.6	2.8	0.2
56	2.7	2.8	0.1
57	2.7	2.7	0.0
58	2.9	2.9	0.0
59	3.2	3.1	-0.1
60	3.4	3.3	-0.1
61	3.5	3.4	-0.1
62	3.5	3.6	0.1
63	3.8	3.7	-0.1
64	3.6	3.8	0.2
65	4.1	4.0	-0.1
66	4.3	3.8	-0.5
67	4.2	4.3	0.1
68	4.3	4.3	0.0
69	4.2	4.2	0.0
70	4.4	4.5	0.1
71	4.5	4.7	0.2
72	4.6	4.6	0.0
73	4.6	4.6	0.0
74	4.0	4.1	0.1
75	2.9	3.3	0.4
76	2.6	2.6	0.0
77	2.7	2.3	-0.4
78	2.1	1.6	-0.5
79	1.7	1.4	-0.3
80	1.5	1.4	-0.1
81	1.0	1.2	0.2
82	0.3	0.8	0.5
83	0.0	0.1	0.1
		Mean	0.00
		S.D.	0.22

$t_d = 0.00$, df = 33 ($t_{.05} = 2.035$)

Table D-3. Intensity Distribution Values for All Subjects in the Laboratory Stress Experiment; Intensity Values Are Expressed in dB rc:1mv.

	Speaking Condition		
Intensity (dB)	Normal	Stress	Difference
50	0.7%	0.7%	0.0%
51	1.8	1.7	-0.1
52	1.8	1.8	0.0
53	2.3	2.0	-0.3
54	2.0	2.0	0.0
55	2.1	2.2	0.1
56	2.3	2.3	0.0
57	2.5	2.4	-0.1
58	2.6	2.4	-0.2
59	2.9	2.6	-0.3
60	3.1	2.8	-0.3
61	3.1	2.9	-0.2
62	3.2	3.2	0.0
63	3.4	3.4	0.0
64	3.6	3.5	-0.1
65	3.9	3.7	-0.2
66	4.0	3.7	-0.3
67	4.2	4.2	0.0
68	4.5	4.5	0.0
69	4.7	4.5	-0.2
70	5.0	4.8	-0.2
71	5.3	5.2	-0.1
72	5.4	5.2	-0.2
73	4.7	4.7	0.0
74	3.9	4.1	0.2
75	3.4	3.7	0.3
76	3.1	3.4	0.3
77	3.0	3.1	0.1
78	2.5	2.6	0.1
79	2.1	2.4	0.3
80	1.7	2.2	0.5
81	1.0	1.7	0.7
82	0.2	0.7	0.5
83	0.0	0.1	0.1
		Mean	0.01
		S.D.	0.24

$t_d = 0.24$, df = 33 ($t_{.05} = 2.035$)

Table D-4. Intensity Distribution Values for the Male Subjects in the Situational Stress Experiment; Intensity Values are Expressed in dB re:1mv.

	Speaking Condition		
Intensity (dB)	Normal	Stress	Difference
50	0.9%	1.7%	0.8%
51	1.1	3.3	2.2
52	1.7	3.8	2.1
53	1.3	4.1	2.8
54	1.5	3.9	2.4
55	1.8	3.9	2.1
56	1.9	4.2	2.3
57	2.1	4.6	2.5
58	2.2	4.3	2.1
59	2.2	4.5	2.3
60	2.7	4.6	1.9
61	2.4	4.8	2.4
62	2.8	4.7	1.9
63	2.7	4.6	1.9
64	3.3	4.4	1.1
65	3.3	4.1	0.8
66	3.7	4.0	0.3
67	3.9	3.8	-0.1
68	4.1	3.4	-0.7
69	4.0	3.4	-0.6
70	4.5	3.3	-1.2
71	4.7	3.7	-1.0
72	4.7	3.5	-1.2
73	4.8	3.5	-1.3
74	4.9	3.0	-1.9
75	4.8	2.2	-2.6
76	4.6	0.7	-3.9
77	4.5	0.1	-4.4
78	4.2	0.0	-4.2
79	3.7	0.0	-3.7
80	2.8	0.0	-2.8
81	1.5	0.0	-1.5
82	0.5	0.0	-0.5
83	0.1	0.0	-0.1
		Mean	0.00
		S.D.	2.20

$t_d = 0.00$, $df = 33$ ($t_{.05} = 2.035$)

Table D-5. Intensity Distribution Values for the Female Subjects in the Situational Stress Experiment; Intensity Values are Expressed in dB re:1mv.

