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A Description and Analysis of the Operation and Validity of the Psychological Stress Evaluator

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ABSTRACT: A detailed description and analysis are presented of the psychological stress evaluator (PSE), an instrument purported to measure accurately and to portray graphically differential levels of stress in human speech. In addition, two studies are presented that attempt to validate this instrument against better known measures of stress or A-state anxiety. The PSE measures were compared with heart rate and State Trait Anxiety Inventory (STAI) A-state scores obtained under conditions where the level of stress was experimentally manipulated through threat of shock or the presentation of taboo words. The first study revealed that PSE, STAI, and heart rate measures accurately reflect different levels of stress and are significantly correlated with one another. The second study failed to replicate the validity of the PSE. This failure to replicate is attributed to lower levels of induced stress and a reduction in baseline measures of stress.

KEY WORDS: criminalistics, lie detection, anxiety

Since its inception in 1971, the psychological stress evaluator (PSE) has attracted considerable attention from professionals in both lie detection and personnel selection as well as researchers interested in the measurement of stress [*1*]. The rapid acceptance and interest in this device as a means of detecting deception in preference to more conventional polygraphic techniques stem from its purported ability to detect accurately heightened levels of stress in a "noninvasive" manner. According to its manufacturer, Dektor, Inc., the PSE accomplishes this by graphically displaying frequency components of speech that are thought to indicate differential levels of stress.

Much of the PSE's notoriety has been derived from its analysis of voice samples associated with the assassinations of John and Robert Kennedy [*2–5*], the kidnapping of Patty Hearst [*6*], and various Washington scandals [*7–9*]. The widespread publicity and sensationalism surrounding this instrument have raised questions concerning its potential for abuse of civil rights, as can be seen by the 1976 congressional ban on the use of the PSE by federal agencies [*10*].

Although the PSE is extensively used in law enforcement and as an employment screening device, its validity has not been adequately established. Those studies that have examined

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the PSE in controlled laboratory settings have typically found it not to be a reliable or valid instrument [*11–13*]. This paper presents an analysis of the functioning of the PSE, together with two studies that compare the PSE with better established indices of stress.

General Description of Instrument

The PSE is a compact, portable, audio signal processor housed within a standard 125-mm-thick attaché case. This instrument, which is typically used in conjunction with a Uher Model 4000 tape recorder, selectively filters and graphically portrays low frequency components of speech believed to change during periods of moderate to extreme stress [*14*].

Audio signals enter the PSE via an input jack and are rectified and fed into one of four resistor-capacitor filtration circuits. The resulting signal is amplified to drive a pen motor and associated heat stylus. In this manner, a curvilinear tracing or "voice chart" is formed on heat-sensitive paper. The response characteristics of the pen motor together with one of the four filtration circuits attenuate the higher audio frequencies while selectively accentuating the lower frequency components of speech.

Theory of Operation

The basic assumption underlying the PSE is the belief that detectable changes in voice qualities reflect differential levels of stress. It has long been recognized that high levels of stress can produce gross changes in speech rate, volume, and voice quality. The PSE is unique, however, in its purported ability to measure more subtle changes in speech that are not readily discernible without the aid of electronic processing. These more subtle changes in voice quality are thought to result from slight tensing of the vocal chords, which produces a dampening of certain subsonic frequency components of speech [*14*]. When graphically portrayed by the PSE, these changes are thought to become readily apparent to the trained examiner.

The PSE selectively filters out the higher frequencies produced by the resonant cavities of the throat, nose, mouth, and sinus cavities. The remaining frequencies, which are graphically portrayed, represent the predominant frequency of the vocal chords, which varies between 100 and 300 Hz depending on such factors as gender. During unstressed speech this primary frequency or glottal puff is said to be modulated by an 8- to 12-Hz frequency known as "microtremor." According to the developers of the PSE, increased levels of autonomic arousal, associated with stressful situations, produce a suppression of these subsonic microtremors.

Mode of Operation

The advantages of the PSE, according to its proponents, involve not only its noninvasive nature, but additionally, its greater degree of versatility. The PSE can be used not only to assess stress during formal structured interviews analogous to a polygraphic examination, but also to analyze statements and comments in less formal settings. Unlike the polygraph, the PSE does not require the attachment of sensors to the subject and may therefore be used to measure stress in any given sample of speech, with or without the individual's knowledge.

An analysis of the degree of stress reflected in a sample of speech involves the playback of selected words or phrases from a tape recorder into the PSE. Depending on tape recorder playback speed and type of analysis desired, one of four push-button switches is depressed. These switches are labeled Mode 1 through Mode 4 and determine the extent to which the voice signal is filtered. Filtration in all four modes is accomplished with a resistor and capacitor that together function as a low pass filter. Technically, passive filters of this nature perform the electric analog of the mathematical integration of a signal over time. Mode 1 integrates the signal over the longest period of time and produces a rather smooth curve that predominantly reflects variations in speech amplitude. Modes 2, 3, and 4 each employ resistor-capacitor circuits that result in progressively shorter integration times. These settings produce more jagged tracings that selectively accentuate the subsonic modulations of the primary frequency of the vocal chords.

