ESOPHAGEAL AND PHYSIOLOGICAL EFFECTS OF STRESS AND RELAXATION

BY

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by

Kathleen Shea Abrams

This dissertation is dedicated, with love, to my husband and to the memory of my father.

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To determine whether esophageal motility changes occur in response to stress and to relaxation, an experiment was conducted employing 28 healthy medical and premedical students. Results of previous studies indicated that stress may increase esophageal motility in healthy adults and symptomatic individuals with esophageal motor disorders. The present study defined stress as an oral intellectual achievement test and relaxation as taped autogenic relaxation instructions. Subjects were assigned to the High Anxiety (HA) group or to the Low Anxiety (LA) group on the basis of their anxiety trait scores on the State-Trait Anxiety Inventory. HA and LA subjects were randomly assigned to either the Early Relaxation (ER) order, i.e. relaxation presented prior to stress, or to the Early Stress (ES) order, i.e. stress presented prior to relaxation. Esophageal contractions were measured simultaneously at four sites in the body of the

the esophagus. At each site, four esophageal variables were measured: frequency and intensity of swallow-related contractions (FrSw, InSw), and frequency and intensity of spontaneous contractions (FrSp, InSp). Concomitant measurement of physiological variables occurred: frontalis EMG mean and standard deviation (EMGM, EMGSD), fingertip skin conductance level mean and standard deviation (SCLM, SCLSD), and hand temperature mean and standard deviation (TEMPM, TEMPSD). An experimental session was comprised of seven 10-minute phases: Phase 1, physiological baseline; 2, standard esophageal manometry (a diagnostic procedure to determine normalcy of esophageal motility); 3, recovery from manometry; 4, relaxation for ER subjects and stress for ES subjects; 5, recovery from either stress or relaxation; 6, stress for ER subjects and relaxation for ES subjects; 7, recovery from either stress or relaxation. For each of the dependent variables, a repeated measures ANOVA tested for significant ($p \leq .05$) main effects and interactions, followed by the Duncan's multiple range test to identify significant ($p \leq .05$) differences between means.

It was found that (1) SCLM increased significantly during stress and decreased significantly during relaxation, suggesting that the stress situation was sufficiently stressful and the relaxation situation sufficiently relaxing to affect biologic functioning; (2) no significant differences in InSp or in InSw occurred during stress, compared with relaxation, at any esophageal site; (3) the LA group showed a significantly lower FrSp during relaxation than the HA group at two esophageal sites; (4) the HA and LA groups showed no significant differences during stress on any measured esophageal variable at any site; (5) without respect to site, InSp significantly increased during recovery from stress and recovery from relaxation, compared with stress and relaxation, respectively; (6) FrSp significantly increased during recovery from stress, compared with stress, at one site, and during recovery from relaxation, compared with relaxation, at one other site; and (7) ER subjects had a significantly higher InSw than ES subjects, without respect to treatment situation or esophageal site.

Conclusions were that (1) no important esophageal motility changes occurred <u>during</u> stress or relaxation; (2) the HA and LA groups showed few significant differences in esophageal motility; (3) ER and ES subjects may have been initially different in InSw, but were comparable on other variables; (4) there may be delayed InSp and FrSp responses to stress and relaxation; (5) the apparent delayed responses are not significantly different to stress than to relaxation; (6) the esophagus may respond similarly to a variety of stimuli situations; and (7) the possibility that stress may significantly change the esophageal motility of symptomatic individuals is not ruled out.

It is suggested that future research determine the effects of a variety of stimuli, not solely stress, on the esophageal functioning of symptomatic individuals.

INTRODUCTION

Studies of the Esophagus

Research about the effects of stress on the gastrointestinal system has primarily focused on the stomach and the intestines (Sleisinger & Fordtran, 1978; Grace, Wolf, & Wolff, 1951). A small body of literature, both research and clinical, suggests that the esophagus (or "gullet") reacts to a variety of noxious stimuli of physical or psychological origin (Earlam, 1975). For instance, diffuse esophageal spasm and achalasia, both of which are esophageal disorders characterized by swallowing difficulty and non-propulsive peristalsis, are thought to be exacerbated by stress (Pope, in Sleisinger & Fordtran, 1978; Cohen & Snape, 1977). However, investigations of the effects of stress on esophageal functioning have had serious methodological flaws, such as inadequate pre-stress measures of esophageal functioning and a lack of objective, standardized stressful stimuli, e.g. Faulkner, 1940a; Faulkner, 1940b; Wolf and Almy, 1949; Nagler and Spiro, 1961; Rubin, Nagler, Spiro and Pilot, 1962. Consequently, research to date has not adequately investigated the possible effects of stress on esophageal functioning. Moreover, the effects of relaxation on the esophagus have been neglected. An intensive literature search revealed no studies in this area.

The importance of investigating the effects of stress and of relaxation on the esophagus derives, in part, from the lack of sound research in the area. Moreover, considerable difficulty has been noted in attempts to treat successfully some esophageal motor disorders, like diffuse esophageal spasm, with usual medical treatments like medication and rest (Pope, in Sleisinger & Fordtran, 1978). Symptoms of these disorders may be mild or may be severe enough in some cases to result in hospitalization and surgery (Pope, in Sleisinger & Fordtran, 1978). The most common symptoms of which patients complain are dysphagia, or difficulty in swallowing, and discomfort, but some patients experience intense pain, apparently from severe esophageal spasms that may mimic a heart attack (Pope, in Sleisinger & Fordtran, 1978).

Faulkner (1940a, 1940b) was among the first to report that "the presence of esophageal spasm . . . was determined by emotional factors" in symptomatic patients (1940a, p. 140). Faulkner (1940b) subsequently reported similar findings with 13 other symptomatic patients. However, both these studies lacked adequate controls for the investigator's expectations and for the possible hyperreactivity of a symptomatic esophagus to any novel stimulus situation, such as the one used in these studies, i.e. insertion of a tube into the esophagus during an interview about the patient's troubles (Faulkner, 1940a, 1940b). Subsequent studies (Wolf & Almy, 1949; Rubin et al., 1962; Nagler & Spiro, 1961) were similarly flawed, using circular reasoning to make post-facto judgments about the stressful nature of the interviewer's questions on the basis of the presence or absence of esophageal spasms. Rubin et al. (1962) studied asymptomatic paid volunteers with no history of esophageal disorder, and suggested that there may be a relationship between stress and esophageal motor dysfunction "in some healthy young adults" (1962, p. 175). These interesting findings must be viewed cautiously, for reasons already noted, but also because the investigator's presentation of stressful stimuli was not standardized from one subject to the next, or from one examination to the next of the same subject. As recently as 1978, a reviewer of treatment studies of gastrointestinal disorders, including esophageal disorders, called for experiments to investigate clinical impressions that symptoms "often occur in response to stressful environmental events" (Whitehead, 1978, p. 383).

Since 1978, one experimental study has found that nonpropulsive, or spontaneous, esophageal contractions occur in response to intense acoustical stimuli (Stacher, Steinringer, Blau, & Landgraf, 1979). The sample was comprised of 16 young adults with no known history of esophageal disorder. Fourteen of the 16 subjects developed nonpropulsive, spontaneous esophageal contractions in response to a 95-decibel (dBA) tone (Stacher et al., 1979).

The investigators reported that both the frequency and the intensity of these contractions increased as stimulus intensity increased from 65 to 80 to 95 dBA. Contractions were considered to be stimulus-induced if the onset of a contraction occurred within two seconds after stimulus onset. Concomitant monitoring of heart rate revealed "no definite relationship between the occurrence of an esophageal contractile response and a decelerative or accelerative heart rate response" (p. 240). No other physiological variable was monitored. The study suggests that certain kinds of sensory stimuli, processed by the central nervous system, have the potential for altering esophageal motor activity in individuals without a history of esophageal disorders.

The physiological and clinical significance of spontaneous esophageal contractions is based on their frequency and intensity (Pope, in Sleisinger & Fordtran, 1978). Healthy individuals show low frequency, low intensity spontaneous contractions whereas individuals with certain types of esophageal disorders may show contractions at a much higher rate and amplitude (Pope, in Sleisinger & Fordtran, 1978). At high frequencies and intensities, these contractions may be referred to as esophageal spasms. To comprehend more fully the nature and significance of spontaneous contractions, it is necessary to understand the basics of normal esophageal functioning. "The function of esophagus is to expedite the passage of swallowed food into the stomach by nicely regulated peristaltic contractions" (Wolf & Goodell, 1968, p. 66). The esophagus, a muscular, hollow tube approximately 40 to 45 centimeters (16 to 17 inches) long, is comprised of skeletal muscle in its proximal third and smooth muscle in its distal two-thirds (Mechanisms of Disease, 1979). Its proximal end begins at the back of the mouth and its distal end terminates where the esophagus joins the stomach. The sympathetic and parasympathetic nervous systems innervate the esophagus (Mechanisms of Disease, 1979). The motor nerve supply to the esophagus (Figure 1) comes from the vagus nerve and the spinal accessory nerve (Pope, in Sleisinger & Fordtran, 1978). "The latter innervates the high cervical portion of the esophagus; the vagus supplies most of the rest of the esophageal musculature" (Pope, in Sleisinger & Fordtran, 1978, p. 498). Therefore, the vagus nerve is "probably important in coordinating the striated and smooth muscle portion of the esophagus" (Pope, in Sleislinger & Fordtran, 1978, p. 505). Three separate zones of the esophagus have been identified: (1) the upper sphincter zone, composed of striated muscle; (2) the body of the esophagus, composed of smooth and striated muscle; and (3) the esophagastric area, composed of smooth muscle, in which the lower esophageal sphincter is located (Pope, in Sleisinger & Fordtran, 1978).

Pope in Sleisinger and Fordtran (1978) described normal esophageal motor functioning as follows:

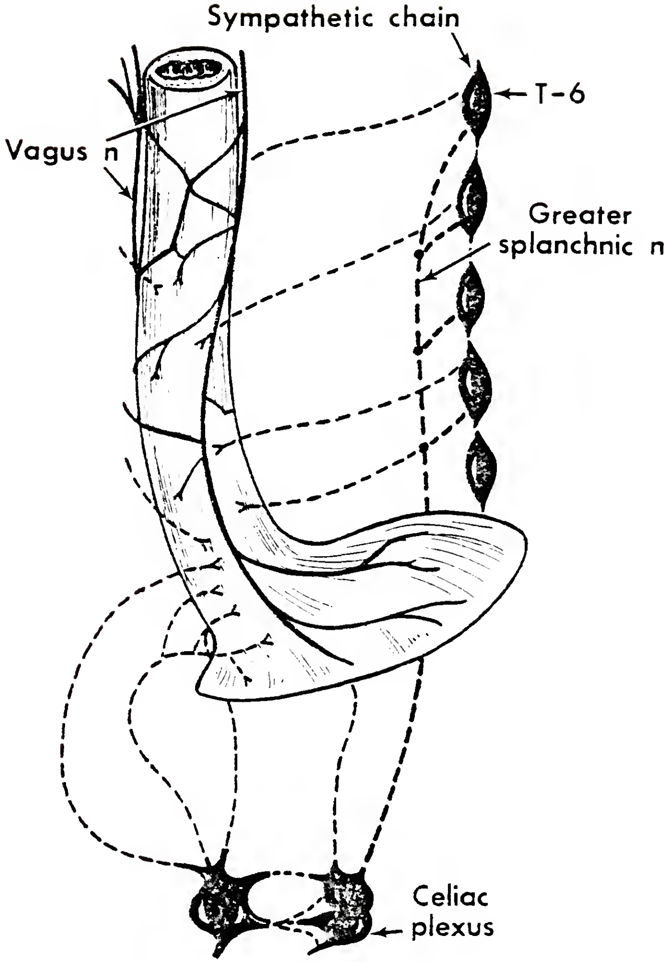

Figure 1. Autonomic innervation of the esophagus.

> Muscular events in the body of the esophagus are most commonly set in motion by a swallow (primary peristalsis). A moving ring contraction sweeps down the esophagus from the upper sphincter to, but not through, the lower esophageal sphincter zone. . . . If multiple recording tips are used [on a multiple lumen catheter, or tube, passed into the esophagus through the nose or mouth], the progressive nature of the moving ring contraction will be recognizable. . . . Several factors influence the amplitude and occurrence of peristalsis. There is much variance in amplitude of a dry swallow [no ingested fluid] when recorded from the same site in the same individual. Also, amplitudes vary considerably from one end of the esophagus to the other, and between normal individuals. Values are quite constant for the same individual, however, when studied on different days. (p. 507)

By comparison, examination of esophageal functioning in individuals with diffuse esophageal spasm reveals

> normal functioning of the upper esophageal sphincter and upper third of the esophagus. However, in the lower two-thirds, the deglutition [swallowing] occasionally causes a normally progressive peristaltic wave, but, more frequently, a simultaneous contraction occurs [i.e. contractions occur at more than one esophageal site simultaneously, rather than progressively]. The contractions in the lower two-thirds tend to be of higher amplitude [than normal]. . . . Pharmocologic relief of the pain and dysphagia [difficulty in swallowing] of diffuse spasm has been uniformly disappointing. (Pope in Sleisinger & Fordtran, 1978, p. 531)

Contractions may also occur spontaneously, without swallowing, in normal individuals, but more frequently in individuals with diffuse spasm (Cohen, 1979).

Representative Studies of Relaxation and Biofeedback Affecting Biological Functioning

Although no studies of the effects of relaxation on esophageal functioning were found, one study of the effects of biofeedback on reflux, or "heartburn," reported success in changing lower esophageal sphincter pressures in the desired direction with three normal subjects and six patients having a history of esophageal reflux (Schuster, Nikoomanesch, & Wells, 1973). The findings reported by Schuster et al. (1973) suggest that psychological treatment methods might have some potential in the treatment of certain esophageal disorders. Muscle relaxation has been noted as an important treatment modality for a number of physical disorders thought to be stress-induced or stress-exacerbated (Tarler-Benlolo, 1978). A recent review of studies of physiological correlates of relaxation training summarized the studies' findings as follows: "Relaxation is associated with decreases in respiratory rate, heart rate and blood pressure; increases in peripheral skin temperature; lowered levels of frontalis EMG activity; a decrease in skin conductance level" (Tarler-Benlolo, 1978, p. 730). Comparative studies of various relaxation training methods have reported that the methods studied seem to be equally effective in treating tension headaches, pain syndromes, insomnia, and functional bowel disorders (Tarler-Benlolo, 1978). However, the majority of these studies have been criticized as poorly designed, without adequate follow-up or standardization of technique (Tarler-Benlolo, 1978; Jacobson, 1978). Additionally, Johnson (1978) found no significant differences in heart rate between relaxation and pseudotreatment groups selected on the basis of self-reported test anxiety.

In summary, then, evidence for physiological effects specific to relaxation is inconsistent. Furthermore, studies comparing relaxation with biofeedback for treatment of some stress-related disorders have yielded conflicting results about the superiority of one method over the other (Tarler-Benlolo, 1978). Despite the weaknesses of many studies of relaxation treatment, Tarler-Benlolo (1978) concluded that there are sufficient studies that appear methodologically sound to justify further investigation of relaxation as a treatment method. Therefore, the present study investigated the effects of relaxation training on several esophageal and physiological variables, specifically, forehead EMG, hand temperature and fingertip skin conductance level. As previously noted, the effects of relaxation training on these physiological variables, except esophageal functioning, have been studied in previous research but with inconsistent results.

Anxiety Measurement

Findings of some anxiety studies indicate that individuals rated as highly anxious on self-report measures may respond to stress with greater behavioral and physiological changes than do individuals rated as less anxious (O'Neil, 1970; O'Neil, Hansen, & Spielberger, Note 1; O'Neil, Spielberger & Hansen, 1969). However, the correlation between physiological and self-report measures of anxiety has generally been low (Schachter, in Spielberger, 1966). While it can be assumed that reports of anxiety are related both to physiological and cognitive changes, physiological changes are thought to be a necessary condition but may not be a sufficient condition for changes in self-reported anxiety (Schachter, in Spielberger, 1966). Nonetheless, O'Neil, Spielberger and Hansen (1969) found that college students' systolic blood pressure and their scores on the State scale of the State-Trait Anxiety Inventory (STAI) covaried with the degree of difficulty encountered on a learning task. In a follow-up study by the same investigators (O'Neil, Hansen, & Spielberger, Note 1), students with high scores on the STAI State scale showed greater performance impairment on a learning task than did those with low scores on the same measure. Hall (1970) found similar results in a study of 156 male high school seniors. Therefore, some evidence suggests greater behavioral and physiological changes in those described as highly anxious than those described as less anxious on the STAI.