	Speaking Condition		
Intensity (dB)	Normal	Stress	Difference
50	0.7%	1.0%	0.3%
51	1.5	2.4	0.9
52	1.8	2.7	0.9
53	1.2	2.7	1.5
54	1.9	3.1	1.2
55	2.0	2.8	0.8
56	2.1	3.2	1.1
57	2.5	3.5	1.0
58	2.5	3.2	0.7
59	2.7	3.7	1.0
60	2.9	3.5	0.6
61	2.8	3.6	0.8
62	2.9	4.1	1.2
63	3.2	3.9	0.7
64	3.5	4.1	0.6
65	3.7	4.2	0.5
66	4.0	4.1	0.1
67	3.9	5.0	1.1
68	4.1	5.1	1.0
69	4.1	4.8	0.7
70	4.4	5.3	0.9
71	4.3	4.9	0.6
72	4.5	4.9	0.4
73	4.7	4.8	0.1
74	4.6	4.7	0.1
75	4.7	3.4	-1.3
76	4.4	0.9	-3.5
77	4.5	0.2	-4.3
78	3.6	0.1	-3.5
79	2.7	0.1	-2.6
80	2.1	0.0	-2.1
81	0.9	0.0	-0.9
82	0.4	0.0	-0.4
83	0.1	0.0	-0.1
		Mean	0.00
		S.D.	1.50

$t_d = 0.00$, df = 33 ($t_{.05} = 2.035$)

Table D-6. Intensity Distribution Values for All Subjects in the Situational Stress Experiment; Intensity Values are Expressed in dB re:1mv.

	Speaking Condition		
Intensity (dB)	Normal	Stress	Difference
50	0.8%	1.4%	0.6%
51	1.3	2.9	1.6
52	1.7	3.3	1.6
53	1.3	3.5	2.2
54	1.7	3.6	1.9
55	1.9	3.4	1.5
56	2.0	3.8	1.8
57	2.3	4.1	1.8
58	2.3	3.8	1.5
59	2.4	4.2	1.8
60	2.8	4.1	1.3
61	2.6	4.3	1.7
62	2.8	4.5	1.7
63	2.9	4.3	1.4
64	3.4	4.3	0.9
65	3.5	4.1	0.6
66	3.8	4.0	0.2
67	3.9	4.3	0.4
68	4.1	4.1	0.0
69	4.0	4.0	0.0
70	4.5	4.1	-0.4
71	4.5	4.2	-0.3
72	4.6	4.1	-0.5
73	4.8	4.0	-0.8
74	4.8	3.7	-1.1
75	4.8	2.7	-2.1
76	4.5	0.8	-3.7
77	4.5	0.1	-4.4
78	4.0	0.0	-4.0
79	3.3	0.0	-3.3
80	2.5	0.0	-2.5
81	1.3	0.0	-1.3
82	0.5	0.0	-0.5
83	0.1	0.0	-0.1
		Mean	-0.01
		S.D.	1.86

$t_d = -0.03$, df = 33 ($t_{.05} = 2.035$)

APPENDIX E

TABULATED VALUES FOR SFF DISTRIBUTIONS

Table E-1. Speaking Fundamental Frequency (SFF) Distribution for the Male Subjects in the Laboratory Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF		Speaking Condition		
ST	Hz	Normal	Stress	Difference
20	51.9	0.3%	0.3%	0.0%
21	55.0	0.4	0.3	-0.1
22	58.3	0.5	0.3	-0.2
23	61.7	0.4	0.3	-0.1
24	65.4	0.4	0.4	0.0
25	69.3	0.5	0.5	0.0
26	73.4	0.6	0.6	0.0
27	77.8	0.6	0.6	0.0
28	82.4	1.0	0.8	-0.2
29	87.3	1.1	1.1	0.0
30	92.5	1.9	2.3	0.4
31	98.0	5.0	6.0	1.0
32	103.8	9.5	8.5	-1.0
33	110.0	8.5	6.3	-2.2
34	116.5	9.1	6.5	-2.6
35	123.5	12.5	10.0	-2.5
36	130.8	10.5	10.3	-0.2
37	138.6	8.6	9.5	0.9
38	146.8	6.4	6.8	0.4
39	155.6	5.4	5.8	0.4
40	164.8	5.1	6.1	1.0
41	174.6	4.0	5.1	1.1
42	185.0	2.8	4.7	1.9
43	196.0	2.1	3.6	1.5
44	207.7	1.4	1.9	0.5
45	220.0	0.5	0.6	0.1
46	233.1	0.4	0.4	0.0
47	246.9	0.1	0.1	0.0
48	261.6	0.1	0.1	0.0
49	277.2	0.0	0.1	0.1
50	293.7	0.0	0.0	0.0
			Mean	0.01
			S.D.	0.99