Initially, PSE examiners were trained to interpret charts made in all four modes. In recent years, however, the determination of stress has typically been made from tracings obtained in Mode 3, using a playback speed of one fourth or one eighth normal speed. The popularity of Mode 3 has resulted from changes in the training that Dektor Inc. provides its examiners.[2]

Chart Analysis

The determination of the degree of stress contained within a selected sample of speech is made through the visual examination of various aspects of the chart tracings by a trained examiner. The four aspects of a tracing thought to reveal differential levels of stress are amplitude, leading edge, cyclic rate change, and "blocking."

Mode 1 is typically used to provide a rapid overview of the amplitude of the various parts of speech. In this case, amplitude changes, reflecting the lowering or raising of the voice, are thought to be an indication of stressful utterances.

Leading edge can be analyzed in Modes 2, 3, and 4 and reflects the rate of energy input from the initial voice signal. In normal unstressed speech the energy associated with the beginning of each syllable is thought to build gradually from an initially low level to its full intensity. Stress is said to exist when an utterance begins with an initial high-amplitude burst.

Cyclic rate change refers to changes in the frequency of the glottal puff. Stress is considered to be present when there is a rapid change in the primary frequency of an utterance.

Although amplitude, leading edge, and cyclic rate change have been thought to reveal stress, today the only aspect of the tracing considered to be important is the presence or absence of "blocking." Blocking is considered to exist when the predominant frequency is clearly present in the absence of low frequency subsonic modulation (microtremor). In other words, blocking exists to the extent that frequencies cluster in a manner that permits straight parallel lines to form an envelope [*14*]. Figure 1, Tracings 3A and 3B, represent PSE tracings of the word "contest" said by the same subject under conditions of low and high stress. These two tracings were made in Mode 3 at a playback speed of one eighth real time and represent differential amounts of blocking. Brackets have been placed around Tracing 3B to indicate the greater degree of blocking present as compared to 3A.

Electronic Circuitry

Figure 2 is the electronic schematic of the PSE. An examination of this circuit reveals that it functions as a simple, passive, low frequency filter. Audio signals are rectified and switched to one of four filters (Mode 1 through 4). Modes 1, 2, and 3 each use a single resistor and capacitor, while Mode 4 adds an additional inductance coil. The filtered signal is then amplified by a 749 operational amplifier, the output of which is fed to power transistors that drive the pen motor. In addition, the circuit contains a poorly regulated power supply together with components that have no obvious utility. Figure 1, Tracings 1A and 1B through 4A and 4B, were produced by playing the word "contest" said by the same

[2] A. Bell, personal communication, 14 April 1976.

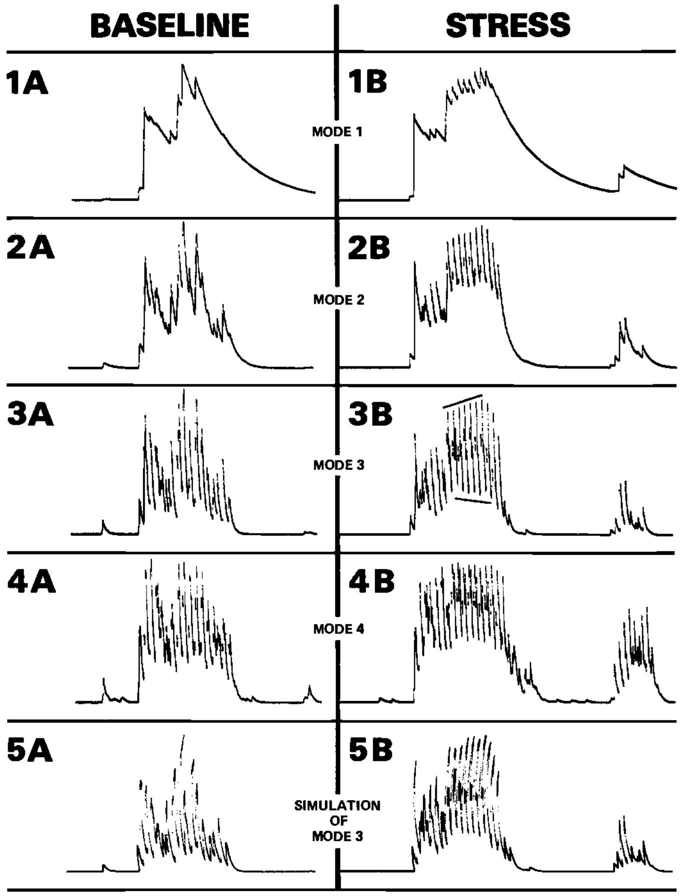

FIG. 1—*PSE tracings made of the same word said by the same individual under conditions of low* (baseline) *and high* (stress) *state anxiety. Tracings 1A and 1B through 4A and 4B were made in Modes 1 through 4, respectively. Tracings 5A and 5B were made with a simple circuit that simulates Tracings 3A and 3B.*

person under conditions of low or high stress into the PSE at one-eighth speed in Modes 1 through 4, respectively. It can be seen that Mode 1 gives the greatest degree of integration of the signal whereas Mode 4 gives the least.