The STAI is comprised of separate self-report scales for measuring state anxiety and trait anxiety, considered to be two different types of anxiety (STAI Manual, 1970). The STAI is a brief questionnaire titled the "Self-Evaluation Questionnaire" on the answer form itself, which college students generally complete in fewer than 10 minutes (STAI Manual, 1970). Trait and State scales are scored separately, providing two scores for each subject. The STAI norms for college students are based on approximately 1,500 Florida undergraduate college students' responses (STAI Manual, 1970). Several studies that used the STAI to measure anxiety levels before, during, and following stress provide estimates of the instrument's validity as a measure of a relatively consistent behavior pattern, termed trait anxiety. For instance, Auerbach (1973) compared the effects of "success feedback" and of "failure feedback" during an intelligence test on college students with high anxiety trait scores and on those with low anxiety trait scores on the STAI. Differences between high and low _trait_ subjects for anxiety _state_ scores were greatest in the "failure feedback" condition (Auerbach, 1973). McAdoo (1971) found similar results in a study of the effects of failure feedback on students' anxiety levels while performing an intellectual task. The findings of Auerbach (1973) and McAdoo (1971) suggest that individuals with high _trait_ anxiety report greater _state_ anxiety under stress than do subjects with low _trait_ anxiety. The findings of O'Neil (1970) suggest that high trait anxiety subjects not only report greater anxiety under stress, but also experience more anxiety than low trait anxiety subjects. Consequently, the present study chose two groups of students—one group with high trait anxiety and the other with low trait anxiety, as measured by the STAI—in order to maximize potential differences between the two groups during the study's stressful stimulus situation.

Selection of a Stressful Stimulus Situation

Academic and intellectual examinations appear to result in identifiable physiological changes associated with stress. Dreyfuss and Czaczkes (1959) documented physiological changes in blood cholesterol and uric acid thought to be associated with the stress experienced by medical students during academic examinations. Schiffer, Hartley, Schulman, and Abelmann (1976) investigated the effects of stress associated with an intellectual performance task on executives and non-executives, both with and without ischemic heart disease. Of the total 43 subjects, 33 were considered executives. The executives were divided into three groups: control, angina with a history of hypertension, and angina without a history of hypertension. Both of the angina groups of executives responded to the intellectual performance task with higher heart rates during the task than did the nonexecutives with angina and the control group of executives. Subjects' post-task self-reports also suggested that the executives with angina had experienced greater feelings of anxiety than had the nonexecutives with angina. Taken together, the findings of Schiffer et al. (1976) and of Dreyfuss and Czaczkes (1959) indicate that individuals with high achievement motivation and behavior, like medical students and executives, may demonstrate a variety of physiological changes related to the stress of academic or intellectual examination.

Therefore, the present study selected an intellectual examination task as its stressful stimulus, and chose as subjects medical and premedical students because of their presumed high achievement motivation.

Selection of a Relaxing Stimulus Situation

The choice of a relaxation situation was based on several factors—ease of administration, standardization, and prior results. A recent review by Tarler-Benlolo (1978) of relaxation treatment studies reported that autogenic training methods appear to achieve the same type and degree of physiological changes as other relaxation methods, such as progressive muscle relaxation. Autogenic training is a term applied to a self-induced relaxation method developed by Johannes Shultz, a German psychiatrist, in the 1960s (Tarler-Benlolo, 1978). The autogenic method focuses on achieving feelings of warmth and heaviness in the extremities, regulation of cardiac and respiratory activity and other related physiological changes thought to be associated with relaxation (Tarler-Benlolo, 1978). The autogenic training method has been adapted and standardized on a series of audiotapes developed by Budzynski (1974) for patients' use at home. Evidence for the effects of autogenic relaxation training on several of the physiological variables of interest in the present study, specifically forehead EMG and hand temperature, is found in Cleaves (1971).

PURPOSE OF THE STUDY

The purpose of the present study was to investigate the esophageal and physiological effects of stress and relaxation in healthy adults. The study was exploratory, in part, in order to investigate whether psychologically-induced stress and relaxation have any measurable effects on normal esophageal functioning. Since previous studies had suggested that some esophageal variables are more likely than others to react to stress, the present study investigated certain hypotheses about the nature and direction of changes in esophageal functioning in response to stress.

It was hypothesized that stress would increase the frequency and intensity of spontaneous contractions, and would also increase the intensity of swallow-related (propulsive) contractions. It was not known whether any change might occur in the frequency of swallow-related contractions, because of a lack of literature on that topic.

It was not known whether any change would occur in any of the esophageal variables—frequency and intensity of spontaneous contractions, frequency and intensity of swallow-related contractions—in response to relaxation, because of similar lack of literature on that subject. However, if changes did occur in response to relaxation, it was expected that those changes would take the form of decreases in the frequency and intensity of spontaneous contractions, and decreases in the intensity of swallow-related contractions, compared with baseline levels. Once again, no assumption was made about the nature or direction of any change in the frequency of swallow-related contractions.

It was hypothesized that highly anxious individuals would be more likely to demonstrate stress-related and relaxation-related changes in esophageal functioning than would less anxious individuals.

It was further expected that the lower two-thirds of the esophagus would be more likely than the upper third to show changes associated with stress and relaxation. This expectation derived from previously discussed literature about the greater incidence of esophageal changes in the lower two-thirds of the esophagus shown under stress by some patients with diffuse esophageal spasm.

A previous study of esophageal response to an intense auditory stimulus (Stacher et al., 1979) monitored heart rate and found no significant relationship between heart rate and esophageal contractions. Therefore, the present study selected for monitoring three other physiological variables—forehead EMG, hand temperature, and fingertip skin conductance—discussed in the literature as being sensitive to stress and to relaxation. No assumption was made about whether changes in any of these physiological variables would be correlated with changes in any of the esophageal variables. Nonetheless, the present study investigated whether significant correlations might occur between esophageal and physiological variables.

It was hypothesized that mean forehead EMG would increase, mean hand temperature would fall, and mean skin conductance level would rise in response to stress compared with baseline levels. In response to relaxation, it was expected that changes in the opposite direction would occur for each of the physiological variables. It was further expected that the variability of each of the physiological variables would be lower during either stress or relaxation than it would be during baseline.

It was expected that highly anxious individuals would be more likely than less anxious individuals to demonstrate changes in the physiological variables in response to stress and to relaxation.

Finally, the present study formulated no hypothesis about the possible effects of the order in which the stress situation and the relaxation situation would be presented to subjects. The present study varied the order of presentation in order to control for possible differential effects of presenting one situation prior to the other.

METHOD

Subjects

Studies were performed on 28 healthy young adults, 24 men and 4 women, all of whom were medical or premedical students at the University of Miami. None of the subjects reported any history of esophageal disorder. Upon examination by standard manometry, a method for measuring esophageal contractions, all subjects were found to have esophageal functioning within the normal range.

A sample of subjects was initially selected on the basis of scores on the STAI Trait scale. Two groups were chosen from those who completed the questionnaire: a High Anxiety (HA) group and a Low Anxiety (LA) group. To select the HA group, a cutoff score of 42 was used, representing the 68th percentile for males and the 73rd percentile for females, based on undergraduate college norms (STAI Manual, 1970). No specific norms for medical or for premedical students were found for the STAI. To select the LA group, a cutoff score of 30 was used, representing the 24th percentile for males and the 15th percentile for females, based on the same undergraduate norms as for the HA group (STAI Manual, 1970).

The STAI was administered to freshmen, sophomore, and junior medical students at the end of a regular class session. Students had already received a written request signed by the Chief of the Gastroenterology Section of the Miami Veterans Administration Medical Center (V.A.M.C.) requesting their cooperation in completing the questionnaire. The experimenter explained to the students that the administration of the questionnaire was the first stage of a cooperative study between the Psychology Service and the Gastroenterology Section of the Miami V.A.M.C. The experimenter, with the assistance of the esophageal technician, distributed the questionnaires, titled "Self-Evaluation Questionnaire," to all students in the classroom and collected completed questionnaires as students exited from the classroom. Students had already been informed that their scores would be confidential, and that those who qualified for the next stage of the study would be notified by mail. A total of 200 medical students completed the questionnaire. Subsequently, the questionnaire was administered to approximately 80 undergraduate junior and senior premedical students because a larger subject pool was required to identify a sufficient number of subjects qualified and willing to participate in the second stage of the study.

The decision to use medical and premedical students as subjects was based, in part, on availability and on an assumption of their interest and willingness to participate as paid volunteers in a medically-related study. However, this assumption may have been in error. For instance, of an initial group of 40 medical students whose questionnaire scores qualified them for further participation in the study, only four responded to a written invitation to participate further, accompanied by an offer of fifty dollars compensation for approximately two and a half hours of their time (Appendix A). Students who had not responded to the invitation within one week's time were contacted by phone by the experimenter. Many of these students reported to the experimenter that they were unwilling to allow a nasogastric tube, used for measuring esophageal contractions, to be passed into their esophagus. Some of these students reported that they had witnessed tubes being passed into patients' esophagi, and they felt that it was a very uncomfortable procedure. Reassurance about the minimal discomfort that other subjects had experienced in similar studies was successful in changing the decision of only one student who had been initially unwilling to participate.

Subsequent to the phone contacts with reluctant but otherwise qualified subjects, the reimbursement fee was raised from the initial fifty dollars to one hundred dollars. The STAI was then administered to another 120 medical students, nearly half of whom qualified for further participation in the study. Twenty of those 56 qualified students responded to the written invitation accompanied by an offer of one hundred dollars. Of those 20, however, all but 2 were in the Low Anxiety (LA) group. High Anxiety (HA) subjects were apparently unwilling to participate further, even for greater financial compensation.

The initial intention had been to select subjects on the basis of two measures: their STAI score and their baseline measures of forehead EMG, hand temperature and skin conductance. Students with concordance on the STAI and at least two of the three physiological measures, i.e. high-high or low-low, would then qualify for further participation in the study.

Although the correlation between physiological and self-report measures of anxiety has generally been low, as previously discussed, the use of a self-report measure alone as an indicator of a subject's anxiety level seemed unjustified in a study whose purpose was to investigate physiological variables. On the other hand, the use of any or all of the physiological variables as measures of anxiety without a self-report measure seemed equally unjustified because of contradictory evidence, previously discussed, of the correlations of physiological changes to various anxiety levels. Therefore, the initial intention of the present study was to require agreement between self-reports and physiological measures because neither one alone seemed a sufficient index of anxiety. It was assumed that the use of a double screening procedure to select a sample of approximately 30 qualified subjects would require a large subject pool of willing participants. However, when so few students volunteered for participation in the study even in response to increased compensation, the double screening procedure was replaced with a single screening procedure, the STAI or self-report measure, as described.

Even with this change to a single screening procedure, the number of medical students willing to participate beyond the completion of the STAI was insufficient to provide the sample size intended for the study. Therefore, the STAI was administered to approximately 80 junior and senior premedical students in order to increase the size of the subject pool. In this way, a sample of 28 qualified students was selected, with an equal number in the HA and LA groups, as planned. It should be noted that HA students generally responded only after two written invitations and a follow-up phone call.

Of a total of 36 subjects, both HA and LA, who were scheduled to participate in the second stage of the study, eight were unable to complete the study past Phase 1, the physiological baseline. These eight subjects were unable to have the nasogastric tube passed through the nose or mouth into the esophagus. No data exist in the literature on the incidence of this difficulty in esophageal research. However, the esophageal technician who performed the esophageal measurement procedures estimated that the incidence of difficulty in the present study was substantially higher than in other esophageal studies she had performed with medical students as subjects.

The final sample of 28 subjects represents approximately 10% of the student population to whom the STAI was administered. The difficulties encountered in completing the sample are not likely to bias the representativeness of the sample, because all subjects met the selection criteria and all had esophageal functioning within the normal range. The group of 8 subjects who were unable to complete the study was evenly divided between females and males, and between HA and LA categories. Therefore, this group of subjects did not differ significantly from the sample on the basis of the HA: LA ratio, but did differ on the basis of the sex ratio. Females comprised 50% of the dropped subject group but only 14% of the final sample. The circumference of the four-lumen nasogastric tube appeared to have been too large for more females than males in the present study.

Experimental Design

The study was designed to investigate the effects of two independent variables—an orally-presented "stress quiz" and orally-presented relaxation introduction—on two types of dependent variables, esophageal and physiological. Each of the 28 subjects participated individually in one experimental session, the second stage of the study following the administration of the STAI. An experimental session was of approximately two and a half hours duration. Prior to the experimental session, subjects had been assigned either to the HA or to the LA group on the basis of their STAI Trait Scale score, as previously described. Subjects in both groups were then randomly assigned either to an Early Stress/Late Relaxation order (referred to as the Early Stress order for the remainder of this report) or to the Early Relaxation/ Late Stress order (referred to as the Early Relaxation order). In this way, half of the HA group and half of the LA group were randomly assigned to the Early Stress order, and half of each group was randomly assigned to the Early Relaxation order.

An experimental session consisted of seven 10-minute phases as follows: Phase 1, Physiological Baseline; Phase 2, Standard Manometry (initial measurement of esophageal functioning to determine normalcy); Phase 3, Recovery from Manometry; Phase 4, the Stress condition for subjects in the Early Stress order and the Relaxation condition for subjects in the Early Relaxation order; Phase 5, Recovery; Phase 6, the Relaxation condition for subjects in the Early Stress order and the Stress condition for subjects in the Early Relaxation order; and Phase 7, Recovery. Table 1 shows the seven phases of the multiple baseline, two-experimental treatment, group design.

Throughout the course of the study, the esophageal technician was responsible for taking measurements of esophageal variables and the experimenter was responsible for the measurements of physiological variables. The technician, the experimenter, and the subject were the only persons present

Table 1
Measurement of Dependent Variables During Successive Phases and Their Corresponding Treatment Situations for Group by Order Combinations of Subjects

Group[a] by Order	N	Phases (Treatment Situation)[c] 1 (B)	2 (SM)	3 (RM)	4 (R)	5 (RR)	6 (S)	7 (RS)
ER: HA	7	Variables:[d] EMGM EMGSD SCLM SCLSD TEMPM TEMPSD	same as in 1, plus: FrSp InSp FrSw InSw	same as in 2	same as in 2	same as in 2	same as in 2	same as in 2
LA	7	same as for ER/HA in 1	same as for ER/HA in 2	same as in 2	same as in 2	same as in 2	same as in 2	same as in 2
		1 (B)	2 (SM)	3 (RM)	4 (S)	5 (RS)	6 (R)	7 (RR)
ES: HA	7	same as for ER/HA in 1	same as for ER/HA in 2	same as in 2	same as in 2	same as in 2	same as in 2	same as in 2
LA	7	same as for ER/HA in 1	same as for ER/HA in 2	same as in 2	same as in 2	same as in 2	same as in 2	same as in 2

Table 1—(extended)

[a]Group:

HA = High Anxiety
LA = Low Anxiety

[b]Order:

ER = Early Relaxation
ES = Early Stress

[c]Treatment Situations

B = Baseline
SM = Standard Manometry
RM = Recovery from Manometry
R = Relaxation
RR = Recovery from Relaxation
S = Stress
RS = Recovery from Stress

[d]Variables:

EMGM = Mean forehead EMG
EMGSD = Forehead EMG standard deviation
SCLM = Mean skin conductance level
SCLSD = Skin conductance standard deviation
TEMPM = Mean hand temperature
TEMPSD = Hand temperature standard deviation
FrSp = Frequency of spontaneous contractions
InSp = Intensity of spontaneous contractions
FrSw = Frequency of swallow-related contractions
InSw = Intensity of swallow-related contractions

during an experimental session. The measurements of physiological variables—forehead EMG, hand temperature, and fingertip skin conductance level—were recorded continuously from Phase 1 through Phase 7. Measures of esophageal variables were recorded continuously from Phase 2 through Phase 7. The nasogastric tube for measuring esophageal variables was introduced into a subject's esophagus at the beginning of Phase 2. During Phase 2, the normalcy of the esophagus was determined by standard manometry. Phase 3 marked the beginning of continuous measurement of esophageal functioning in the body of the esophagus. The physiological and psychological effects of the tube's introduction were not known in advance because of a lack of literature on the topic. However, the experimenter assumed that the experience was likely to be mildly to moderately stressful for most subjects. Therefore, Phase 1 served as a prenasogastric tube physiological baseline.

The Stress Situation

In the present study, stress was defined as the administration of a taped, oral intellectual achievement test under timed conditions (Appendix B). Taped instructions preceding the test informed the subject that results of previous research indicated that above average performance on the quiz accurately predicts future success in medical school. Other parts of the taped instructions were similarly designed to increase the subject's motivation and anxiety about the test. For example, the subject was informed that his or her overall performance would not be disclosed until the completion of the experimental session. To increase further the anxiety-producing characteristics of the stress condition, subjects received "failure feedback" about their performance on the first part of the quiz, after Question 17. As suggested by the findings of Auerbach (1973) and McAdoo (1971), failure feedback tends to increase anxiety of low anxiety and of high anxiety subjects, though the latter group is likely to show a greater increment in measured anxiety on a self-report questionnaire.

In summary, five characteristics of the stimulus situation designed to induce stress were the use of an intellectual achievement task requiring answers whose correctness was difficult for subjects to judge; instructions describing task performance as a predictor of future academic success; oral administration; failure feedback; and the requirement of oral answers to an audience, one member of whom scored their correctness.

The Relaxation Situation

The relaxing stimulus situation was operationalized as the presentation of audiotaped relaxation instructions focusing on the upper and lower extremities. The tape is part of an autogenic self-instruction relaxation training program called the "Relaxation Training Program," developed for home use by patients (Budzynski, 1974). Tape 4, "Limb Heaviness and Warmth," as narrated by Judith Proctor, was used in the present study. On this tape, the narrator instructs the subject to use mental imagery to achieve feelings of warmth and heaviness in the arms and legs. Tape 4 was chosen because of its focus on hand temperature, one of the physiological variables of interest in the present study, and because of evidence suggesting that hand temperature increases are related to heightened muscle relaxation (Kappes, 1979). Finally, the present study used a relaxation training tape narrated by a female because the taped quiz used in the stress condition also had a female narrator.