(t_d = 0.06, df = 30 ($t_{.05}$ = 2.042)

Table E-2. Speaking Fundamental Frequency (SFF) Distribution for the Female Subjects in the Laboratory Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF ST	SFF Hz	Speaking Condition Normal	Speaking Condition Stress	Difference
27	77.8	0.1%	0.0%	-0.1%
28	82.4	0.0	0.1	0.1
29	87.3	0.1	0.1	0.0
30	92.5	0.2	0.2	0.0
31	98.0	0.3	0.4	0.1
32	103.8	0.4	0.4	0.0
33	110.0	0.3	0.5	0.2
34	116.5	0.3	0.4	0.1
35	123.5	0.3	0.3	0.0
36	130.8	0.3	0.2	-0.1
37	138.6	0.3	0.2	-0.1
38	146.8	0.5	0.3	-0.2
39	155.6	1.0	0.6	-0.4
40	164.8	3.0	2.8	-0.2
41	174.6	4.9	5.9	1.0
42	185.0	8.0	8.3	0.3
43	196.0	10.5	11.5	1.0
44	207.7	12.8	12.7	-0.1
45	220.0	9.1	8.4	-0.7
46	233.1	14.6	13.0	-1.6
47	246.9	8.7	8.8	0.1
48	261.6	8.5	8.7	0.2
49	277.2	7.3	7.4	0.1
50	293.7	4.2	4.6	0.4
51	311.1	2.2	2.6	0.4
52	329.6	1.4	1.2	-0.2
53	349.2	0.5	0.4	-0.1
54	370.0	0.0	0.0	0.0
55	392.0	0.0	0.0	0.0
56	415.3	0.0	0.0	0.0
			Mean	0.01
			S.D.	0.45

$t_d = 0.12$, df = 29, ($t_{.05} = 2.045$)

Table E-3. Speaking Fundamental Frequency (SFF) Distribution for All Subjects in the Laboratory Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF ST	SFF Hz	Speaking Condition Normal	Speaking Condition Stress	Difference
20	51.9	0.2%	0.2%	0.0%
21	55.0	0.2	0.2	0.0
22	58.3	0.3	0.2	-0.1
23	61.7	0.3	0.3	0.0
24	65.4	0.4	0.4	0.0
25	69.3	0.5	0.5	0.0
26	73.4	0.5	0.6	0.1
27	77.3	0.5	0.5	0.0
28	82.4	0.7	0.6	-0.1
29	67.3	0.8	0.7	-0.1
30	92.5	1.2	1.4	0.2
31	98.0	3.1	3.6	0.5
32	103.8	6.0	5.2	-0.8
33	110.0	6.2	4.8	-1.4
34	116.5	7.4	6.3	-1.1
35	123.5	10.6	9.3	-1.3
36	130.8	10.5	10.8	0.3
37	138.6	10.4	10.8	0.4
38	146.5	7.5	7.5	0.0
39	155.6	9.2	8.8	-0.4
40	164.8	6.6	7.2	0.6
41	174.6	5.9	6.6	0.7
42	185.0	4.7	5.8	1.1
43	196.0	3.0	4.0	1.0
44	207.7	1.7	2.2	0.5
45	220.0	0.9	0.9	0.0
46	233.1	0.4	0.4	0.0
47	246.9	0.1	0.1	0.0
48	261.6	0.1	0.1	0.0
49	277.2	0.0	0.1	0.1
50	293.7	0.0	0.0	0.0
			Mean	0.01
			S.D.	0.56

$t_d = 0.10$, df = 30, ($t_{.05} = 2.042$)

Table E-4. Speaking Fundamental Frequency (SFF) Distribution for the Male Subjects in the Situational Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF		Speaking Condition		
ST	Hz	Normal	Stress	Difference
20	51.9	0.1%	0.1%	0.0%
21	55.0	0.2	0.1	-0.1
22	58.3	0.3	0.2	-0.1
23	61.7	0.4	0.3	-0.1
24	65.4	0.5	0.4	-0.1
25	69.3	0.5	0.4	-0.1
26	73.4	0.7	0.5	-0.2
27	77.8	0.9	0.8	-0.1
28	82.4	1.1	0.9	-0.2
29	87.3	1.9	1.2	-0.7
30	92.5	4.2	1.9	-2.3
31	98.0	7.6	3.1	-4.5
32	103.8	11.2	5.5	-5.7
33	110.0	10.7	7.3	-3.4
34	116.5	11.1	10.7	-0.4
35	123.5	10.1	12.2	2.1
36	130.8	7.3	9.4	2.1
37	138.6	6.7	9.8	3.1
38	146.8	5.6	8.8	3.2
39	155.6	5.2	6.7	1.5
40	164.8	4.8	6.1	1.3
41	174.6	3.1	5.1	2.0
42	185.0	2.5	3.2	0.7
43	196.0	1.4	2.2	0.8
44	207.7	1.0	1.5	0.5
45	220.0	0.4	0.7	0.3
46	233.1	0.4	0.6	0.2
47	246.9	0.2	0.2	0.0
48	261.6	0.1	0.1	0.0
49	277.2	0.0	0.1	0.1
50	293.7	0.0	0.1	0.1
			Mean	0.00
			S.D.	0.80