To fully illustrate the simplicity of the PSE, the first author sought to duplicate the PSE tracings with the aid of three components: a resistor, a capacitor, and a diode. Figure 3 represents the configuration and circuit values found to most closely approximate Mode 3 of the PSE. With the aid of the driver amplifier and pen motor of a Grass polygraph, Tracings 5 A and 5B (shown in Fig. 1) were made from the identical recorded words used in making Tracings 3A and 3B. A close examination reveals a surprising degree of correspondence between these tracings.

Experiment 1

Experiment 1 was designed to compare the PSE with measures of stress obtained from the State Trait Anxiety Inventory (STAI) and heart rate under conditions in which stress was experimentally manipulated.

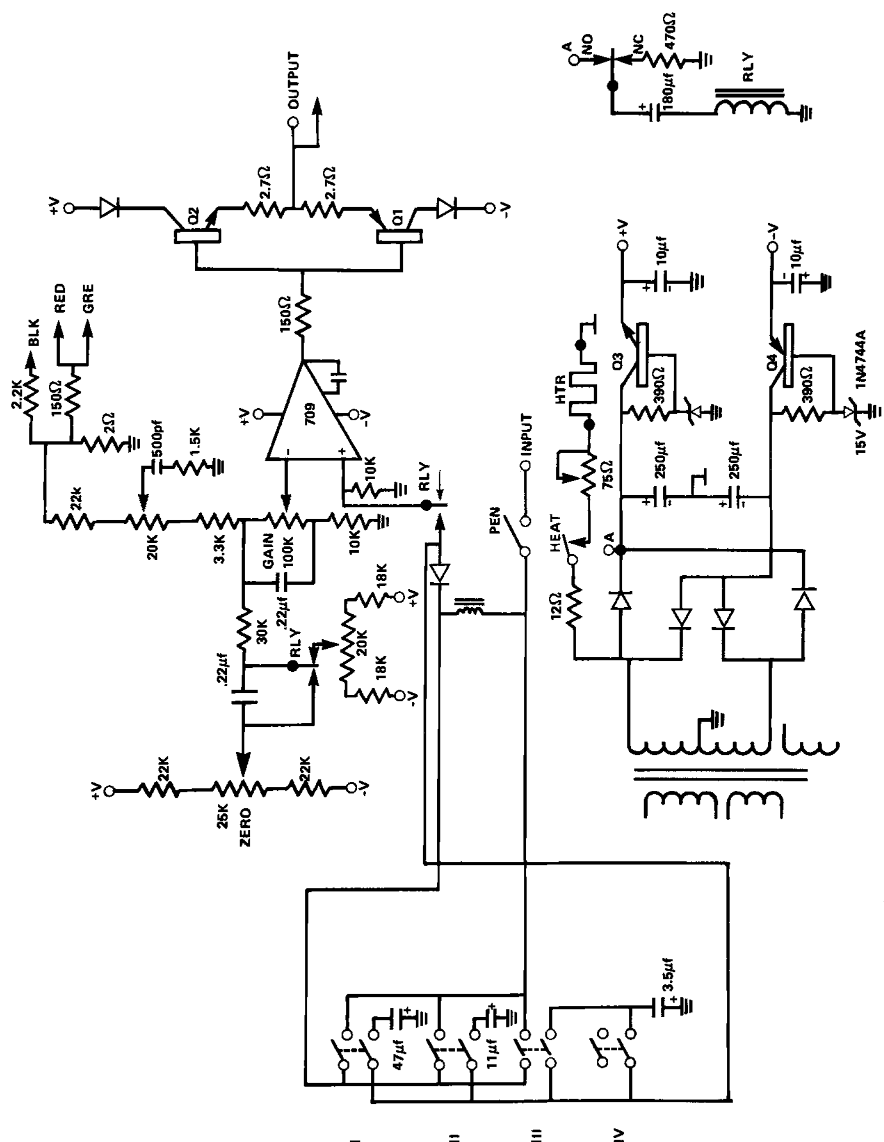

FIG. 2—*Electronic schematic of the PSE.*

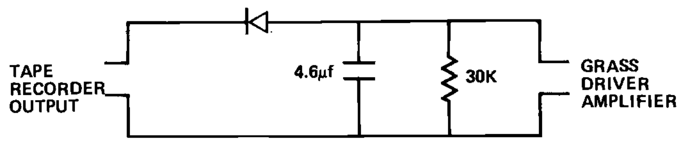

FIG. 3—*Electronic schematic of the circuit that accurately simulates the signal processing of the PSE in Mode 3.*

Method

Sixty male undergraduate volunteers were randomly assigned to one of three experimental conditions (shock threat, ego threat, and control).