The State-Trait Anxiety Inventory (STAI)

The STAI is a widely-used self-report questionnaire with two scales, a State Anxiety Scale and a Trait Anxiety Scale (STAI Manual, 1970). The present study selected the STAI to identify subjects for the HA and LA groups because the STAI can be quickly administered (approximately 10 minutes for college students), its norms are appropriate for the research population, and it provides a score, the trait anxiety score, that appears to measure a relatively consistent behavior pattern. Additionally, test-retest correlations for the Trait Anxiety Scale range from .73 to .86, whereas those for the State Anxiety Scale are significantly lower (STAI Manual, 1970).

The STAI Trait Anxiety Scale consists of 20 statements asking a subject to describe how he or she generally feels

(STAI Manual, 1970). By comparison, the STAI State Anxiety Scale asks for a description of feelings at the time a subject is completing the 20 questions comprising that scale (STAI Manual, 1970). In a study of the relationship of STAI scores to subjects' reactions to stressful stimuli, Hodges and Felling (1970) found that the STAI Trait Anxiety Scale correlated significantly with three types of situations that all involved psychologically induced stress, specifically, threats of academic or social failure, but not with situations involving pain or physical threat.

In summary, the characteristics of the STAI itself and the research it has generated indicate the appropriateness of the STAI for the present study.

Physiological Variables

Six physiological variables were measured: the mean and the standard deviation of forehead EMG, of hand temperature, and of fingertip skin conductance level. Means and standard deviations were calculated for each phase of the experimental session, resulting in six physiological measurements for each of the seven 10-minute phases, or a total of 42 measures for each subject.

Forehead EMG

Electromyographic (EMG) activity is the electrical activity that accompanies muscle action. It is detected by metal electrodes attached to the surface of the skin. Electromyographic activity is measured in microvolts or millionths of a volt (Autogen 1700 Manual, 1975). Since muscular action, also known as muscle tension, is proportional to the degree of electrical discharge stimulating the muscle, the EMG is a direct physiological index of muscle contraction or relaxation (Grings & Dawson, 1978). The lower the microvolt level of EMG activity, the more relaxed the monitored muscle (Hassett, 1978). The forehead, or frontalis muscle, was chosen because of evidence of its sensitivity to generalized muscle tension in the upper part of the body (Whitehead, 1978). Budzynski (1973) concluded that lessening of forehead EMG levels contributes to "a general decrease in arousal level" (1973, p. 541). However, other investigators have reported opposite conclusions about the generalization of lowered forehead EMG activity to other muscles (Siddle & Wood, 1978).

The present study considered other muscle groups, such as the forearm and neck muscles, for EMG activity measurement. However, movement of arm and throat muscles, necessitated by experimental activities like talking and position adjustments, interfered with valid measurement of stress-related and relaxation-related changes in EMG activity. The Autogen 1700 Feedback Myograph was the instrument used, without the feedback modalities, to measure a subject's forehead EMG activity (Figure 2).

Figure 2. Subject with forehead EMG electrodes, nasogastric tube, and throat collar in place.

Figure 3. Autogen 1700, 2000b, and 3000 for monitoring physiological variables.

Hand Temperature

Hand temperature is affected by sympathetic activity of the autonomic nervous system (Danskin & Walters, 1973).

> The temperature of the skin is largely a function of peripheral circulation. Vasoconstriction, a decrease in diameter of peripheral arteries caused by sympathetic nervous system (SNS) activation, lowers skin temperature. Vasodilation, an increase in the diameter of peripheral arteries caused by SNS relaxation, raises skin temperature. (Hassett, 1978, p. 65)

Although skin temperature can be affected by climate and blood viscosity, it was assumed that these variables remained constant during an experimental session. However, a several second lag often occurs between vasodilation and temperature increase at the skin surface (Autogen 2000b Manual, 1975).

The present study measured hand temperature with the Autogen 2000b Feedback Thermometer, without using its feedback modalities (Figure 3). A temperature probe was attached to the upper surface of the left hand (Figure 4). At the tip of the probe was a tiny semiconductor embedded in an epoxy bead. The semiconductor served as a temperature sensor when the epoxy bead was in contact with the skin surface. A strip of tape maintained the epoxy bead in position on the subject's hand.

Skin Conductance

Skin conductance is ". . . linearly related to sweat secretion" (Hassett, 1978, p. 36). "The unanimity of studies on the topic of increased sweating to emotionally charged stimuli is quite compelling" (Hassett, 1978, p. 35).

Figure 4. Temperature probe taped to hand and skin conductance sensors attached to fingers.

Figure 5. Autogen 5600 and P-5000 Alphanumeric Printer.

The term "skin conductance level" denotes the absolute value of electrodermal activity measured in a specific skin area (Autogen 3000 Manual, 1975). Autonomic nervous system activation is associated with increased skin conductance; relaxation is associated with lessened skin conductance. The Autogen 3000 was used to measure skin conductance level (Figure 3). The present study measured skin conductance by means of sensors attached with velcro fasteners to the tips of the index, middle, and ring fingers of the left hand (Figure 4).

Data Collection and Recording

The Autogen 5600 minicomputer (Figure 5) collected data from the EMG, temperature, and skin conductance monitoring equipment and computed means and standard deviations of each physiological variable for each phase of the experimental session. The P-5000 Alphanumeric Printer (Figure 5) provided a printed record tape of these data for each subject.

Esophageal Variables

Four esophageal variables were measured: frequency and intensity of swallow-related contractions and frequency and intensity of spontaneous contractions. Measurements of these variables occurred at each of four esophageal sites: the proximal, upper-mid, lower-mid, and distal areas. In this way, the length of the body of the esophagus was monitored.

The upper esophageal sphincter and the lower esophageal sphincter were both excluded from study.

Swallow-Related Contractions

Swallow-related contractions are normal sequelae of the act of swallowing (Benjamin, Gerhardt, & Castell, 1979). Their frequency is related to the frequency of swallowing. Their intensity, that is, their peak pressure as measured by the contraction with the greatest amplitude within a given time interval, is judged to be within the normal range if it falls between 75 and 175 mm Hg, as measured by standard manometry (Benjamin et al., 1979).

Spontaneous Contractions

Spontaneous, or nonswallow-related contractions, generally occur at a low rate in individuals without esophageal motor disorders, although their incidence varies from individual to individual in the normal population (Nagler & Spiro, 1961). Spontaneous contractions in the lower two-thirds of the esophagus seem to occur with greater frequency and intensity in individuals with esophageal motor disorders, such as diffuse esophageal spasm, than in normal individuals (Pope, in Sleisinger & Fordtran, 1978).

Esophageal Measurement

Initial evaluation of esophageal function took place by means of a procedure called standard manometry. In the present study, standard manometry entailed the introduction of a four-lumen, flexible polyvinyl tube (Figure 2, Figure 6) into the esophagus through the nose or mouth. The distal end of the tube was initially positioned in the stomach before being withdrawn in small gradual steps during standard manometry. Each lumen of the tube had a side orifice for the purpose of measuring contractile pressures. The lower-most, or distal, orifice was four centimeters from the distal tip of the tube. The distal orifice measured pressures in the distal esophagus when the tube was so positioned. The other three orifices, located above the distal one, measured pressures in the lower-mid, upper-mid, and proximal esophagus, respectively. Each orifice was located approximately four centimeters from the next one when the tube was in position within the esophagus. Manometric, or esophageal, measurements were, therefore, obtained over a 16-centimeter length of esophagus simultaneously. The lumens were mechanically perfused with water on a continuous basis, in order to measure esophageal pressures. A contraction squeezed the water column in a lumen and the amount of pressure exerted by the contraction was measured. To assess whether a subject's esophageal functioning was within the normal range, a procedure called standard manometry was performed during Phase 2 of the experimental session.

During standard manometry, the esophageal, or nasogastric, tube was gradually withdrawn from the stomach through the lower esophageal sphincter into the body of the

Figure 6. Four-lumen, flexible nasogastric tube (at right) swallow-recording throat collar (at left).

esophagus, resulting in a gradual rise and fall in pressure readings. This rise and fall indicated that the pressure recording units had entered the body of the esophagus (Earlam, 1975). The units were pulled out at one centimeter intervals while swallows occurred at least once every 45 seconds. In this way, swallow-related contractions were measured. If a subject did not swallow for approximately 60 seconds, the technician instructed the subject to swallow so that a sufficient number of swallow-related contractions was assured for valid measurement.

A Hewlett-Packard 7758A, eight-channel writer-recorder (Figure 7) provided tracings on thermographic paper. Similar to ECG tracings of cardiac activity, these tracings provided records of esophageal pressure measurements at a rate of one millimeter per second. The tracing's peaks and valleys represented the frequency and intensity of esophageal contractions (Appendix C). Swallow-related contractions were differentiated from spontaneous, or nonswallow-related, contractions by referrings to tracings of the throat's muscular activity. The throat's muscular activity was measured with a water-perfused pressure recording tube imbeded in a soft gauze collar which was attached with velcro strips around a subject's neck (Figure 2). Spontaneous contractions were identified where a contraction had occurred without reference to the act of swallowing, as recorded on Channel 7 of the thermographic paper. Five channels, or horizontal rows,

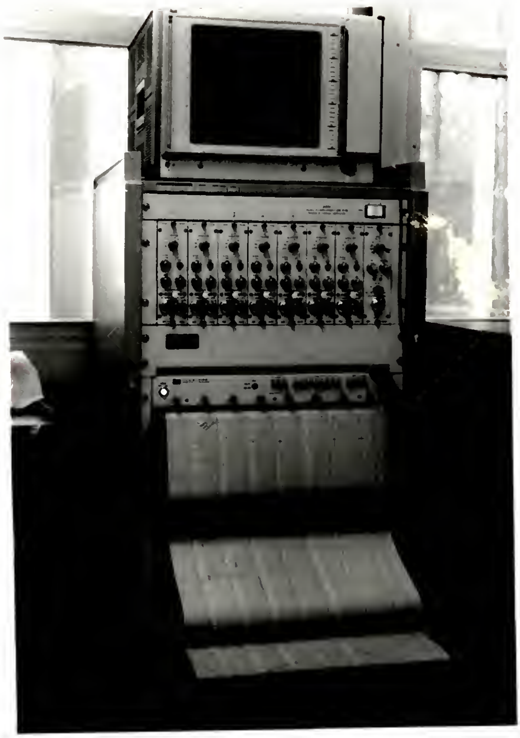

Figure 7. Hewlett-Packard 7758A eight-channel writer-recorder.

of tracings appeared on a subject's esophageal record. Channels 1 through 4 correspond to the four monitored esophageal sites. Channel 1, located at the top of the record (Appendix C), represents readings from the proximal esophageal area; Channel 2, immediately below Channel 1 on the record, shows upper-mid area measurements; Channel 3, lower-mid; and Channel 4, distal. Channels 5 and 6 were left blank. Channel 7 (Appendix D) displays measurements of throat movements associated with the act of swallowing.

The writer-recorder lacked the capability of time recording. Therefore to coordinate data recording of esophageal variables with that of physiological variables, the technician marked the beginning and the end of each phase during the experimental session with several vertical black lines and wrote the phase number beneath that section of the record for identification purposes.

Procedures

Upon arrival at the Esophageal Studies Laboratory of the Miami Veterns Administration Medical Center, a subject was asked to sign an informed consent form (Appendix E), which indicated voluntary participation in the study. The subject also signed a financial compensation voucher in the amount of one hundred dollars for the subject's participation in the study. The informed consent form presented the study as an investigation of the possible effects of stress and of relaxation on esophageal functioning. The stressful stimulus was described as "timed testing" and the relaxing stimulus as "music" on the informed consent form. However, a relaxation instructions tape was substituted for music, and the subjects were orally informed of that change by the experimenter. No further explanation of either the stressful or of the relaxation stimulus was given except that the stressful stimulus would not be painful. The esophageal technician and the experimenter walked the subject around the laboratory, explaining and demonstrating their equipment, with which most subjects were unfamiliar, except for the nasogastric tube. Then, the experimenter instructed the subject to sit on the hospital table and to assume a comfortable supine position. While the experimenter explained what she was doing, she scrubbed the subject's forehead with an alcohol wipe to remove traces of oil, and attached three EMG electrodes, one above each eyebrow and the third, or ground, in the middle of the forehead (Figure 2), according to instructions in the EMG manual (Autogen 1700 Manual, 1975). A temperature probe was attached with tape to the subject's left hand, on its upper surface, between the thumb and forefinger. Skin conductance sensors were attached to the index, middle, and ring fingers of the subject's left hand. Following these procedures, the experimenter instructed the subject to lie quietly while she checked the equipment for proper functioning. The subject was told that he or she was allowed to speak, and the esophageal technician talked with the subject for a 10-minute adaptation interval, during which the experimenter checked the equipment.

Phase 1 (Baseline)

After checking the equipment, the experimenter informed the subject that baseline data on EMG, skin temperature, and skin conductance would be collected, and that the subject could continue talking during the baseline interval.

At the end of the 10-minute physiological baseline, or Phase 1, the technician instructed the subject to sit up and face her. The recording sensors remained in place, and physiological measurement continued. The technician informed the subject that she would ease a lubricated tube into one of the subject's nostrils until it reached the back of the throat, at which time she would instruct the subject to begin swallowing, so that the tube could enter the esophagus. The technician passed the tube into and up the nostril and once it entered the esophagus, she instructed the subject to continue swallowing so that peristaltic activity could move the tube down the esophagus. The technician monitored its progress and positioned it so that one end of the tube was in the subject's stomach. The subject was then instructed to resume a comfortable supine position (Figure 8). The technician attached a swallow-recording collar around the subject's neck with velcro straps. Following that sequence of procedures, a five-minute recovery interval occurred to allow the subject to adapt to the tube and the collar, while the technician checked her equipment.

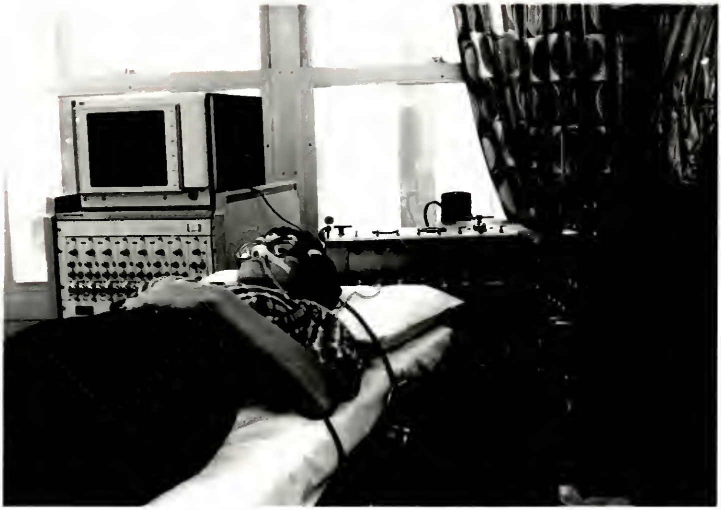

Figure 8. Subject in supine position with recording equipment.

Phase 2 (Standard Manometry)

Following the recovery interval, the technician performed a standard manometry procedure during Phase 2. During standard manometry, the tube was withdrawn from the stomach into the esophagus in 1 cm steps, until the Channel 1, or proximal, recording device had passed through the lower esophageal sphincter into the distal esophagus. The tube continued to be moved up the body of the esophagus in 1 cm. steps, while the subject swallowed at least once each minute. If a subject failed to swallow for approximately 60 seconds, the technician asked the subject to swallow. In this way, a sufficient number of swallow-related contractions were produced to assure accurate assessment. At the completion of the standard manometry, or Phase 2, the technician repositioned the tube so that the proximal recording device, corresponding to Channel 1 on the esophageal tracing, was in the proximal esophagus; the upper-mid recording device, corresponding to Channel 2, was in the upper-mid esophagus; the lower-mid device, corresponding to Channel 3, was in the lower-mid esophagus; and the distal device, corresponding to Channel 4, was in the distal esophagus. The technician then anchored the tube with adhesive tape strapped to the cheek and the bridge of the nose (Figure 2). The tube remained stationary throughout the remainder of the experimental session, and did not interfere with breathing or talking.

Phase 3 (Recovery from Manometry)

Following Phase 2, subjects were once again informed that they could talk, if they wished, while more baseline measurement occurred (Phase 3). Phase 3 provided 10 minutes of both physiological and esophageal measurement, while the subject was allowed to recover from the previous procedures.