$t_d = 0.00$, df = 30, ($t_{.05} = 2.042$)

Table E-5. Speaking Fundamental Frequency (SFF) Distribution for the Female Subjects in the Situational Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF ST	SFF Hz	Speaking Condition Normal	Speaking Condition Stress	Difference
27	77.8	0.1%	0.1%	0.0%
28	82.4	0.1	0.1	0.0
29	87.3	0.3	0.2	-0.1
30	92.5	0.3	0.2	-0.1
31	98.0	0.4	0.3	-0.1
32	103.8	0.3	0.4	0.1
33	110.0	0.3	0.3	0.0
34	116.5	0.5	0.3	-0.2
35	123.5	0.5	0.5	0.0
36	130.8	0.3	0.5	0.2
37	138.6	0.4	0.6	0.2
38	146.8	0.4	1.0	0.6
39	155.6	1.0	2.3	1.3
40	164.8	4.8	5.7	0.9
41	174.6	9.9	9.2	-0.7
42	185.0	15.3	12.9	-2.4
43	196.0	14.0	13.3	-0.7
44	207.7	11.4	13.1	1.7
45	220.0	8.0	8.7	0.7
46	233.1	12.0	10.7	-1.3
47	246.9	7.1	5.4	-1.7
48	261.6	4.8	4.1	-0.7
49	277.2	3.2	3.5	0.3
50	293.7	1.9	2.2	0.3
51	311.1	1.0	1.4	0.4
52	329.6	0.8	1.0	0.2
53	349.2	0.5	0.7	0.2
54	370.0	0.2	0.3	0.1
55	392.0	0.2	0.6	0.4
56	415.3	0.1	0.2	0.1
			Mean	0.00
			S.D.	1.90

$t_d = 0.00$, df = 29, ($t_{.05} = 2.045$)

Table E-6. Speaking Fundamental Frequency (SFF) Distribution for All Subjects in the Situational Stress Experiment; Values of SFF Are Expressed in Semitone (ST) Intervals.

SFF ST	SFF Hz	Speaking Condition Normal	Speaking Condition Stress	Difference
20	51.9	0.1%	0.1%	0.0%
21	55.0	0.2	0.1	-0.1
22	58.3	0.3	0.2	-0.1
23	61.7	0.4	0.3	-0.1
24	54.4	0.5	0.4	-0.1
25	69.3	0.4	0.4	0.0
26	73.4	0.5	0.4	-0.1
27	77.8	0.7	0.6	-0.1
28	82.4	0.9	0.7	-0.2
29	87.3	1.2	0.9	-0.3
30	92.5	2.6	1.4	-1.2
31	98.0	4.6	2.2	-2.4
32	103.8	7.0	4.2	-2.8
33	110.0	8.3	6.6	-1.7
34	116.5	10.6	10.1	-0.5
35	123.5	12.2	12.5	0.3
36	130.8	10.1	11.0	0.9
37	138.6	8.6	11.2	2.6
38	146.8	6.6	8.8	2.2
39	155.6	8.0	8.3	0.3
40	164.8	5.7	5.8	0.1
41	174.6	3.8	4.7	0.9
42	185.0	2.8	3.3	0.5
43	196.0	1.6	2.2	0.6
44	207.7	1.0	1.5	0.5
45	220.0	0.6	0.8	0.2
46	233.1	0.4	0.6	0.2
47	246.9	0.2	0.2	0.0
48	261.6	0.1	0.3	0.2
49	277.2	0.0	0.1	0.1
50	293.7	0.0	0.1	0.1
			Mean	0.00
			S.D.	1.05

$t_d = 0.00$, df = 30, ($t_{.05} = 2.042$)

APPENDIX F

TABULATED VALUES FOR TIME-ENERGY DISTRIBUTIONS (TED)

Table F-1. Mean Values for the Time-Energy Distributions (TED) for the Laboratory Stress Experiment; Values Are the Per Cent of Time for Each of Nine Energy Levels.