Five familiar, neutral words were presented in all three experimental conditions and provided the basis for PSE analysis: child, house, dance, glass, and river. Interspersed between these words in the ego-threat conditions were five taboo words: pubic, balls, hymen, Kotex, and penis. These words were previously found to evoke elevations in A-state scores [*15*]. In the shock threat and control conditions the taboo words were substituted with five words matched for phonetic similarity: public, bald, hyphen, contest, and pencil. Each word was typed in capital letters on individual 3 by 5 index cards.

Dependent Measures of Stress

PSE Charts—The five familiar, neutral words read aloud by subjects in all three conditions provided the voice samples that were analyzed by PSE. Magnetic recordings for use in the PSE analysis were obtained by a Uher Model 4000 tape recorder at a speed of 190 mm/s (7½ in./s). These were played at 24 mm/s (one eighth normal speed) into a PSE set on Mode 3. In this fashion 15 PSE charts were obtained for each subject.

The PSE charts were prepared for visual analysis in the following fashion: the three tracings made of a particular familiar word were randomly affixed, one above the other, to a 200- by 250-mm (8- by 10-in.) piece of paper. A code number on each piece of paper permitted only the experimenter to decipher the correct order of the tracings, the word they represented, the subject, and the experimental condition.

The resulting 300 sheets of paper or chart sets were rated for relative degree of stress by a PSE examiner trained by the Dektor Corp. The only information given the examiner was that a particular set of three PSE charts was of the same word said by the same person under various degrees of stress, that the order of the charts was random, and that the top chart should serve as a reference for scoring the other two. Each chart was scored on a 7-point scale with 1 representing relatively little stress, 4 the same stress, and 7 considerably more stress than the referent. (It should be noted that although the third author had received training by the Dektor Corp., he was not involved in the scoring of PSE data.)

Heart Rate—Electrocardiogram recordings were obtained from a Lead 1 configuration with Beakman electrodes and a Grass Model 7 polygraph. Measurements of heart rate were obtained coincidentally with the subject's verbalizations of the stimulus words, both before and after the introduction of the experimental treatment.

Self-Reported Measure—The STAI was administered to all subjects before and after experimental treatment. This questionnaire yields measures of both state and trait anxiety [*16*] and has been found to correlate highly with physiological measures of autonomic arousal.

Procedure

Subjects were tested individually by a female experimenter, in a 2.5- by 3-m room that contained a table, two chairs, a tape recorder, and polygraph equipment. Subjects were seated facing the experimenter throughout the experiment. The experimental session was made up of three periods: baseline, prestress, and stress.

Baseline—After being seated the subjects were told that the purpose of the study was to learn more about the relationship between physiological responses and voice quality. After giving written consent to participate in the experiment, subjects completed the STAI A-state and A-trait questionnaires. After adjustments were made in the audio recording equipment, subjects were asked to read out loud each of the ten neutral words as they were presented individually at 5-s intervals. Electrodes were then attached to the subjects to measure heart rate.

Prestress Period—To assess any changes in stress that may have been induced by the attachment of monitoring equipment and to obtain additional baseline data, subjects were again required both to read aloud the ten neutral stimulus words and to complete the STAI A-state form.

Control Group—In the control condition subjects were again presented with the same ten neutral words at 5-s intervals and required to complete the STAI A-state scale. Subjects then completed the STAI A-trait scale and were debriefed by the experimenters.

Ego Threat Group—In the ego threat condition, subjects were informed that there would be taboo words intermixed in the next list of words. After giving written consent, the subjects read the five taboo words together with the high frequency neutral words at 5-s intervals. Subjects were then given the A-state and A-trait scales of the STAI and debriefed.

Shock Threat Group—Subjects in the shock threat condition were informed that an electric shock would be administered when they read the next list of words. Subjects were then shown the "high voltage" shock generator and ankle electrodes and told that "although the shock will be extremely painful, it will not result in any permanent damage." After obtaining signed consent from each subject (all subjects continued to participate) electrodes were attached and subjects again read the ten neutral words without being shocked. The STAI A-state and A-trait scales were then administered before the debriefing.

Results

Figure 4 represents the mean STAI A-state scores for the baseline, prestress, and stress periods of subjects in the ego threat, shock threat, and control conditions. A 3 by 3 repeated measures analysis of variance revealed a significant periods main effect ($F = 4.1$, degrees of freedom = 2, $P < 0.01$) as well as a significant conditions by periods interaction ($F = 13.5$, degrees of freedom = 4, $P < 0.001$). This interaction can be seen in Fig. 4, which shows a large increase in A-state in the shock threat condition, a smaller increase in A-state scores in the ego threat condition, and a decline in A-state scores for the control condition.