Phase 4 (Stress or Relaxation)

At the beginning of Phase 4, the experimenter delivered one of two possible sets of oral instructions to the subject, depending on whether the subject had been assigned to the Early Stress order or to the Early Relaxation order. If the subject had been assigned to the Early Stress order, the experimenter told the subject that a tape of a quiz would be played very shortly, and that the subject should speak only at the times indicated by the taped instructions preceding the quiz. Taped instructions preceding the quiz told the subject to answer questions aloud in the allotted time before the next question began, and that the tape would be stopped halfway through the quiz, in order to provide feedback about the subject's performance on the first part of the quiz. Following the taped instructions and before the quiz began, the experimenter told the subject that she would write down the subject's answers to the quiz questions, as the subject said them aloud. The quiz tape was begun and then stopped halfway through the quiz, following Question 17. Without regard to the subject's actual quiz performance, the experimenter informed the subject that he or she had made six errors of the total of 17 questions on the first part of the quiz, which placed the subject's performance somewhat below the norm for medical (premedical) students for that part of the quiz. The experimenter urged the subject to concentrate in order to improve his or her performance during the second part of the quiz. The quiz tape resumed where it had been stopped, and the remaining quiz questions were heard while the experimenter continued to write down the subject's answers. The taped instructions preceding the quiz had informed the subject that the final score would be disclosed only at the termination of the experimental session. If the subject inquired or commented about his or her performance during the experimental session, the experimenter replied noncommittally that she would disclose the subject's final score at the end of the session.

If the subject had been assigned to the Early Relaxation order, the experimenter informed the subject that a tape of relaxation instructions would be played very shortly, and that the subject should refrain from speaking while the tape played, but should follow the instructions heard on the tape. The tape played for a 14-minute interval, during which the experimenter and the technician refrained from speaking and seated themselves out of the subject's range of vision, to avoid distracting the subject. Physiological and esophageal measurements were recorded during the final 10 minutes of the relaxation tape. If the subject had been assigned to the Early Stress order, the same measurements were recorded during the final 10 minutes of the taped quiz. In each case, the first 5 minutes were unrecorded to allow the subject to adapt to the stimulus situation.

Phase 5 (Recovery from Stress or Recovery from Relaxation)

Following Phase 4, a 10-minute recovery interval, Phase 5, occurred, during which the technician and the experimenter talked with the subject while esophageal and physiological measurements were recorded automatically. The technician and the experimenter refrained from discussing the experiment during each of these conversations with the subject. The subject was encouraged to speak so that the activity that the subject engaged in during the recovery phases would be comparable to the activity, i.e. talking, required during the stress situation of the experimental session.

Phase 6 (Stress or Relaxation)

Phase 6 represented the stress situation for subjects assigned to the Early Relaxation order and the relaxation condition for subjects assigned to the Early Stress order. The stress situation and the relaxation situation were presented in the same manner as already described in Phase 4.

Phase 7 (Recovery from Stress or Recovery from Relaxation)

Phase 7, the final 10-minute interval, was another recovery phase during which esophageal and physiological measurements were recorded, as before, while the technician and the experimenter talked with the subject. Following Phase 7, the equipment was turned off and the recording sensors and the nasogastric tube were removed from the subject's body.

Termination of the Experimental Session

After allowing the subject several minutes for recovery, the experimenter typically informed the subject that his or her performance during the second part of the quiz had been superior to that of the first part, and, therefore, the overall score was slightly above the norm for comparable students. In a few cases in which the subject had ceased answering all or most questions during the second part of the quiz, the experimenter modified this procedure, and informed the subject that the quiz had no demonstrable relationship with medical school performance and that there was no evidence to suggest that performance on the quiz could predict future success in medical school. The experimenter told the subject that the study was still in progress, and that it was important to the study's success that the subject refrain from discussing it with colleagues until the study's completion. The experimenter explained that the subject's data and those of previous subjects would not be useful if future subjects knew the details of the experiment. However, the subject was told that he or she could answer questions from other students about the nasogastric tube and the esophageal measurement procedure, a topic about which students seemed to be curious. All subjects agreed to refrain from discussing the study. The experimenter questioned subjects following the experimental session and found no evidence that subjects had any prior knowledge of the nature of the stress or relaxation condition, other than the description they had read in the informed consent.

Data Compilation and Analysis

Data Compilation

Prior to statistical analysis, the esophageal records were converted into numerical data. The peak contractions were computed by measuring the height of every contraction along the vertical axis, within each 10-minute phase, and identifying the highest peak for each phase. The frequency of contractions was computed by counting the number of contractions along the horizontal axis for each phase. In this way, the frequency and intensity of contractions for each of the four esophageal sites, corresponding to Channels 1 through 4 on the esophageal records, were computed (Appendix F). Swallow-related contractions were differentiated from spontaneous, or nonswallow-related, contractions by referring to Channel 7, the tracings of throat movements associated with the act of swallowing. Systematic spot checks of the counting and recording procedures helped to assure accuracy. As previously described, means and standard deviations of each of the physiological variables had been computed and recorded automatically for each subject for each phase of the experimental session. Those data and the numerical esophageal data were transferred to tabulation forms for ease of data access. The means and standard deviations for the esophageal and the physiological variables are found in Appendix G.

Data Analysis

A multiple analysis of variance (MANOVA) was performed on the esophageal and on the physiological data, yielding significant results. Therefore, the present study used a repeated measures analysis of variance (ANOVA) for preliminary analysis of the esophageal and the physiological data. The Duncan's multiple range test followed the ANOVA to test for significant differences between means where the ANOVA had identified significant main effects or interactions. The Duncan's test is a multiple comparison procedure for carrying out all pairwise comparisons among means (Kirk, 1968). The Duncan's procedure is most appropriately used for hypothesis testing. The present study used the Duncan's test uniformly for testing all variables, even in the case of one variable, the frequency of swallow-related contractions, where no prior hypothesis had been formulated. Since relatively few significant differences were revealed for that variable, it was decided to forego further testing with a more conservative procedure than the Duncan's.

Statistical analysis of the esophageal data took place for each of four variables: frequency of spontaneous contractions, intensity of spontaneous contractions, frequency of swallow-related contractions, and intensity of swallow-related contractions. Since important neurological and myogenic differences affect the various esophageal sites, as previously discussed, the data for each esophageal variable were not averaged across esophageal sites. Instead, each variable was analyzed for each site separately. The esophageal data analysis omitted consideration of the baseline and standard manometry situations because continuous esophageal measurement had not occurred during those situations, as previously noted. The ANOVA tested for differences within and between groups (HA, LA), between treatment situations (excluding baseline and standard manometry) within and between orders (Early Relaxation, Early Stress) and between esophageal sites (proximal, upper-mid, lower-mid, distal) (Table 2).

Statistical analysis of physiological data took place for each of six variables: forehead EMG mean, forehead EMG standard deviation, hand temperature mean, hand temperature standard deviation, skin conductance mean, and skin conductance standard deviation. The ANOVA tested for differences within and between groups, within and between orders, and between treatment situations (including baseline and standard manometry) for each variable (Table 5). The analysis

Table 2
Main Effects Tested for in ANOVA for Esophageal Variables

1.	Esophageal Site:	Proximal (Px) Upper-Mid (Um) Lower-Mid (Lm) Distal (Dl)
2.	Group:	High Anxiety (HA) Low Anxiety (LA)
3.	Order:	Early Relaxation (ER) Early Stress (ES)
4.	Treatment:[a]	(c) Recovery from Manometry (RM) (d) Stress (S) (e) Recovery from Stress (RS) (f) Relaxation (R) (g) Recovery from Relaxation (RR)

[a]The letters preceding the treatments are for ease of reference. They do not refer to order of importance or to the chronological sequencing of the treatments during an experimental session. For instance, data for subjects exposed to the Relaxation treatment during Phase 4 of an experimental session were grouped with data for subjects exposed to the same treatment during Phase 6.

of physiological data differed from that for esophageal data in two ways: the former lacked the esophageal site dimension and the latter lacked data from the baseline and standard manometry situations. These differences between the two data sets necessitated the use of separate statistical models in the data analysis. A .05 rejection region was adopted for the ANOVA and for the Duncan's test.

Correlations were computed between physiological and esophageal variables within each phase. A correlation of ±.70 or above was considered significant.

RESULTS

Esophageal Variables

Table 2 shows the categories of main effects for which the ANOVA of each esophageal variable tested. The ANOVA also tested for significant interactions between two or more of the categories listed in Table 2. Table 3 shows the results of the ANOVA of each esophageal variable. Table 4 shows the results of the Duncan's tests for the esophageal variables.

Frequency of Spontaneous Contractions (FrSp)

The ANOVA found no significant main effects, but two significant two-way interactions: an esophageal site by treatment interaction and a treatment by group interaction.

Esophageal site by treatment interaction

The Duncan's tests were performed to identify significant differences in frequency of spontaneous contractions during various treatment situations at each esophageal site.

In the proximal esophagus, (f) relaxation was associated with significantly fewer spontaneous contractions than was any other treatment situation.

In the upper-mid esophagus, (d) stress was associated with significantly fewer spontaneous contractions than

Table 3
Summary of Analyses of Variance for Esophageal Variables:
Mean Squares

Sources of Variation	df	FrSp	InSp	FrSw	InSw
Model					
S(Gp by Or)					
Gp	1	1665.720	186.746	733.339	7726.828
Or	1	137.524	2539.121	793.006	37409.962*
Gp by Or	1	421.167	396.291	90.054	9334.629
Error	24	459.490	2499.041	709.202	7371.442
Model					
S by Ch (Gp by Or)					
Ch	3	166.550	1626.683	63.518****	819.976
Ch by Gp	3	132.978	733.024	5.597	3949.515
Ch by Or	3	233.044	713.531	21.232*	662.630
Ch by Gp by Or	3	108.401	379.200	5.994	3116.195
Error	72	110.939	721.295	6.413	1739.438
Model					
S by Tr (Gp by Or)					
Tr	5	595.224****	5922.846****	1430.935****	613.122
Tr by Gp	5	136.824**	889.577	407.189**	178.763
Tr by Or	5	23.356	225.710	72.699	86.328
Tr by Gp by Or	5	52.585	474.498	18.111	326.311
Error	120	39.424	603.973	55.638	445.688
Model					
Ch by Tr	15	50.510**	465.137	15.851	507.049
Ch by Tr by Gp	15	26.844	150.720	14.214	485.880
Ch by Tr by Or	15	16.847	268.534	11.987	442.298
Ch by Tr by Gp by Or	15	24.666	171.662	5.646	387.747
Error	360	20.982	315.045	8.545	306.193

Table 3—(extended)

Key
(ANOVA)

Note: Different error terms were used in the analysis of variance because of the nesting of some variables, as indicated by the terms within parentheses in the far left hand column.

$*p \leq .05$. $***p \leq .001$.
$**p \leq .01$. $****p \leq .0001$.

FrSp = Frequency of Spontaneous Contractions.
InSp = Intensity of Spontaneous Contractions.
FrSw = Frequency of Swallow-related Contractions.
InSw = Intensity of Swallow-related Contractions.

S = Subject.
Gp = Group.
Or = Order.
Ch = Esophageal Site.
Tr = Treatment.

Table 4
Summary of Duncan's Tests for Esophageal Variables: Means

Variable	Signif. Effect Found by ANOVA		RM	S	RS	R	RR
InSw	Or						
	ER		100.940[a]				
	ES		86.202[b]				
	Treatment:		RM	S	RS	R	RR
InSp	Tr		32.786[a]	22.112[b]	36.680[a]	19.893[b]	35.466[a]
FrSw	Gp by Tr						
	Gp	HA	23.286[b]	17.768[a]	19.393[b]	13.161[b]	18.500[b]
		LA	26.839[a]	17.982[a]	22.589[a]	15.393[a]	22.607[a]
FrSp	Gp by Tr*						
	Px	HA	8.643[a]	7.357[a]	6.071[a]	2.214[a]	7.714[a]
		LA	4.643[a]	6.857[a]	9.500[a]	.928[a]	6.571[a]
	Um	HA	12.000[a]	8.297[a]	10.171[a]	10.286[a]	15.928[a]
		LA	6.429[a]	6.722[a]	8.925[a]	3.214[a]	6.214[b]
	Lm	HA	8.786[a]	7.643[a]	11.000[a]	8.143[a]	12.071[a]
		LA	5.214[a]	4.357[a]	9.000[a]	2.214[b]	6.786[a]
	Dl	HA	9.286[a]	4.857[a]	8.928[a]	11.428[a]	11.928[a]
		LA	5.286[b]	4.642[a]	6.286[a]	2.857[b]	7.143[b]

Table 4—(continued)

Variable	Signif. Effect Found by ANOVA		Px	Um	Lm	Dl
	Esophageal site:		Px	Um	Lm	Dl
FrSp	Ch by Tr					
		RM	6.643^{a}	9.214^{a,b}	7.000^{a,b}	7.286^{a,b}
		S	7.107^{a}	5.071^{b}	6.000^{a,b}	4.750^{b}
	Tr	RS	7.786^{a}	10.821^{a}	10.000^{a}	7.607^{a,b}
		R	1.571^{b}	6.750^{a,b}	5.179^{b}	7.143^{a,b}
		RR	7.143^{a}	11.071^{a}	9.428^{a}	9.536^{a}
FrSw	Ch by Or					
	Or	ER	21.000^{a}	21.417^{a}	21.060^{a}	19.857^{a}
		ES	17.833^{b}	19.214^{a}	19.357^{a}	18.238^{a}

Note: a,b = two means with the same superscript not significantly different from each other. Those with different superscripts are significantly different, at the .05 level.

InSw = Intensity of swallow-related contractions
InSp = Intensity of spontaneous contractions
FrSp = Frequency of spontaneous contractions
FrSw = Frequency of swallow-related contractions

RM = Recovery from manometry
S = Stress
RS = Recovery from stress
R = Relaxation
RR = Recovery from relaxation

Gp = Group
Tr = Treatment

Ch = Esophageal site
Or = Order

HA = High Anxiety
LA = Low Anxiety

ER = Early Relaxation
ES = Early Stress

Px = Proximal site
Um = Upper-mid site

Lm = Lower-mid site
Dl = Distal site

*For FrSp, the Gp by Tr interaction varied according to esophageal site, although the ANOVA failed to reveal a Gp by Tr by Ch interaction. The presence of another interaction, Ch by Tr, for the variable FrSp shared a common term, Tr, with the Gp by Tr interaction, thus resulting in a de facto three-way interaction, i.e. Gp by Tr by Ch.

either (e) recovery from stress or (g) recovery from relaxation.

In the lower-mid esophagus, (f) relaxation was associated with significantly fewer spontaneous contractions than either (e) recovery from stress or (g) recovery from relaxation.

In the distal esophagus, (d) stress was associated with significantly fewer spontaneous contractions than (g) recovery from relaxation.

Treatment by group interaction

The Duncan's tests were performed to identify significant differences in frequency of spontaneous contractions during various treatment situations between the HA and LA groups.

During (f) relaxation, the HA group had a significantly greater frequency of spontaneous contractions than the LA group in the lower-mid and the distal esophageal sites. During (g) recovery from relaxation, the HA group had a significantly greater frequency of spontaneous contractions than the LA group in the upper-mid and the distal esophageal sites.

Intensity of Spontaneous Contractions (InSp)

The ANOVA resulted in a significant main effect for treatment, and no significant interactions. The Duncan's tests found that all of the recovery situations—

(c) recovery from manometry, (e) recovery from stress and (g) recovery from relaxation—were associated with significantly higher intensities of spontaneous contractions than were (d) stress or (f) relaxation or (b) standard manometry.

Frequency of Swallow-Related Contractions (FrSw)

The ANOVA resulted in no significant main effects, but in two significant two-way interactions: an esophageal site by order interaction and a treatment by group interaction.

Esophageal site by order interaction

The Duncan's tests were performed to identify significant differences in frequency of swallow-related contractions at each esophageal site between subjects in the Early Relaxation order and those in the Early Stress order.

In the proximal esophagus, subjects in the Early Relaxation order had significantly more swallow-related contractions than did subjects in the Early Stress order, across treatment situations.

Treatment by group interaction

The Duncan's tests were performed to identify significant differences in frequency of swallow-related contractions during treatment situations between the HA and the LA groups.

During (c) recovery from manometry, (e) recovery from stress, (f) relaxation and (g) recovery from relaxation, the LA group had significantly more swallow-related contractions than the HA groups, at all esophageal sites.

Intensity of Swallow-Related Contractions (InSw)

The ANOVA resulted in a significant main effect for order, and no significant interactions. The Duncan's tests showed that subjects in the Early Relaxation order had significantly higher intensities of swallow-related contractions than subjects in the Early Stress order across treatment situations at all esophageal sites.

Physiological Variables

Table 5 shows the categories of main effects for which the ANOVA of each physiological variable tested. The ANOVA also tested for significant interactions between two or more of the categories listed in Table 5. Table 6 displays the results of the ANOVA of each physiological variable. Table 7 displays the results of the Duncan's tests for the physiological variables.

Mean Forehead EMG (EMGM)

The ANOVA resulted in no significant main effects and no significant interactions. Therefore, no Duncan's tests were performed for this variable.

Table 5
Main Effects Tested for in ANOVA
for Physiological Variables

1.	Group:	High Anxiety (HA) Low Anxiety (LA)
2.	Order:	Early Relaxation (ER) Early Stress (ES)
3.	Treatment:[a]	(a) Baseline (B) (b) Standard Manometry (SM) (c) Recovery from Manometry (RM) (d) Stress (S) (e) Recovery from Stress (RS) (f) Relaxation (R) (g) Recovery from Relaxation (RR)

[a]The letters preceding the treatments are for ease of reference. They do not refer to order to importance or to the chronological sequencing of treatments within an experimental session. For instance, data for subjects exposed to Recovery from Stress during Phase 5 of an experimental session have been grouped with data for subjects exposed to the same treatment during Phase 7.