Speaking Condition	Energy Level 1	2	3	4	5	6	7	8	9
A. MALES									
Normal	72.7	56.1	43.0	33.1	25.3	18.5	13.3	8.8	5.8
Stress	73.9	58.2	45.5	35.5	27.1	19.9	13.9	9.1	5.8
Difference	1.2	2.1	2.5	2.4	1.8	1.4	0.6	0.3	0.0
	$\overline{X}_d = 1.37$, $s_d = 0.92$, $t_d = 4.22$, df = 8 ($t_{.05} = 2.306$)								
B. FEMALES									
Normal	73.3	53.7	39.4	29.3	21.4	15.1	10.7	6.9	4.6
Stress	73.5	54.7	41.6	31.3	23.4	16.6	11.8	8.3	5.1
Difference	0.2	1.0	2.2	2.0	2.0	1.5	1.1	1.4	0.5
	$\overline{X}_d = 1.32$, $s_d = 0.69$, $t_d = 5.42$, df = 8 ($t_{.05} = 2.306$)								
C. OVERALL									
Normal	73.0	55.1	41.5	31.5	23.7	17.1	12.2	8.0	5.3
Stress	73.8	56.8	43.9	33.8	25.6	18.6	13.0	8.8	5.5
Difference	0.8	1.7	2.4	2.3	1.9	1.5	0.8	0.8	0.2
	$\overline{X}_d = 1.38$, $s_d = 0.76$, $t_d = 5.14$, df = 8 ($t_{.05} = 2.306$)								

Table F-2. Mean Values for the Time-Energy Distributions (TED) for the Situational Stress Experiment; Values Are the Per Cent of Time for Each of Nine Energy Levels.

Speaking Condition	Energy Level 1	2	3	4	5	6	7	8	9
A. MALES									
Normal	74.3	58.3	45.8	35.6	26.8	19.4	13.6	9.4	5.8
Stress	79.4	62.3	48.9	38.5	30.1	23.1	17.5	12.8	9.4
Difference	5.1	4.0	3.1	2.9	3.3	3.7	3.9	3.4	3.6
	$\overline{X}_d = 3.67$, $s_d = 0.65$, df = 8, $t_d = 15.97$ ($t_{.05} = 2.306$)								
B. FEMALES									
Normal	73.9	52.3	38.3	27.7	20.1	13.9	9.3	6.5	4.4
Stress	78.1	58.3	45.6	36.3	27.8	20.9	15.4	11.2	7.9
Difference	4.2	6.0	7.3	8.6	7.7	7.0	6.1	4.7	3.5
	$\overline{X}_d = 6.12$, $s_d = 1.71$, df = 8, $t_d = 10.12$ ($t_{.05} = 2.306$)								
C. OVERALL									
Normal	74.1	55.8	42.7	32.3	24.0	17.1	11.8	8.2	5.2
Stress	78.9	60.7	47.5	37.6	29.2	22.2	16.6	12.1	8.8
Difference	4.8	4.9	4.8	5.3	5.2	5.1	4.8	3.9	3.6
	$\overline{X}_d = 4.71$, $s_d = 0.58$, df = 8, $t_d = 22.97$ ($t_{.05} = 2.306$)								

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BIOGRAPHICAL SKETCH

James Woodrow Hicks, Jr., was born September 24, 1950, in Jackson, Mississippi. At the age of five months he moved to the Panama Canal Zone. In June, 1968, he was graduated from Balboa High School. From September, 1968 until June, 1969 Mr. Hicks attended Canal Zone College. In September, 1969, he enrolled at the University of Florida and in March, 1973, received the degree of Bachelor of Science in Electrical Engineering. From April, 1973, until September, 1973, Mr. Hicks was employed as an engineering technician with the Panama Canal Company. In September, 1973, he enrolled in the Graduate School of the University of Florida. From September, 1973, until June, 1974, he worked as a research assistant at the Communication Sciences Laboratory. From June, 1974, until September, 1977, Mr. Hicks held a Pre-doctoral fellowship at the Institute for Advanced Study of the Communication Processes (IASCP) at the University of Florida. In August, 1976, Mr. Hicks received the degree of Master of Arts. From January, 1978, until the present Mr. Hicks has worked as a graduate research assistant for IASCP and the Department of Mechanical Engineering at the University of Florida. From August, 1976, until the present time he has pursued his work toward the degree of Doctor of Philosophy. Mr. Hicks' specialty fields are experimental phonetics and underwater communications.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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