Subsequent tests using Fisher's least significant difference (LSD) [*17*] were computed to determine differences between and within group means. The LSD test (LSD = 5.64, $P < 0.05$) revealed that the three experimental conditions did not differ in the baseline and prestress periods. In the stress period, however, the shock threat group was significantly higher in A-state than the ego threat group. In addition, the ego threat group was found to be significantly higher in A-state than the control group.

Subsequent LSD tests indicated (1) a significant increase in A-state across periods for the shock threat group; (2) no significant changes in A-state over periods for ego threat conditions; and (3) a significant decrease in A-state for the control condition over periods.

Figure 5 depicts the average percentage of change in heart rate from baseline to prestress and from baseline to stress periods for the control, ego threat, and shock threat conditions.

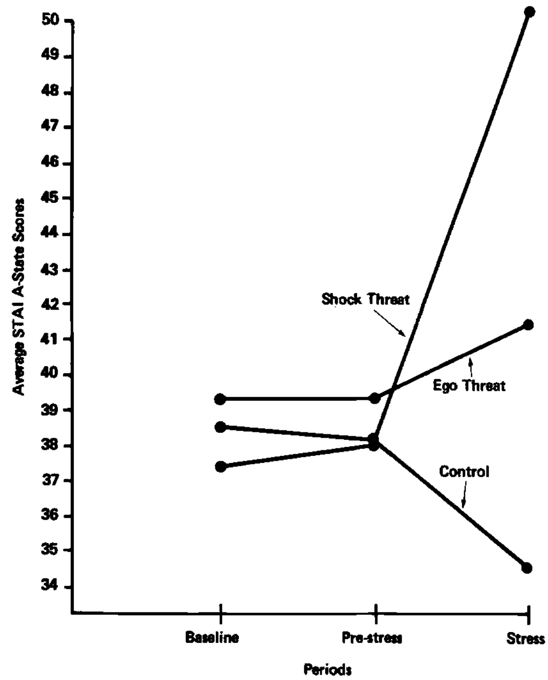

FIG. 4—*Mean STAI A-state scores for the baseline, prestress, and stress periods of subjects in the shock threat, ego threat, and control conditions.*

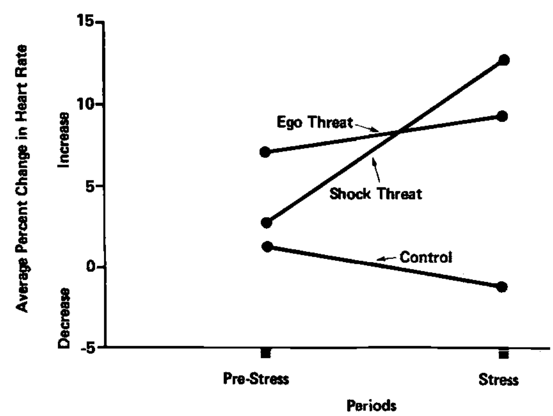

FIG. 5—*Average change (percentage) in heart rate from baseline to prestress and from baseline to stress periods for the control, ego threat, and shock threat conditions.*

Repeated measures of analysis of variance revealed a significant periods effect ($F = 6.83$, degrees of freedom = 1, $P < 0.025$), conditions effect ($F = 4.30$, degrees of freedom = 3, $P < 0.025$), and conditions by periods interaction ($F = 8.72$, degrees of freedom = 2, $P < 0.001$).

The LSD tests found significant differences (LSD = 4.28, $P < 0.05$) between ego threat and shock threat and between ego threat and control conditions during the prestress period. Additional LSD tests revealed that the percentages of heart rate increase were greater in the shock threat and ego threat conditions than in the control conditions during stress periods. No significant difference was found between ego threat and shock threat conditions during this period.

Significant increases in heart rate were found to occur from prestress to stress periods in the shock threat conditions. No significant differences, however, were found in the control and ego threat conditions from prestress to stress periods.

Figure 6 illustrates the average percentages of changes found in PSE scores for the three experimental conditions from baseline measures to prestress and from baseline to stress periods. In general, the PSE data are similar to the STAI A-state scores and heart rate data.

A repeated measures analysis of variance computed on these data revealed a significant periods effect ($F = 12.62$, degrees of freedom $= 1$, $P < 0.001$), a significant difference between experimental conditions ($F = 5.04$, degrees of freedom $= 2$, $P < 0.025$), and a conditions by periods interaction ($F = 18.43$, degrees of freedom $= 2$, $P < 0.001$).

The LSD tests (LSD $= 8.06$, $P < 0.05$) revealed that there were no significant differences between any of the experimental conditions during the prestress period, whereas the control, ego threat, and shock threat conditions were all significantly different from one another during the stress period. Further, the LSD test indicated that there were significant increases in PSE scores from prestress to stress periods only in the case of the shock threat condition.