Table 6
Summary of Analyses of Variance for Physiological Variables: Mean Squares

Sources of Variation	df	EMGM	EMGSD	SCLM	SCLSD	TEMPM	TEMPSD
Model							
S(Gp by Or)							
Gp	1	16.235	2.657	1623.802	6.225	8.949	0.287
Or	1	1.529	1.940	331.058	0.033	11.290	0.019
Gp by Or	1	0.666	1.000	1475.602	14.554	0.025	0.050
Error	24	11.544	7.207	732.059	5.534	56.438	0.280
Model							
Tr	6	2.564	4.216****	164.446****	3.459***	18.684****	0.109
Gp by Tr	6	1.827	0.336	0.705	0.645	0.776	0.126
Or by Tr	6	1.158	0.898	19.745	0.354	4.276*	0.089
Gp by Or by Tr	6	1.929	1.069	7.524	1.816*	1.211	0.315*
Error	144	1.269	0.719	13.888	.796	1.719	0.142

Note: Different error terms were used in the analysis of variance because of the nesting of some variables, as indicated by the terms within parentheses in the far left-hand column.

*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
****$p \leq .0001$.

S = Subjects
Gp = Group
Or = Order
Tr = Treatments

EMGM = Mean of forehead EMGs
EMGSD = Standard deviation of forehead EMGs
SCLM = Mean of skin conductance levels
SCLSD = Standard deviation of skin conductance levels
TEMPM = Mean of hand temperatures
TEMPSD = Standard deviation of hand temperatures

Table 7

Summary of Duncan's Tests for Physiological Variables: Means

Variable		Signif. Effect Found By ANOVA	Treatment						
			B	SM	RM	S	RS	R	RR
EMGSD		Tr	1.931^{b}	2.204^{ab}	2.215^{ab}	2.236^{ab}	2.592^{a}	1.405^{c}	2.451^{a}
SCLM		Tr	15.791^{e}	18.820^{cd}	19.070^{cd}	22.957^{a}	21.498^{ab}	17.219^{de}	19.635^{bc}
SCLSD		Gp by Or by Tr							
		ER							
	Gp	HA	2.857^{a}	1.878^{a}	2.464^{a}	2.184^{a}	1.851^{a}	2.650^{a}	3.363^{a}
		LA	2.031^{a}	1.867^{a}	1.276^{b}	1.316^{b}	1.686^{a}	1.193^{a}	1.570^{b}
		ES							
	Gp	HA	2.964^{a}	1.721^{a}	1.893^{a}	1.297^{a}	1.914^{a}	1.341^{a}	2.120^{a}
		LA	2.191^{a}	1.628^{a}	2.038^{a}	1.497^{a}	2.237^{a}	2.197^{a}	2.781^{a}
TEMPM		Or by Tr							
		ER	89.234^{a}	87.084^{a}	87.211^{c}	87.827^{bc}	86.996^{c}	87.675^{bc}	88.431^{ab}
		ES	90.248^{a}	88.234^{bc}	88.557^{b}	88.305^{bc}	87.449^{bc}	87.356^{c}	87.669^{bc}
TEMPSD		Gp by Or by Tr							
		ER							
	Gp	HA	0.706^{a}	0.488^{a}	0.434^{a}	0.413^{a}	0.537^{a}	0.376^{a}	0.270^{a}
		LA	0.326^{a}	0.320^{a}	0.403^{a}	0.468^{a}	0.254^{b}	0.477^{a}	0.216^{a}
		ES							
	Gp	HA	0.208^{a}	0.333^{a}	0.387^{a}	0.336^{a}	0.497^{a}	0.981^{a}	0.220^{b}
		LA	0.497^{a}	0.388^{a}	0.366^{a}	0.300^{a}	0.256^{b}	0.271^{a}	0.473^{a}

Table 7—(extended)

KEY

Note: Two means with the same superscript are not significantly different from each other. Those with different superscripts are significantly different, at the .05 level.

EMGSD = Standard deviation of forehead EMG.
SCLM = Mean of skin conductance level.
SCLSD = Standard deviation of skin conductance level.
TEMPM = Mean of hand temperature.
TEMPSD = Standard deviation of hand temperature.

B = Baseline.
SM = Standard Manometry.
RM = Recovery from Manometry.
S = Stress.
RS = Recovery from Stress.
R = Relaxation.
RR = Recovery from Relaxation.

Gp = Group.
Or = Order.
Tr = Treatment.

HA = High Anxiety.
LA = Low Anxiety.

ER = Early Relaxation.
ES = Early Stress.

Forehead EMG Standard Deviation (EMGSD)

The ANOVA resulted in a significant main effect for treatment and no significant interactions. The Duncan's tests found that (f) relaxation was associated with significantly less variability for forehead EMG than any other treatment situation. Moreover, the (a) baseline situation was associated with significantly less variability for forehead EMG than either (e) recovery from stress or (g) recovery from relaxation.

Skin Conductance Level (SCLM)

The ANOVA resulted in a significant main effect for treatment and no significant interactions. The Duncan's tests found that a significantly higher mean skin conductance level was associated with (d) stress than with any other treatment situation, except (e) recovery from stress. Furthermore, (e) recovery from stress was associated with a higher mean skin conductance level than (b) standard manometry, (c) recovery from manometry, or (f) relaxation.

A significantly lower mean skin conductance level occurred during (a) baseline during any other treatment situation, except (f) relaxation.

A significantly higher mean skin conductance occurred during (e) recovery from stress than during (b) standard manometry, (c) recovery from manometry, (a) baseline or (f) relaxation.

Skin Conductance Level Standard Deviation (SCLSD)

The ANOVA resulted in no significant main effects, but in a significant three-way interaction: group by order by treatment. The Duncan's tests were performed to identify significant differences in skin conductance level standard deviation between group by order combinations during each treatment situation.

During (c) recovery from manometry, (d) stress, and (g) recovery from relaxation, the HA subjects in the Early Relaxation order had significantly greater skin conductance level variability than the LA subjects in the Early Relaxation order.

Mean Hand Temperature (TEMPM)

The ANOVA found no significant main effects but a significant two-way interaction: order by treatment. The Duncan's tests compared mean hand temperature between treatment situations within the Early Relaxation and within the Early Stress orders.

Early Relaxation order

A significantly higher mean hand temperature occurred during the (a) baseline situation than during any other treatment situation except (g) recovery from relaxation.

During (g) recovery from relaxation, mean hand temperature was significantly higher than during (b) standard manometry, (c) recovery from manometry, or (e) recovery from stress.

Early Stress order

A significantly higher mean hand temperature occurred during the (a) baseline situation than during any other treatment situation.

A significantly lower mean hand temperature occurred during (f) relaxation than during (c) recovery from manometry (or (a) baseline).

Hand Temperature Standard Deviation (TEMPSD)

The ANOVA resulted in no significant main effects, but in a significant three-way interaction: group by order by treatment. The Duncan's tests were performed to identify significant differences in hand temperature variability between group by order combinations during each treatment situation.

During (e) recovery from stress, the HA subjects had significantly greater hand temperature variability than the LA subjects in both the Early Relaxation and the Early Stress orders.

During (g) recovery from relaxation, the LA subjects had significantly greater hand temperature variability than the HA subjects in the Early Stress order.

Correlational Data

Table 8 displays the significant correlations (± .70 or greater) between esophageal and physiological variables. Significant correlations were found for some group by order

Table 8
Significant Esophageal-Physiological Correlations
for Group by Order Combinations

Group by Order			Esophageal[a]			
Early Relaxation			FrSw	InSw	FrSp	InSp
HA	Physiological[b]	EMGM	-.79(R)[c]			
		EMGSD	.79(RR)			
		SCLM			-.73(R) -.81(RM)	-.83(RM)
		SCLSD				-.79(RM)
		TEMPM	-.70(R)	.79(RR)	-.87(R) -.84(RR)	
		TEMPSD				
LA		EMGM				
		EMGSD				
		SCLM			-.82(R) -.88(S)	-.92(R)
		SCLSD	-.77(RR)			
		TEMPM				
		TEMPSD				
Early Stress						
HA	Physiological[b]	EMGM				
		EMGSD				
		SCLM	.83(RS) .78(RR)	-.72(RM)		
		SCLSD		.76(R) .97(RR)		
		TEMPM	-.74(R)		.72(S)	
LA		EMGM	.83(R)			-.71(S)
		EMGSD	.73(R)			
		SCLM				
		SCLSD			.72(RR)	-.97(RS)
		TEMPM				
		TEMPSD	-.89(S)			

Key for Table 8
Esophageal-Physiological Correlations

Note: Significant = $\pm$ .70 or above

[a]Esophageal Measures:

FrSp = Frequency of Spontaneous Contractions
InSp = Intensity of Spontaneous Contractions
FrSw = Frequency of Swallow-related Contractions
InSw = Intensity of Swallow-related Contractions

[b]Physiological Measures:

EMGM = Mean Forehead EMG
EMGSD = Forehead EMG Standard Deviation
SCLM = Mean Skin Conductance Level
SCLSD = Skin Conductance Level Standard Deviation
TEMPM = Mean Hand Temperature
TEMPSD = Hand Temperature Standard Deviation

[c]Treatment Situations

RM = Recovery from Manometry
S = Stress
RS = Recovery from Stress
R = Relaxation
RR = Recovery from Relaxation

combinations within one or more treatment situations, but not across all subjects or across all treatments situations.

HA and LA/ Early Relaxation

Significant negative correlations between the frequency of spontaneous contractions and mean skin conductance were found during (f) relaxation for both the HA and the LA groups in the Early Relaxation order.

For HA subjects in the Early Relaxation order, a significant negative correlation between the frequency of swallow-related contractions and mean hand temperature was found during (f) relaxation.

HA and LA/ Early Stress

For HA subjects in the Early Stress order as in the Early Relaxation order, a significant negative correlation between the frequency of swallow-related contractions and mean hand temperature was found during (f) relaxation.

DISCUSSION

Esophageal Variables

The most striking finding in the present study is that there were relatively few independent variables which significantly affected esophageal functioning. Furthermore, the significant differences that occurred were seldom in the predicted direction.

Changes During Stress

It had been predicted that stress, compared with the other treatment situations, would increase the frequency and intensity of spontaneous contractions and the intensity of swallow-related contractions. However, no increase in <u>intensity of spontaneous contractions</u> occurred during stress, compared with the other treatment situations, at any of the four esophageal sites monitored in the present study (Table 4). Moreover, no change in the <u>frequency of spontaneous contractions</u> occurred at two out of the four esophageal sites during the stress situation. At the other two sites, the upper-mid and the distal, recovery from relaxation was associated with significantly more spontaneous contractions than was the stress situation. Finally, no increase in <u>intensity of swallow-related contractions</u> occurred during stress, compared with the other treatment situations, at any of the four esophageal sites.

Changes During Relaxation

As a result of a lack of literature about the effects of relaxation on esophageal functioning, the present study did not formulate formal predictions about changes during relaxation. However, it was tentatively proposed that, if changes during relaxation occurred, those changes would take the form of decreases in the frequency and intensity of spontaneous contractions and in the intensity of swallow-related contractions. One of these variables, frequency of spontaneous contractions, showed a change in the expected direction but only in the proximal esophagus (Table 4). In the lower-mid esophagus, the frequency of spontaneous contractions during the relaxation situation did not differ significantly from the frequency during the stress situation or during recovery from manometry. Therefore, little support was provided for the expectation that relaxation would be associated with significantly fewer spontaneous contractions than any other treatment situation. Table 4 shows that for another variable, intensity of spontaneous contractions, no significant decreases occurred during relaxation at any esophageal site. Table 4 further shows that no decrease in a third variable, intensity of swallow-related contractions, occurred during the relaxation situation at any esophageal site. In summary, it appears that relaxation was associated with few decreases in any of the expected variables.

Comparison of Changes During Stress and During Relaxation

The present study had predicted that esophageal functioning during stress would differ significantly from that during relaxation. Contrary to this expectation, esophageal functioning during the two situations was remarkably similar for most esophageal variables at most esophageal sites. Table 9 compares esophageal variables during stress and during relaxation. Table 9 shows that no significant differences in the intensity of swallow-related contractions occurred during stress compared with relaxation at any esophageal site. For another variable, frequency of spontaneous contractions, no significant differences during stress compared with relaxation were noted at three out of four sites—the distal, the lower-mid, and the upper-mid. These three sites had been expected to show changes during stress. Based on a body of literature that described the lower two-thirds of the esophagus in symptomatic individuals to be more likely than the upper third to show various changes during stress, it had been expected that these sites might show an increased frequency of spontaneous contractions during stress in the present study. However, the present study found that an increased frequency occurred in the proximal esophagus, or the upper third, but not in the lower

Table 9
Comparison of Esophageal Variables During Stress and During Relaxation

Esophageal Site	N.S.D.	Stress>Relax'n	Relax'n>Stress
Proximal	InSp[a]	FrSp[b]	none
	InSw[c]	FrSw[d]	
Upper-Mid	FrSp	FrSw	none
	InSp		
	InSw		
Lower-Mid	FrSp (HA only)	FrSp (LA only)	none
	InSp	FrSw	
	InSw		
Distal	FrSp (LA only)	FrSw (LA only)	FrSp (HA only)
	InSp		
	FrSw		
	InSw		

[a]InSp = Intensity of spontaneous contractions
[b]FrSp = Frequency of spontaneous contractions
[c]InSw = Intensity of swallow-related contractions
[d]FrSw = Frequency of swallow-related contractions

two-thirds of the esophagus, contrary to the literature about individuals with diffuse esophageal spasm (Pope, in Sleisinger & Fordtran, 1978). For the variable, intensity of spontaneous contractions, Table 9 shows that no significant difference between stress and relaxation was found at any esophageal site. Therefore, almost no support for the predicted differences in esophageal variables during stress compared with relaxation was found.

The present study had advanced no specific prediction about the variable, frequency of swallow-related contractions, because of a lack of literature about the effects of either stress or relaxation on that variable. The present study's findings revealed some significant differences in the frequency of swallow-related contractions, depending on group, order, and site.

Comparisons of Esophageal Sites

Before proceeding further, it is important to consider evidence that different esophageal sites behave differently. The present study found significant differences in esophageal variables at different esophageal sites. As has been noted in the Introduction to this study, two different nerves provide esophageal motor innervation. Those nerves are the spinal accessory nerve for the high cervical portion of the esophagus and the vagus nerve for most of the rest of the esophageal musculature (Pope, in Sleisinger & Fordtran, 1978). The proximal esophageal site that was monitored in the present study corresponds roughly to the high cervical area, and the other three sites (upper-mid, lower-mid, and distal) correspond to the area referred to as innervated by the vagus nerve. Therefore, it is possible that the proximal site monitored in the present study might be expected to behave differently from the other three sites. Furthermore, the lower two-thirds of the esophagus, which would encompass the upper-mid, lower-mid, and distal sites in the present study, tends to develop motor disorders more frequently than the upper third, as previously mentioned (Pope, in Sleisinger & Fordtran, 1978). Therefore, it is reasonable to expect that stress would be more likely to be associated with increases in contractile frequency and intensity at the lower three esophageal sites than at the proximal site in the present study. In like manner, it would be reasonable to expect that, if relaxation resulted in any esophageal changes, those changes would be more likely to occur at the lower three sites than at the proximal site.

The present study found only partial confirmation for these predictions about differences among esophageal sites. In almost all instances where a significant difference between esophageal sites occurred, that difference was based on an interaction between site and group or between site and order. Even then, there were several instances in which significant differences between esophageal sites during stress were contrary to expectations. Specifically, for the HA group, the stress situation was associated with significantly fewer spontaneous contractions than was relaxation in the distal esophagus. There were no significant differences for this variable during stress and relaxation in the upper-mid and lower-mid esophagus (Table 9).

Results in the expected direction occurred for the LA group at only one esophageal site, the lower-mid. In the lower-mid esophagus, relaxation was associated with significantly fewer spontaneous contractions than was stress or recovery from relaxation, for the LA group. At the other three sites, no significant differences between stress and relaxation took place. In summary, relatively few significant differences in esophageal functioning during stress and during relaxation occurred. Thus, the significant difference that occurred in the expected direction was confined to one esophageal site, the lower-mid for one group alone, the LA group.

The variable, frequency of swallow-related contractions, provided the most evidence of decreases during relaxation, compared with stress and other treatment situations. In the proximal, upper-mid and lower-mid, esophagus, relaxation was associated with significantly fewer swallow-related contractions. The distal esophagus alone failed to demonstrate any significant change in frequency during relaxation. For the stress situation, none of the four esophageal sites provided evidence of significant change in the frequency of swallow-related contractions. Interpretation of these findings about the effects of relaxation on the frequency of swallow-related contractions must be tempered with the knowledge that subjects did not speak during the relaxation situation and, thus, swallowed less often during relaxation than during the stress situation or any other treatment situation. Since the frequency of swallow-related contractions is a function of the frequency of swallows, the most likely interpretation of the findings about the low frequency of swallow-related contractions during relaxation is that the frequency is related to instructions not to speak, rather than to any possible esophageal effects of the relaxation situation.

Comparison of HA and LA Groups

It had been predicted that the HA group would be more likely to show esophageal changes associated with stress and relaxation than would the LA group. Table 10 compares the HA and LA groups. These comparisons of the HA and LA groups reveal significant differences in the expected direction for one variable, frequency of spontaneous contractions. No significant differences between the two groups were found for two other variables—intensity of spontaneous contractions and intensity of swallow-related contractions.

Table 10
Comparisons of Esophageal Variables Between the HA and LA Groups

Esophageal Site	N.S.D.	HA>LA	LA>HA
Proximal	InSp FrSw (during stress only) InSw FrSp	none	FrSw (for all but stress)
Upper-Mid	InSp FrSw (during stress only) InSw FrSp	none	FrSw (for all but stress)
Lower-Mid	InSp FrSw (during stress only) InSw	FrSp (during relaxation only)	FrSw (for all but stress)
Distal	InSp FrSw (during stress only) InSw	FrSp (during relaxation, recovery from relaxation & recovery from manometry)	FrSw (for all but stress)

For the variable, frequency of spontaneous contractions, the HA group showed a significantly higher frequency than the LA group in the distal esophagus during three out of the five treatment situations: relaxation, recovery from manometry, and recovery from relaxation. In the lower-mid esophagus, the HA group also showed a higher frequency than the LA group, but only during the relaxation situation. No significant differences between the HA and LA groups occurred at any other esophageal site.

For the variable, frequency of swallow-related contractions, the present study had not formulated any specific predictions about differences between the HA and LA groups. However, the LA group was found to have significantly more swallow-related contractions at all four esophageal sites than the HA group in all treatment situations but stress.

Taken together, these findings about the frequency of spontaneous contractions and the frequency of swallow-related contractions indicate some significant differences between the HA and LA groups, but not entirely in the predicted direction. For example, the LA group showed a significantly lower frequency of spontaneous contractions during relaxation compared with other situations, whereas the HA group did not.

One possible interpretation of these comparisons of the HA and LA groups is that the LA group may have been characterized by generally lower esophageal reactivity than the HA group. Contrary to such an interpretation, it may be argued that the LA group had significantly more swallow-related contractions than the HA group in all but one treatment situation. This difference in the frequency of swallow-related contractions might suggest that the LA group has a more reactive esophagus than the HA group. As previously discussed, however, the frequency of swallow-related contractions, unlike the frequency of spontaneous contractions, is a function of the frequency of swallowing. Therefore, the LA group's higher frequency of swallow-related contractions indicates that LA subjects simply swallowed more often than HA subjects did in the same treatment situations. An examination of other esophageal variables reveals no significant difference between the HA and LA groups in the intensity of swallow-related or of spontaneous contractions. Consequently, it seems unlikely that the LA group had a generally less reactive esophagus than the HA group. Furthermore, Table 10 shows _no_ significant difference between the two groups during _stress_ on any of the esophageal variables. In summary, the relaxation situation seemed to have a differential effect on the LA and HA groups by significantly decreasing the frequency of spontaneous contractions at one esophageal site for the LA group, but not for the HA group. The stress situation did not differentiate between the two groups.

Comparison of Early Relaxation and Early Stress Orders

The present study did not formulate any hypotheses about the effect of order, i.e. stress prior to relaxation or relaxation prior to stress, on esophageal functioning. As previously indicated, no literature on the subject of the effects of order of stimuli presentation was found. It is interesting, therefore, that for two of the esophageal variables—frequency of spontaneous contractions and intensity of spontaneous contractions—no significant differences between the Early Relaxation and the Early Stress orders were found. For a third variable, frequency of swallow-related contractions, Table 11 shows a significant difference in favor of the Early Relaxation order in the proximal esophagus and no significant differences in the rest of the esophagus. Table 11 also shows that for the variable, intensity of swallow-related contractions, a consistent pattern of significant differences in favor of the Early Relaxation order was found at all four esophageal sites across all treatment situations. Order was the only main effect found to be significant in the ANOVA for the variable, intensity of swallow-related contractions; no significant interactions were found. These results suggest that the sequencing of stimuli in esophageal studies may determine one esophageal response parameter, the intensity of swallow-related contractions. As will be discussed in more detail later in this report, order also seemed to have a

Table 11
Comparisons of Esophageal Variables Between the Early Relaxation and Early Stress Orders

Esophageal Site	N.S.D.	E.R.[a]>E.S.[b]	E.S.>E.R.
Proximal	FrSp[c]	FrSw[d]	none
	InSp[e]	InSw[f]	
Upper-Mid	FrSp	InSw	none
	InSp		
	FrSw		
Lower-Mid	FrSp	InSw	none
	InSp		
	FrSw		
Distal	FrSp	InSw	none
	InSp		
	FrSw		

[a]E.R. = Early Relaxation
[b]E.S. = Early Stress
[c]FrSp = Frequency of spontaneous contractions
[d]FrSw = Frequency of swallow-related contractions
[e]InSp = Intensity of spontaneous contractions
[f]InSw = Intensity of swallow-related contractions

significant effect on mean hand temperature during one treatment situation, recovery from relaxation. Although the effect of order on mean hand temperature is not as broad in scope as the effect of order on intensity of swallow-related contractions, it provides further evidence for the possible importance of order as a variable in studies of esophageal response to stressful stimuli. As a cautionary note, however, it is necessary to point out that the significant difference in intensity of swallow-related contractions between subjects in the Early Relaxation order compared with the Early Stress order might have been the result of lack of comparability between the two sets of subjects that existed before the study. Although random assignment of subjects to the two orders occurred, it might not have controlled for the possibility of a significant difference between the two sets of subjects on the variable, intensity of swallow-related contractions. Some evidence for such a possibility can be seen in the significant difference in the intensity of swallow-related contractions that occurred in all situations, including recovery from manometry which preceded either stress or relaxation. Esophageal responses to order alone would be expected to occur following stress and relaxation, not preceding their presentation. Thus, the order of presentation of stress and relaxation may be an important variable in esophageal research, but pre-existing differences in intensity of swallow-related contractions between subjects in the Early Relaxation and the Early Stress orders may be responsible for the significant differences in that esophageal variable.

Comparisons of Recovery Situations with Relaxation, Stress and Standard Manometry

Comparisons of stress and relaxation and comparisons of HA and LA subjects have revealed relatively few significant differences on any esophageal variable. However, a comparison of treatment situations, other than a comparison solely of stress and relaxation, reveals unanticipated differences between the recovery situations, on the one hand, and the stress, relaxation, and standard manometry situations, on the other. (Esophageal data recorded during standard manometry has been excluded thus far in the present report, because of a lack comparability in the esophageal measurement procedures used during standard manometry compared with subsequent treatment situations, as previously discussed. However, discussion of data recorded during standard manometry has been included here for purposes of discussing the variable, intensity of spontaneous contractions, during recovery from manometry and standard manometry.) Specifically, for the variable, intensity of spontaneous contractions, all the recovery situations—recovery from manometry, recovery from stress and recovery from relaxation—were associated with similar intensities at each esophageal site. The intensities during the recovery situations were significantly higher than those during stress, during relaxation, or during standard manometry at each corresponding site. Furthermore, the variable, frequency of spontaneous contractions, increased significantly during recovery from relaxation compared with relaxation at one site, the lower-mid esophagus. A similar pattern was noted in the upper-mid esophagus where recovery from stress was associated with a significantly higher frequency of spontaneous contractions than was the stress situation.

A possible interpretation of these findings about the differences between the recovery situations and the other treatment situations is that there may be a delayed esophageal response to stress, relaxation, and standard manometry. The apparent delayed response seems to occur in the recovery situations following stress, relaxation, and standard manometry. The apparent delayed response takes the form of significant increases in frequency and intensity of spontaneous contractions during the recovery situations. It must be noted that if a response specific or unique to the relaxation situation had occurred during the recovery from relaxation situation, it would be expected that a significantly lower, not higher, frequency and intensity of spontaneous contractions would occur during recovery from relaxation than during relaxation. That did not occur. Thus, a surprising aspect of the apparent delayed response is that the esophagus did not seem to differentiate between stress, relaxation, and standard manometry. Instead, the esophagus responded similarly in frequency and intensity of spontaneous contractions without respect to the order in which they were presented or the group to which a subject belonged.

It might be argued that the reason for these similarities in esophageal response immediately following stress and relaxation is that the stress situation and the relaxation situation did not differ sufficiently from each other to affect esophageal functioning differentially. This line of argument would describe the stress situation as not sufficiently stressful and the relaxation situation as not sufficiently relaxing. If this were the case in the present study, then it would be expected that the esophagus had responded similarly to the two situations as a result of insufficient differences between the two.

However, analysis of several physiological variables, to be discussed in more detail later in this study, indicates that stress and relaxation had significantly different effects in the expected direction on mean skin conductance level and on EMG variability. Furthermore, the stress situation in the present study had been used in a previous study (Schiffer et al., 1976), which found that the administration of an intellectual achievement test was associated with heart rate changes consistent with stress. The choice of an intellectual achievement test as a stress situation for students was based on a number of studies that found a variety of physiological changes consistent with stress occurring during the administration of the task (O'Neil et al., Note 1; Dreyfuss & Czaczkes, 1959; Frankenhaeuser, VonWright, Collins, VonWright, Sedvall & Swahn, 1978). Therefore, it is unlikely that the stress situation in the present study was not sufficiently stressful.

As for the relaxation situation, the taped relaxation instructions used in the present study have been widely used with patients who have tension and anxiety complaints (Budzynski, 1974). Moreover, autogenic relaxation training is considered to be characteristic of the general class of relaxation training methods, since it has been found to have similar effects as other methods (Tarler-Benlolo, 1978). Nonetheless, it is possible that a brief, 15-minute exposure to taped relaxation instructions (during which 10 minutes of esophageal and physiological responses were recorded) might not have been sufficient to affect the frequency and intensity of spontaneous contractions. However, even if the relaxation situation were not sufficiently relaxing, it is unlikely that it would have an effect similar to those of the stress situation. Nonetheless, that is precisely what happened in the present study: the frequency and intensity of spontaneous contractions during recovery from relaxation increased, as they did during recovery from stress. Therefore, it appears that the esophagus not only responded in a delayed manner to stress, to relaxation, and to standard manometry but the esophagus also did not differentiate among the three stimulus situations in terms of the intensity or, to a somewhat lesser extent, the frequency of spontaneous contractions.

Before comparing the present study's findings with those of previous studies, it is appropriate to discuss in greater detail the present study's physiological findings.

Physiological Variables

The means and standard deviations of forehead EMG, hand temperature,and skin conductance were measured during seven situations during an experimental session: baseline, standard manometry, recovery from manometry, stress, recovery from stress, relaxation, and recovery from relaxation. The present study had predicted that stress would be associated with a higher mean EMG, a higher mean skin conductance and a lower mean hand temperature than would other situations. It was also proposed that relaxation would be associated with a lower mean EMG, a lower mean skin conductance, and a higher mean hand temperature than other situations. Compared with the other treatment stiuations, relaxation and stress were expected to be associated with less variability (smaller standard deviations) for each of the physiological variables.

Changes During Stress and Relaxation

In general, the present study's findings supported the predictions about the effects of stress and of relaxation on mean skin conductance. Support was also provided for the prediction about the effect of relaxation on EMG variability, but not for the effect of stress on that variable. No support was found for the predictions about mean EMG. Specifically, no significant differences in mean EMG were found in any of the comparisons of the seven treatment situations. Partial support was provided for the predictions about mean hand temperature, whereas no support was found for the predictions about hand temperature variability during stress and relaxation.

Mean skin conductance was significantly higher during stress than during relaxation, without respect to the group to which subjects belonged or the order in which stress and relaxation had been presented (Table 7). These findings, thus, provide support for the prediction that stress would be associated with higher mean skin conductance, compared with relaxation. The lowest mean skin conductance occurred during the baseline and relaxation situations. Therefore, it appears that relaxation had a significantly different physiological effect on mean skin conductance than did stress, and that these differences occurred in the predicted direction.

Other important differences emerged when mean hand temperature during various treatment situations was compared for subjects assigned to the Early Stress order and for subjects assigned to the Early Relaxation order. Within the Early Relaxation order, a significantly higher mean hand temperature occurred during recovery from relaxation than during any other situation except baseline (Table 7). Since hand temperature can be expected to respond in a delayed manner, as previously noted, it is possible that the increase found in the present study was a response to the relaxation situation, even though it occurred during recovery from relaxation. Within the Early Stress order, however, no such change occurred during recovery from relaxation or during relaxation. Instead, the highest mean hand temperature recorded within the Early Stress order occurred during baseline. Therefore, it appears that early presentation of the relaxation situation, i.e. presentation on relaxation prior to presentation of stress, had the predicted effect of mean hand temperature, but late presentation of the relaxation situation, i.e., relaxation following stress, did not significantly change mean hand temperature. On the basis of these data, it may seem that presentation of stress prior to relaxation prevented an expected rise in hand temperature following relaxation. Contrary to such a conclusion, however, Figure 9 shows a mean hand temperature increase during recovery from

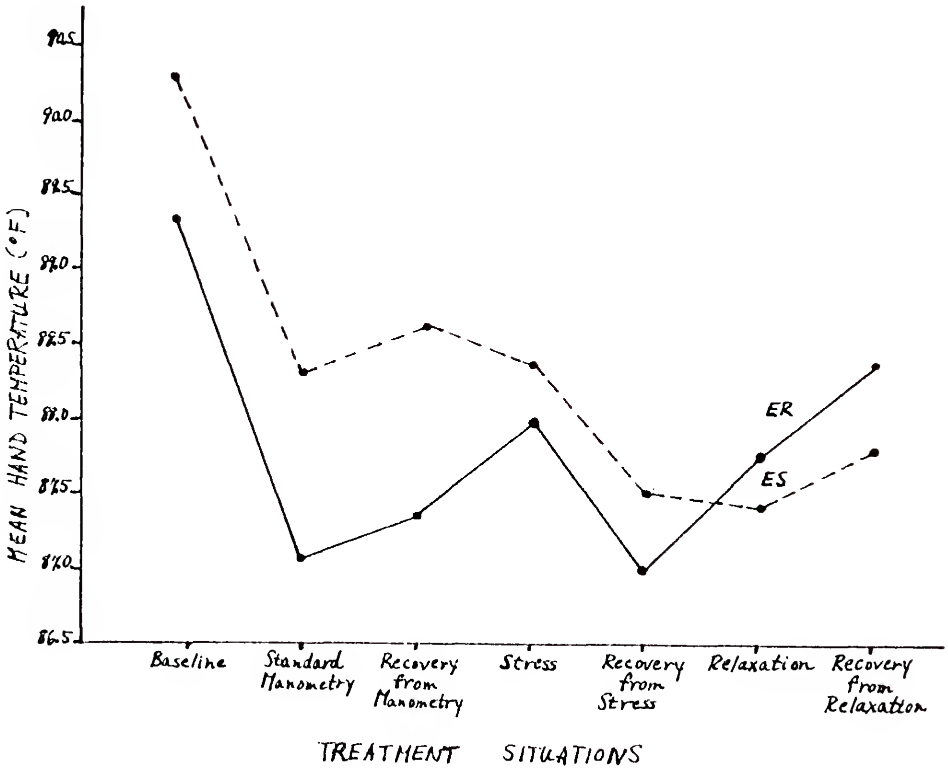

Figure 9. Graph of mean hand temperature for Early Relaxation and Early Stress subjects.

relaxation for Early Stress subjects as well as a more substantial increase during the same situation for Early Relaxation subjects. Thus, a temperature increase for Early Stress subjects occurred but was not sufficient to achieve statistical significance. If the experimental session had been prolonged beyond the recovery from relaxation situation, which was the final phase for Early Stress subjects, it is possible that the temperature increase might have reached significance. However, the present data do not provide enough information either to confirm or deny such a hypothesis.

Comparison of the HA and LA Groups

It had been expected that the HA group would be more likely than the LA group to demonstrate changes in forehead EMG, hand temperature, and skin conductance. Although some significant differences between the two groups occurred, the differences appear to be restricted in number and in importance. For example, the HA group showed significantly greater hand temperature variability than the LA group during recovery from stress, but not during any other situation. Contrary to the expected direction, the LA subjects within the Early Stress order showed significantly greater hand temperature variability than the HA subjects in the same order, but only during recovery from relaxation.

In summary, a few physiological differences between the HA and the LA subjects were found, but they were not entirely in the expected direction. The primary importance of the physiological findings in the present study is that they provide evidence of the differential effects of stress and relaxation on mean skin conductance, thus supporting the position that the stress situation was sufficiently stressful and the relaxation situation was sufficiently relaxing to affect biologic functioning.

Correlational Data

As a result of a lack of literature in the area of possible correlations between esophageal and physiological variables, the present study formulated no hypotheses about the nature or the extent of such correlations. The present study sought to determine whether significant correlations between the sets of variables might exist within the study's parameters. Table 8 shows that few consistent significant (± .70 or above) correlations between the two sets of variables occurred. As a rule, the significant correlations that occurred varied by group, by order, and by treatment situation. Only two somewhat consistent patterns emerged from the data, but even they are restricted by group and treatment situation. Specifically, the frequency of swallow-related contractions for the HA group, without respect to order, was significantly negatively correlated with mean hand temperature during the relaxation situation, but not during other situations. The other correlational pattern occurred in the Early Relaxation order where the frequency of spontaneous contractions was significantly negatively correlated with mean skin conductance during relaxation both for HA and LA subjects.