Pearson product moment correlations computed between STAI A-state, heart rate, and PSE scores for the total sample of 60 subjects, collapsed across conditions, indicated that all three measures of psychological stress were significantly correlated with one another. The STAI A-state scores correlation with heart rate was 0.29 ($P < 0.01$). The correlation between A-state scores and PSE scores was found to be 0.75 ($P < 0.001$). Finally, the heart rate/PSE scores correlation was 0.25 ($P < 0.01$).

Within the shock threat condition it was found that (1) the A-state scores correlation with heart rate was 0.41 ($P < 0.01$); (2) the A-state scores correlation with PSE scores was 0.84 ($P < 0.001$); and (3) the heart rate correlation with PSE scores was 0.41 ($P < 0.05$).

In the ego threat condition there were no significant correlations found between the three measures of psychological stress. The correlation between A-state scores and PSE scores did, however, approach significance ($r = 0.33$, $P < 0.05$).

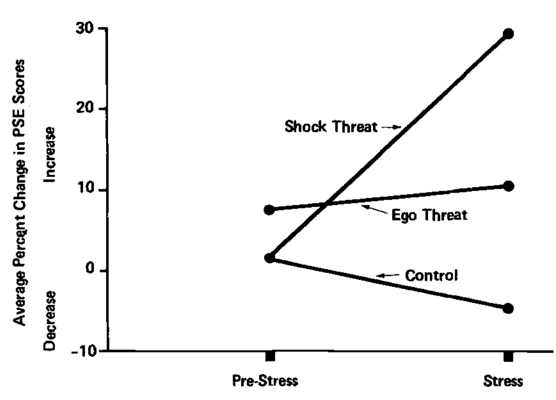

FIG. 6—*Average change (percentage) in PSE scores from baseline to prestress and from baseline to stress periods for the control, ego threat, and shock threat conditions.*

Within the control condition correlations were found to be significant only between A-state scores and PSE scores ($r = 0.48$, $P < 0.05$). The other two correlations were negative and did not approach significance.

Discussion

The primary purpose of this study was to determine if the PSE represents a sensitive measurement of psychological stress or A-state anxiety. To determine the validity of this instrument, PSE scores were compared with STAI A-state scores and heart rate changes under conditions in which stress was experimentally manipulated.

In general, the pattern of results obtained from the PSE data was remarkably similar to the findings obtained from STAI A-state scores and heart rate measures. An examination of Figs. 4, 5, and 6 indicates that all three measures of stress decreased over periods in the control condition. Although the decreases were significant only in the case of A-state scores, this trend is most probably a result of the subjects' habituation to the experimental condition over time.

During the stress period, heart rate, STAI A-state scores, and PSE scores were found to be significantly higher in the ego threat condition than in the control condition. The elevated A-state scores observed in the ego threat condition are consistent with the findings of Gonzalez [*15*], who used the same taboo words in a similar experimental procedure. These findings suggest that both heart rate and PSE accurately reflect heightened levels of A-state anxiety induced by the threat associated with exposure to taboo words.

Not surprisingly, the shock threat condition produced the greatest elevations in A-state as measured by STAI A-state, heart rate, and PSE scores. All three measures were found to be significantly elevated during the stress period in the shock threat condition as compared with the baseline or prestress period.

When the three measures of psychological stress are compared through correlations, the PSE score was found to correlate 0.75 with STAI A-state scores and 0.25 with heart rate for all conditions. In addition, STAI A-state scores correlated 0.29 with heart rate. The finding that PSE scores correlated highly with A-state scores, particularly in the case of the shock threat condition ($r = 0.84$, $P < 0.001$), indicates that the PSE may be a better indicator of the subjective phenomenological component of state anxiety than heart rate. The finding that heart rate may be a less reliable measure of A-state anxiety than self-reported measures has been discussed by other researchers [*18,19*].

In summary, the results obtained in the present study appear to demonstrate the potential utility of the PSE as a measure of state anxiety. In an attempt to insure that the results obtained were not peculiar to this particular study, a second experiment was conducted.

Experiment 2

The intent of Experiment 2 was to replicate the findings of Experiment 1, particularly with respect to establishing the validity of the PSE as a measure of heightened levels of A-state anxiety. As in Experiment 1, PSE results were compared against heart rate and STAI A-state scores under conditions in which psychological stress was experimentally manipulated.

This study was identical to Experiment 1 with the following noteworthy exceptions: (1) measures of A-state anxiety were collected during only two periods (pretreatment and posttreatment) as compared to the three periods of Experiment 1; (2) the ego threat condition was eliminated, leaving only the control and shock threat conditions; and (3) a male experimenter was used instead of a female.

Method

Forty-eight male undergraduates were chosen from the same subject pool used in Experiment 1; each received course credit for participation.

The stimulus words presented in the control and shock threat conditions of Experiment 2 were the same as those used in the corresponding condition of Experiment 1.

The STAI A-state and A-trait tests were administered to all subjects before and after experimental treatment in a fashion identical to Experiment 1.