As previously discussed, the frequency of spontaneous contractions during relaxation was not significantly different, i.e. higher or lower, than most other situations at two of the four esophageal sites—the upper-mid and the distal. At the other two sites, relaxation was associated with significantly fewer spontaneous contractions that most other situations. Therefore, the significant negative correlation between frequency of spontaneous contractions and mean skin conductance during relaxation is not likely to be based on a higher frequency of spontaneous contractions during relaxation than during other situations. On the other hand, mean skin conductance during relaxation was significantly lower than during all other situations, except baseline. Therefore, the significant negative correlation between these two variables for the Early Relaxation order appears to be based on variation in one variable, mean skin conductance, but not in the other, frequency of spontaneous contractions, compared with other treatment situations. The same pattern seems to characterize the other significant correlation mentioned: a significant negative correlation between the frequency of swallow-related contractions and mean hand temperature for the HA group. As already discussed, mean hand temperature did not change significantly during relaxation, whereas the frequency of swallow-related contractions decreased significantly during relaxation, as compared with other situations. Therefore, the negative correlation between the two variables seems to derive from variation in frequency of swallow-related contractions during relaxation, and not from a corresponding variation in mean hand temperature during relaxation. Therefore, the significant correlations in the two instances described seem to be random events, rather than the result of some general relaxation effect on the variables in question. Thus, the correlational findings fail to provide important new information about the possible relationship between various bodily responses to stress and to relaxation in the present study.

Comparison of Present Study with Previous Studies

The present study developed from an interest in correcting the methodological flaws characteristic of most of the previous studies of the effects of stress on esophageal functioning. These previous studies were critically reviewed in the present study's Introduction. To review, an early study by Faulkner (1940b) found that stress seemed to exacerbate symptoms of patients with diffuse esophageal spasm. Other investigators (Rubin et al., 1962) studied the effects of stress on the esophageal functioning of healthy young adults and found stress to be associated with temporary dysrhythmic changes. However, these and other studies (Faulkner, 1940a; Wolf & Almy, 1949; Nagler & Spiro, 1961) were methodologically flawed by a lack of adequate prestress measurement of esophageal functioning and a lack of objective, standardized stressful stimuli.

The present study controlled for several variables that the other studies had not. For example, the present study made pre- and poststress measures of esophageal functioning and did so by means of a stationary catheter that allowed the monitoring of esophageal activity at four sites distributed over the length of the body of the esophagus. Furthermore, a standardized stressful stimulus situation, i.e. a taped intellectual achievement test, was used. Additionally, the present study controlled for the possibility that esophageal motility might change in response to any unusual or novel stimulus situation, not solely to a stressful situation. The present study controlled for this possibility by using contrasting stress and relaxation situations, during which esophageal functioning was measured. Finally, the present study controlled for the possibility that the order in which stress and relaxation are presented might have a differential effect on esophageal functioning. To control for this possibility, subjects were randomly assigned either to the Early Relaxation or to the Early Stress order.

In contrast with the findings of previous studies, the present study found little evidence of esophageal motility changes in young adults with no history of esophageal disorder. The present study's findings raise the possibility that the abnormalities in esophageal functioning shown by healthy young adults in previous studies might have been an artifact of the methodology used in those studies. Another important finding not reported in any of the previous studies is the present study's finding of a significant increase in intensity of spontaneous contractions during all three recovery situations and a significant increase in frequency of spontaneous contractions at several esophageal sites during two of the three recovery situations, compared with the frequency during stress or relaxation. These findings suggest that esophageal motility changes to certain stimuli may be delayed 10 minutes or more after the onset of stress or relaxation. An important facet of these findings is that the difference between the recovery situations, on the one hand, and stress or relaxation, on the other, was not dependent on the particular content of the stress or relaxation situations in the present study. In brief, the esophagus responded similarly in terms of intensity of spontaneous contractions and, to a somewhat lesser extent, frequency of spontaneous contractions during stress and relaxation.

Before discussing possible explanations for the present study's findings, it is important to discuss a very recent experimental study by Stacher et al. (1979) because it is an apparently well-designed and adequately-controlled study also conducted with healthy young adults. To review briefly, Stacher et al. (1979) concluded that nonpropulsive esophageal contractions form "part of the defense reaction of the healthy organism" (1979, p. 240). The same investigators rejected the possibility that nonpropulsive contractions represent part of an orienting response to acoustical stimuli because their subjects' esophageal responses occurred to "stimuli with intensities beyond the range to which the organism is able to orient" (Stacher et al., 1979, p. 240). Furthermore, it was felt that such esophageal responses were not part of an orienting response because there was "no sign of habituation" (Stacher et al., 1979, p. 240).

It is difficult to interpret precisely the meaning of the contention that most of the nonpropulsive esophageal contractions occurred to stimuli with intensities beyond the range to which the organism is able to orient. An examination of the data reported by Stacher et al. (1979) reveals that most of the esophageal responses in question followed the 95 decibel (dBA) tone rather than the 80 or 65 dBA tones. To describe briefly the study's design, 65, 80, and 95 dBA tones with signal content (the signal condition) and without signal content (the nonsignal condition) were used. In the nonsignal condition, the tones were invariably presented in the sequence 65-80-95, with an interstimulus interval of 30 seconds (Stacher et al., 1979). In the signal condition, three pairs of tones differing in intensity were presented, with an interstimulus interval of 30 seconds. The three pairs of tones in the signal condition were 65-80, 80-80, and 95-80 dBA tone sequences (Stacher et al., 1979). Thus, only one pair out of the three in the signal condition presented a higher intensity tone prior to a lower intensity tone, i.e. the 95-80 dBA tone sequence. Furthermore, the tone sequence used in the nonsignal condition never presented a higher intensity tone prior to a lower intensity one. To return to the interpretation of the contention made by Stacher et al. (1979) about high intensity acoustical stimuli, it will be assumed that their statement refers to data that the majority of the esophageal nonpropulsive contractions observed followed the 95 dBA tone, not the 80 or 65 dBA tones.

A possible flaw in the evidence on which Stacher et al. (1979) apparently based their statement is that the stimulus presentation sequence in the nonsignal condition was invariably 65-80-95 dBA. Thus, the study by Stacher et al. (1979) did not investigate the esophageal effects of different tone sequences in the nonsignal condition. However, it is possible that the increase in nonpropulsive contractions following the 65-80-95 dBA sequence would have occurred following any three-tone sequence, without respect to the dBA level of the third tone in the sequence. Such a possibility gains strength if the present study's findings about an increased frequency and intensity of spontaneous contractions following stress or relaxation are considered. The present study's findings suggest that changes in nonpropulsive contractions may occur as a delayed response to auditory stimuli (and perhaps to other kinds of stimuli not yet investigated). Further support for this viewpoint derives from an examination of data from the signal condition reported by Stacher et al. (1979). Specifically, the frequency and intensity of nonpropulsive contractions in response to a 80 dBA tone presented as the second tone of the sequence pair 80-80 dBA or of the sequence pair 95-80 dBA were "generally higher than (that) elicited by the 80 dBA tone presented as the first tone of a pair" (Stacher et al., 1979, p. 239). These findings provide further support for the viewpoint expressed in the present report that a delayed esophageal response to a tone early in the sequence, without respect to its dBA level, appeared only after the interval in which the final tone in the sequence was presented, erroneously leading to the conclusion expressed in Stacher et al. (1979) that the response was an immediate response to the 95 dBA tone. In brief, the nonpropulsive contractions may have been recorded following the 95 dBA tone but may not have been in response to that tone.

Of course, the possibility that changes in nonpropulsive esophageal contractions might have occurred in response to early, rather than to later, tones in a sequence does not by itself rule out the possibility that "acoustically evoked nonpropulsive esophageal contractions form part of the defense reaction of the healthy organism" (Stacher et al., 1979, p. 240). However, another aspect of the present study's findings makes such an interpretation unlikely. The present study found few significant differences in either the frequency or the intensity of spontaneous contractions during the stress situation compared with the relaxation situation, or between the recovery from stress situation and the recovery from relaxation situation. If, in fact, increases in the frequency and intensity of spontaneous contractions occur as part of a "defense reaction," it would be expected that such increases would occur during stress or, if delayed, during recovery from stress, but not during relaxation or recovery from relaxation. However, the present study found that increases occurred during both of these recovery situations, and that the increases were not significantly different during recovery from stress than they were during recovery from relaxation.

In summary, then, the data, if not the conclusions, reported by Stacher et al. (1979) are not inconsistent with the present study's interpretation that spontaneous contractions may occur as a response to auditory stimuli. Rather than a defense reaction, the nonpropulsive contractions reported both in the present study and in the study by Stacher et al. (1979) may be associated with attending behavior in an auditory stimulus situation. Without regard to content differences between the various stimulus situations used in the present study the esophagus may respond similarly, in terms of the frequency or the intensity of spontaneous contractions. The esophagus of healthy individuals appears not to respond uniquely to stress, but, instead, it appears to respond similarly to a variety of stimuli, without respect to the stimuli's potential threat as perceived either by the individual involved or by the investigators.

Conclusions

The present study's findings do not rule out the possibility that individuals with esophageal motor disorders, such as diffuse esophageal spasm, may show esophageal motility changes in response to stress. The present study investigated the effects of stress on esophageal functioning of healthy adults, as have all the reviewed studies of the effects of stress on the esophagus that have appeared in the literature during the past two decades (Nagler & Spiro, 1961; Rubin et al., 1962; Stacher et al., 1979). Three earlier studies investigated the effects of stress on individuals with known esophageal motor disorders (Faulkner, 1940a; Faulkner, 1940b; Wolf & Almy, 1949). Although these early studies concluded that stress exacerbates esophageal motor abnormalities in individuals with those disorders, a critical analysis of the studies' design revealed serious methodological flaws, as previously discussed in the introductory section of the present report. As a result, no well-controlled study has yet investigated the effects of stress on the esophageal functioning of individuals with known esophageal motor disorders.

Of course, it remains possible that the present study found so few significant differences in esophageal functioning during and immediately following stress compared with other situations because the sample was limited to 28 subjects. Perhaps if a larger sample had been studied, a greater number of significant differences might have been found. This criticism has been validly applied to many studies using a group design with a relatively small number of subjects. However, the present study's statistical comparisons of esophageal variables between various treatment situations frequently failed to come close to statistical significance despite a larger sample size than those used in the other esophageal studies reviewed in this report. For example, Stacher et al. (1979) used 16 subjects; Rubin et al. (1962) used 5 subjects; Nagler and Spiro (1961), 10 subjects; and Wolf and Almy (1949), 14 patients and 20 asymptomatic controls. Although it is possible that the present study might have found a greater number of significant differences if it had used a larger sample, it appears unlikely.

The present study's failure to find more than a relatively few significant differences, esophageal or physiological, between the HA and LA groups is not surprising. The two groups were selected on the basis of the subjects' responses to the STAI, a self-report anxiety measure. In the introductory section of this report, evidence for a possible relationship between self-report measures and various physiological measures of anxiety was reviewed, with the conclusion that there appears to be little correlation between the two types of anxiety measures. Although the HA and LA subjects in the present study answered the STAI questionnaire differently, their esophageal and physiological functioning showed relatively few significant differences. It is possible that a different subject selection method, such as selecting subjects solely on the basis of physiological measures, might have resulted in significant esophageal and physiological differences between the two groups during the study. For example, the high physiological reactors (or HA subjects) might have shown a different response during stress than the low reactors (or LA subjects). The present study's original plan to use a double screening procedure—a self-report measure and a physiological measure—was dropped in favor of a simpler, more feasible procedure using self-report alone. The double screening procedure would have required that many subjects be screened and few be chosen, because of the likelihood that most potential subjects would not meet both sets of screening criteria. The present study's difficulty with attracting large numbers of healthy young adults as subjects suggests that broad, minimally restrictive screening criteria be used in future studies with a similar research population. However, future studies that employ symptomatic individuals as subjects could avoid these difficulties because subjects with demonstrated esophageal motor disorders would probably not have to be further selected on the basis of anxiety measures. More importantly, it is time to resume, after a hiatus of nearly 20 years, investigations of the effects of stress (and of other kinds of stimuli) on symptomatic individuals.

It may at first seem surprising that the present study found so few significant correlations between esophageal and physiological variables. Although the study had not assumed the presence of a significant relationship between the two types of variables, knowledge that both types of variables are affected by the autonomic nervous system might suggest a significant correlation between esophageal and physiological variables. However, it appears from the present study's findings that the esophageal variables might have more substantial differences than similarities with the physiological variables. As one example of these differences, skin conductance changes occurred with a very brief latency, in contrast with the lengthy response latency that was characteristic of the esophageal variable, intensity of spontaneous contractions. Furthermore, EMG variability and mean skin conductance level decreased significantly during relaxation while no significant change occurred in frequency of spontaneous contractions during relaxation, except in the proximal esophagus. Consequently, it seems that a common relationship to the autonomic nervous system is not a sufficient basis for expecting significant correlations between the esophageal and physiological variables measured in the present study.

Furthermore, esophageal functioning may not be based on a unitary response system, but rather on a complex, differentiated system. Such a response system is affected by autonomic nervous system activity, but it is almost certainly affected by a variety of other variables such as hormonal activity, myogenic activity, and other neural activity, whose effects on the esophagus are not well-understood at the present time (Cohen & Snape, 1977).

In the future, researchers of the effects of stress on esophageal functioning would be better advised to investigate whether esophageal changes occur in individuals with, and in individuals without, esophageal motor disorders in response to a variety of stimuli, not just to stress. If changes do occur, further studies could identify the precise conditions under which change occurs and the stimuli which tend to increase or decrease esophageal responses. The present study, and previous studies reviewed in this report, have proceeded on the basis of assumptions or expectations that a certain set of stimuli, termed stressful by various investigators, affect esophageal functioning in specific ways. These assumptions or expectations may have narrowed the scope of inquiry prematurely so that the possible effects of other stimuli have not been systematically investigated.

Too little is known about esophageal functioning to proceed any further with ill-founded assumptions about the role of stress in esophageal motor disorders.

APPENDIX A
LETTER TO SUBJECTS

Dear

As you recall, on 23 October you filled out a Self-Evaluation-Questionnaire as part of a cooperative study between the Gastroenterology and Psychology Departments. The questionnaire was the preliminary screening phase of this research study. I have been informed by the Psychology Department that you qualify for the second phase of this study, but in keeping with the agreement you signed, your Self-Evaluation-Questionnaire score has not been revealed to me.

The second phase of this study involves four simultaneous physiologic measurements. The first three are non-invasive techniques (do not enter your body) in which small sensors are taped to the skin of your forehead and hand, and will measure muscle relaxation levels (EMG), sweating (skin conductance) and hand temperature. The fourth test is esophageal manometry, which will measure the pressure and coordination of contractions of your esophagus, utilizing a flexible polyvinyl tube which will be passed through your nose into your esophagus. This is a common clinical procedure and in no way will impair your ability to breathe, swallow or talk. In our experience, this procedure is painless and can be done with minimal discomfort. These tests are expected to take 2 hours, and subjects who complete the tests will be paid $50.

Attached is a detailed informed consent, explaining the entire procedure. Please read it carefully. Also enclosed is a postage-paid reply card for you to return to me with your response. If you check "Yes" or "Maybe," I will call you to set up an appointment and/or answer any questions. Regardless of your response, you are under no obligation to complete phase two of this study. Please return the card with your reply as promptly as possible, as we need to complete this study during November. Scheduling will be on a first-reply-first-schedule basis. If you lose your reply card, please call me at 324-4455, ext. 3527 or 3691.

Also, information obtained in this study, including your Self-Evaluation-Questionnaire score and data from phase two, will not be identified as pertaining to you by name without your expressed permission.

Thank you. Your cooperation is greatly appreciated.

Sincerely yours,

APPENDIX B
TRANSCRIPT OF INTELLECTUAL ACHIEVEMENT TEST

Question number 1: Complete the following sequence: 2, 7, 12, 17, ___

Question number 2: If X is greater than Y and Y is greater than Z, then X is ______ than Z?

Question number 3: Wheel is to car as _______ is to sleigh?

Question number 4: Which is more, 10 or 2 times 4.5?

Question number 5: Music and sculpture are both _______?

Question number 6: Fill in the blank. Far is to near as tall is to _______.

Question number 7: Which word does not have the same meaning as other words: eminent, vulnerable, distinguished, outstanding?

Question number 8: Repeat backwards: 1, 5, 7, 9.

Question number 9: If Y is greater than X and Z is less than X, then Z is _____ than Y.

Question number 10: H_2O is to water as CO_2 is to _______?

Question number 11: Who wrote the novel A Fable?

Question number 12: Kite is to fly as boat is to _______?

Question number 13: 2/3 of 7 is _______?

Question number 14: A man earns $75 a week; his wife earns $20 a week. How much do they earn together in a week?

Question number 15: Who wrote Paradise Lost?

Question number 16: What state borders Colorado to the northeast?

Question number 17: A prerogative is a _______?

Question number 18: Who said "The ballot is stronger than the bullet."

Question number 19: Complete the following sequence: 7, 9, 13, 19, ___.

Question number 20: Who wrote the Iliad?

Question number 21: Which of the following words have the same meaning: vascillate, cultivate, hesitate, and matriculate.

Question number 22: How are the numbers 16 and 121 similar?

Question number 23: If Bob had 1/7 of Mary's amount and Mary had 32, then how much did Bob have?