Heart rate was recorded from subjects throughout the experiment, with measures being taken coincidently with the verbalization of stimulus words before and after experimental treatment. Stimulus words were recorded by a Uher Model 4000 tape recorder and subsequently played back through the PSE in Mode 3, in a manner identical to Experiment 1. The PSE scoring procedure was similar to that used in Experiment 1. Graphic voice charts of five of the stimulus words said before and after treatment were affixed to 215- by 280-mm (8½- by 11-in.) sheets of paper. Each sheet contained two tracings of a particular word said by a given subject. The top and bottom tracings were randomly affixed as to which represented the word said before treatment.

Four PSE raters were employed, the one used in Experiment 1 and three additional raters, all of whom were police detectives who had received training by Dektor, Inc. Their task was to use the top tracing as a referent and to rate the relative amount of stress that existed between it and the bottom tracing. A 7-point scale was employed in a fashion identical to Experiment 1.

It is important to point out that because data were collected during only two periods the raters had only two samples to judge, as opposed to Experiment 1, where three tracings were compared.

Procedure

The procedure was similar to Experiment 1 with the exception that only two experimental conditions (shock threat and control) and two periods (prestress and stress) were employed.

Prestress Period—The procedure was identical for all subjects during the prestress period. Signed consent was secured from the subjects by a male experimenter after they were informed that the purpose of the experiment was to learn more about the relationship between physiological responses and voice quality.

Electrodes were attached for recording heart rate. After 5 min, subjects were required to read aloud the ten stimulus words one at a time into the tape recorder. They were then asked to complete the STAI A-state and A-trait forms.

Control Condition—The subjects in the control condition repeated essentially the same procedure as in the prestress period. After the STAI A-state and A-trait inventories were completed, electrodes were removed and the subjects were debriefed.

Shock Threat Condition—The subjects in the shock threat condition were informed that the purpose of the next phase was to determine the effects that electric shock had on voice quality. They were told that when they read the list of words they would receive a shock that, although painful, would result in no permanent damage. After signing consent forms they read the words without receiving electric shock. They then completed the STAI A-state and A-trait inventories and were debriefed and dismissed.

Results

A 2 by 2 repeated measures analysis of variance of the STAI A-state scores revealed a significant conditions ($F = 10.65$, degrees of freedom $= 1$, $P < 0.01$) and periods ($F = 7.53$, degrees of freedom $= 1$, $P < 0.01$) main effect. The periods by conditions interaction was found to be highly significant ($F = 46.92$, degrees of freedom $= 1$, $P < 0.001$). Fisher's LSD test revealed that STAI A-state scores for subjects in the shock threat condition were significantly higher in the stress period (LSD $= 5.57$, $P < 0.05$) than those of subjects in the control condition. Similar tests showed that from prestress to stress periods, the mean A-state scores increased significantly in the shock threat condition and decreased significantly in the control condition.

Repeated measures of analysis of variance performed on the heart rate data revealed that, although the periods and conditions main effect approached significance, only the periods by conditions interaction was significant ($F = 22.18$, degrees of freedom $= 1$, $P < 0.001$). The LSD tests revealed that shock threat and control conditions were significantly different in the stress periods (LSD $= 8.21$, $P < 0.05$). Heart rate from prestress to stress periods were found to increase significantly in the shock threat condition and to decrease significantly in the control condition.

The reliability of the four PSE raters was computed by using Hoyt's inter-rater reliability test [*20*]. The correlation among raters was 0.86 for PSE ratings in the prestress period and 0.92 in the stress period. Surprisingly, repeated measures analysis of variance computed separately for each rater revealed no significant differences between conditions and periods, and no significant periods by conditions interactions.

Pearson product moment correlations were computed between STAI, PSE, and heart rate data. In the prestress period a significant positive correlation ($r = 0.36$, $P < 0.05$) was found between A-state and heart rate only in the shock threat condition. During the stress period, there was a significant positive correlation between A-state and heart rate when data were combined for shock threat and control conditions ($r = 0.39$, $P < 0.01$).

An analysis of the degree of relationship between STAI A-state and PSE scores revealed small, but significant, correlations. For Raters 2, 3, and 4, there were significant correlations ($r = 0.33$, 0.41, and 0.35, respectively) between A-state and PSE scores during the stress period for the control group. A 0.35 correlation was found for Rater 1 between these two measures during the stress period for the shock threat condition.

Correlations between heart rate and PSE scores revealed no significant relationship during prestress periods for either condition. During the stress period, the PSE scores of Rater 1 were positively correlated ($r = 0.36$, $P < 0.05$) with heart rate for the shock threat but not the control group.

Discussion

The results of Experiment 2 are in many ways quite similar to the findings of Experiment 1. The STAI A-state scores increased for subjects in the shock threat condition and decreased for those in the control condition. Similarly, heart rate increased from prestress to stress periods in the shock threat condition and decreased for those subjects in the control condition. These findings are essentially equivalent to the results of Experiment 1 and indicate that both STAI A-state and heart rate measures reflect differential levels of experimentally induced psychological stress.

The primary purpose of Experiment 2 was to further test the extent to which the PSE can accurately detect and measure stress in the human voice. The results obtained from the four PSE raters were disappointing. Although their inter-rater reliability was high, suggesting that they were attending to the same stimuli, they failed to differentiate significantly between the control and shock threat groups. Correlation data, however, suggest that the PSE was in partial agreement with heart rate and STAI A-state scores.

To explain the discrepancy between Experiment 1 and 2 with respect to PSE data, it is necessary to attend to differences in methods between the two studies. First, in Experiment 1, three tracings, representing the same word said by the same individual under different conditions, were presented to the PSE examiner. This provided the rater with more data upon which to base a judgment than existed in Experiment 2, where only two tracings were compared. These findings suggest that adequate baseline data, with respect to individual voice samples, may be necessary for the PSE to differentiate adequately between different levels of stress or A-state anxiety.

A second difference that may account for the reduced sensitivity of the PSE involves the gender of the experimenter. Heart rate measures as well as informal observations indicated that the female experimenter may have induced greater degrees of stress in the bare-chested male subjects who were expecting to receive a painful shock from one leg to the other via the lower torso. Although the method of attaching the electrodes was the same in the two experiments, subjects seemed to consider the situation as more threatening with the female experimenter. Thus the level of psychological stress or A-state anxiety may prove to be an important factor in the effectiveness of the PSE in detecting different levels of stress in subjects. This factor may explain why researchers such as Kubis [*11*] failed to find the PSE a valid instrument in situations in which lower levels of stress were induced.

General Conclusion

The PSE is an instrument that selectively filters and graphically portrays certain components of speech. Its intended purpose is to allow trained examiners to assess the degree of psychological stress or A-state anxiety reflected in a given sample of speech. As such it is currently being widely used in a number of settings by individuals with different degrees of competence.

The results of Experiment 1, and to a lesser extent Experiment 2, appear to indicate that the PSE, if properly used, can, under certain circumstances, differentiate between groups of subjects who differ with respect to A-state anxiety. One must, however, be cautious in interpreting these findings. Although in Experiment 1 the PSE was found to compare favorably with heart rate and self-reported measures of anxiety, this was not the case in Experiment 2.

The discrepancies between the PSE results of Experiments 1 and 2 point to the present limitations of this instrument. The PSE was found to be effective in situations in which several samples of speech had been collected and compared from a relatively large group of subjects who had been exposed to rather high levels of stress (threat of intense painful shocks). It does not necessarily follow that this instrument is sufficiently reliable to detect deception in individuals in more normal settings.

Another factor that should be considered involved differences between the way we used the PSE and the way it is commonly used. Our results are based upon recordings made during direct face-to-face encounters. In law enforcement situations PSE analysis is frequently conducted on vocalizations mediated by a telephone. The perceived anonymity and insulation afforded by the telephone may eliminate or lessen stimuli that evoke heightened levels of arousal.

Additionally, although our PSE examiner was able to differentiate between groups of stressed and nonstressed subjects, the process employed in the analysis is subjective and poorly understood. The subjective nature of PSE analysis, therefore, creates difficulties in assessing the competence of PSE examiners and makes it difficult to gain an understanding of the specific aspects of the tracings that reflect heightened levels of A-state anxiety. Although the developers of the PSE maintain that heightened levels of autonomic arousal suppress a subsonic, 8- to 12-Hz microtremor, the data supporting such a contention seem to be lacking.

The observations of the PSE voice charts do appear to indicate that heightened levels of A-state anxiety produce more regular or uniform tracings (blocking). That these differences are caused by increases in autonomic arousal is open to debate. An alternate explanation involves learning to control voice quality during stressful situations. That is, individuals in our society may be conditioned to more carefully regulate or control their speech when lying in order to hide the effects of stress on their voice. The blocking or regular frequency pattern associated with stress may represent a learned tendency to control the voice rather than a direct effect of autonomic arousal. This hypothesis, if true, would indicate that the PSE may be more reliable with individuals who are more accustomed to disguising the effects of anxiety associated with lying.

Considering the primitive nature of the PSE's circuitry (as illustrated by our ability to simulate its processing capabilities with a single resistor, capacitor, and diode), it is indeed surprising that it functions as well as it does. If, as our research indicates, there exist measurable differences in stressed versus unstressed speech, then it may be possible to greatly refine our ability to analyze these differences. Through the use of high-speed, high-resolution analog to digital conversion and computer analysis we may in the near future be capable of greatly increasing the reliability and validity of detecting deception through voice analysis.

The potential social and political ramifications of this technology are worth noting. Sophisticated computer analysis of speech may allow us to determine the veracity of a speaker. This would permit those possessing such technology to detect deception covertly, for example from recordings of political speeches or addresses to the United Nations. In addition, it would enable governmental agencies, such as the Internal Revenue Service, to detect heightened levels of A-state anxiety in individuals who are being questioned.

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