Question number 24: The biological function of the fruit of a plant is usually ________.

Question number 25: Freedom and justice are both _______?

Question number 26: Twenty-five coins consisting of nickels and dimes equals two dollars. How many of each kind are there?

Question number 27: Which two words have similar meanings: greed, stupidity, lavishness, and cupidity?

Question number 28: The probability of A winning a race is 1/3, and the probability of B winning is 1/4. What is the probability of neither winning?

Question number 29: James Ford Rhodes is a famous ________?

Question number 30: Home is to family as school is to ________?

Question number 31: In what field did Arthur D. Hershy win the Nobel Prize?

Question number 32: If John had 3 times as many dollars as Bill, but then gave 1/2 his dollars to Bill, then Bill would have how many times his original amount?

Question number 33: The intensity of the heat of an object is referred to as its _______?

Question number 34: Complete the following sequence: C, E, H, L, ___.

Question number 35: If Y is greater than X divided by 2, and Z is less than X divided by 2Y, then Z must be _______.

APPENDIX C
ESOPHAGEAL TRACINGS: CHANNELS 1-4

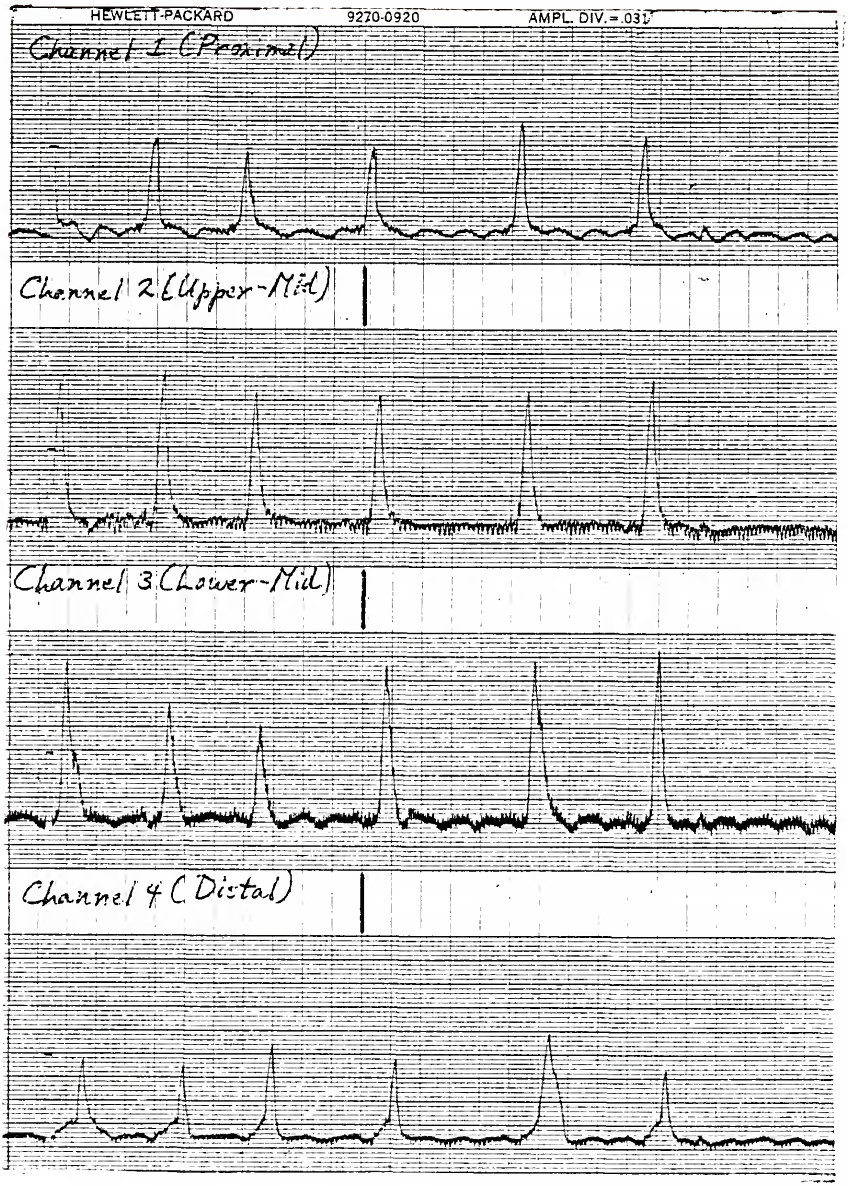

Figure 10. Esophageal tracings: Channels 1-4.

APPENDIX D
ESOPHAGEAL TRACINGS: CHANNELS 5-7

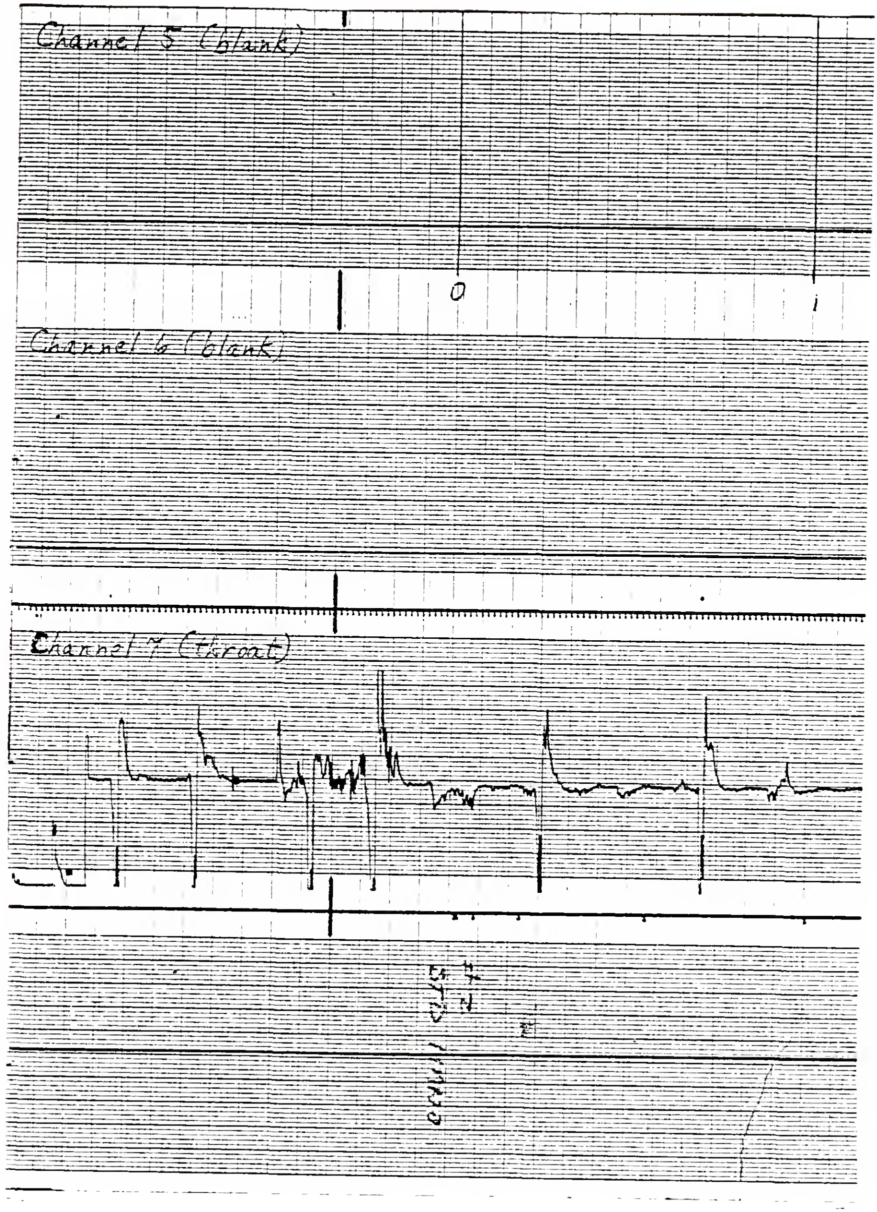

Figure 11. Esophageal tracings: Channels 5-7.

APPENDIX E
INFORMED CONSENT FORM

THE EFFECT OF STRESS ON ESOPHAGEAL FUNCTION IN HUMANS

Purpose: We are attempting to determine whether a defined stress can alter the normal functioning of the esophagus. There are some suggestions that certain diseases of the esophagus are made worse during periods of stress. If it can be demonstrated that stress or, more specifically, a specific type of stress is capable of provoking abnormal esophageal function, then it might be possible to condition the patient against a stress stimulus and modify stress-related esophageal symptoms.

Procedures: The first phase of this study in which you are being asked to participate will evaluate the influence of stress on the function of your esophagus. Because it is important for us to know whether or not you are anxious, a factor which may make your esophagus more sensitive to stress, you will be asked to complete a self-report questionnaire which will require less than thirty minutes. The second phase of this study involves EMG assessment of general muscle relaxation levels while you are at rest for 30 to 60 minutes. Several small sensors will be placed on the skin over the muscles of your forehead and hand with EKG paste and electrical activity will be recorded from the muscles in these regions. The third phase of this voluntary study involves the technique of esophageal manometry. Pressure measurements within your esophagus will be obtained by passing a lubricated 1/4 inch diameter tube through your nose into your stomach, connecting the tubes to pressure sensitive gauges and transmitting pressures to an electronic recording device for permanent recordings of pressure wave patterns in your esophagus. To study the entire length of the esophagus, the tube must be partially withdrawn, and reinserted by gently pushing the tube back into your stomach. During the esophageal manometry (esophageal pressure recording) you will be exposed alternately to pleasant (music) and unpleasant (timed testing) stimuli. Pressure measurements and electrical measurements will be recorded simultaneously. During the pressure measurements you will be asked to perform swallows of dry or wet material and may be asked to hold your breath for 15-20 seconds. The entire procedure is not expected to last more than one hour. Fluoroscopy and/or X-rays will not be employed.

Risks: Occasionally, there can be difficulty passing the tube through the nostrils, and this can cause discomfort and, sometimes, a mild nose bleed. The accumulation of secretions in the back of your throat during the esophageal studies could result remotely in aspiration or emptying into the lungs, which could cause coughing. Gagging occurs transiently when the tube enters the throat from the nose. None of these effects are of lengthy duration and do not persist. A minor throat "irritation" responds to salt water gargling.

Benefits: No benefit can be promised you from your participation in this study. The benefit described under PURPOSE may accrue and afford a new form of therapy for certain forms of esophageal disease. There are not felt to be any suitable alternatives which will allow us to obtain the information we desire.

Your records and results will not be identified as pertaining to you specifically without your expressed permission.

You may ask and will receive answers to any questions during the course of the study. You are free to withdraw your consent at any time during the study and discontinue participation with no prejudice to your further case.

Eligible veterans who participate in clinical, biomedical or behavioral research and suffer injury as a result of participation in such research, may be entitled to indemnity compensation or further treatment in the same manner as if such injury were service connected. Further, eligible veterans may, if negligence is found on the part of the government or its agents, be entitled to renumeration under the Federal Torts Claim Act.

Non-eligible veterans and non-veterans who participate in clinical, biomedical or behavioral research and suffer an injury, may be entitled to medical care and treatment on a humanitarian emergency basis at VA expense for the period of the emergency. Any indemnity compensation for a non-eligible veteran or a non-veteran is limited to situations where negligence occurred and would be controlled by the provisions of the Federal Torts Claim Act.

Any further questions concerning your rights to indemnity compensation and further treatment as a result of your participation in this study can be answered by the Chief of Medical Administration or his designee on ext. 3051.

DATE ____________________ SUBJECT ____________________

WITNESS ____________________

PRINCIPAL INVESTIGATOR ____________________

PRINCIPAL INVESTIGATOR TELEPHONE: (DAY) ______________

(NIGHT) ______________

APPENDIX F
SCORED ESOPHAGEAL TRACINGS

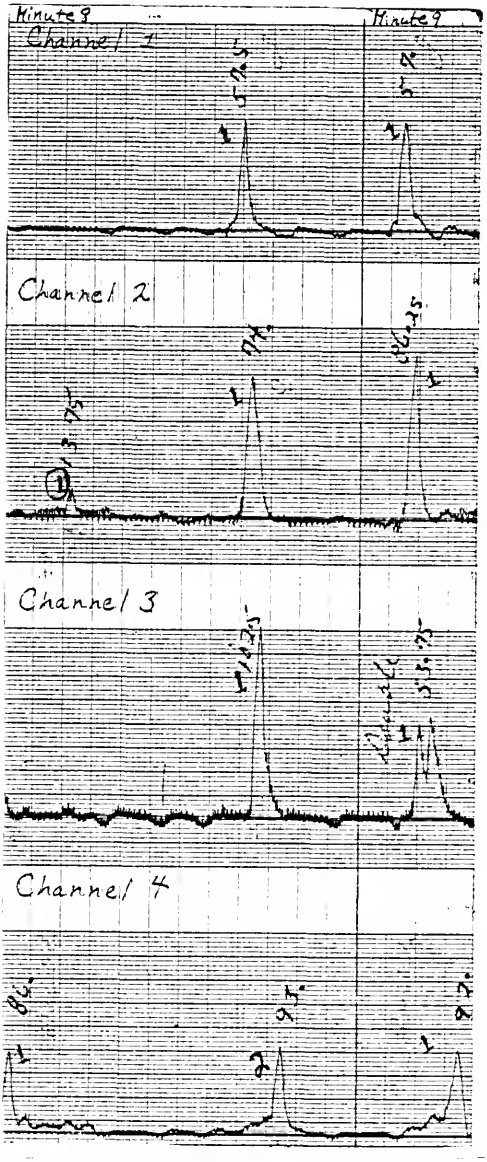

Figure 12. Scored esophageal tracings.

APPENDIX G
TABLES 12 AND 13

APPENDIX G

Table 12

Esophageal Variable Means and Standard Deviations by Treatment Situation, Site, and Group by Order Combinations

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\bar{X}$	S.D.
		Standard Manometry				
FrSw	Px	HA	ES	7	15.000	6.377
InSw					68.571	15.179
FrSp					3.142	3.387
InSp					13.571	15.452
FrSw	Px	LA	ES	7	13.428	6.241
InSw					89.650	26.370
FrSp					2.000	2.828
InSp					19.114	25.901
FrSw	Px	HA	ER	7	19.285	5.498
InSw					83.571	18.249
FrSp					3.000	3.000
InSp					22.857	26.385
FrSw	Px	LA	ER	7	17.000	6.757
InSw					86.514	26.759
FrSp					1.571	1.618
InSp					39.607	22.954
FrSw	Um	HA	ES	7	25.857	11.186
InSw					75.750	20.514
FrSp					6.428	5.223
InSp					26.035	21.311
FrSw	Um	LA	ES	7	21.142	8.315
InSw					83.214	13.728
FrSp					4.285	4.785
InSp					24.828	16.210
FrSw	Um	HA	ER	7	24.142	7.335
InSw					106.964	18.049
FrSp					2.285	1.889
InSp					23.035	23.671
FrSw	Um	LA	ER	7	21.857	4.670
InSw					84.764	21.569
FrSp					3.285	4.070
InSp					47.042	37.865

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
FrSw	Lm	HA	ES	7	23.714	10.995
InSw					84.428	13.736
FrSp					6.285	5.219
InSp					26.642	16.235
FrSw	Lm	LA	ES	7	24.000	5.446
InSw					84.650	15.668
FrSp					4.000	4.434
InSp					23.785	22.098
FrSw	Lm	HA	ER	7	22.142	8.375
InSw					126.571	49.632
FrSp					3.142	3.023
InSp					15.892	12.220
FrSw	Lm	LA	ER	7	22.857	6.229
InSw					86.728	12.982
FrSp					4.428	4.035
InSp					25.250	22.361
FrSw	Dl	HA	ES	7	17.142	9.352
InSw					80.750	18.251
FrSp					2.857	3.436
InSp					20.321	20.643
FrSw	Dl	LA	ES	7	16.857	6.644
InSw					85.185	19.470
FrSp					3.142	4.140
InSp					20.714	22.659
FrSw	Dl	HA	ER	7	13.571	4.894
InSw					110.500	33.102
FrSp					2.428	2.760
InSp					18.292	22.467
FrSw	Dl	LA	ER	7	17.571	6.553
InSw					106.142	18.741
FrSp					3.571	2.992
InSp					25.357	13.894

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
		Recovery from Manometry				
FrSw	Px	HA	ES	7	22.285	6.264
InSw					67.071	18.160
FrSp					5.285	2.288
InSp					24.178	14.677
FrSw	Px	LA	ES	7	26.285	6.824
InSw					78.571	19.796
FrSp					5.285	4.990
InSp					30.464	22.247
FrSw	Px	HA	ER	7	25.000	8.406
InSw					77.714	15.292
FrSp					12.000	12.328
InSp					41.464	27.715
FrSw	Px	LA	ER	7	28.571	11.028
InSw					90.085	41.507
FrSp					4.000	4.320
InSp					43.214	32.785
FrSw	Um	HA	ES	7	21.857	6.362
InSw					69.714	18.253
FrSp					10.714	8.420
InSp					30.321	14.637
FrSw	Um	LA	ES	7	26.285	6.676
InSw					75.500	29.640
FrSp					8.285	9.655
InSp					33.178	23.302
FrSw	Um	HA	ER	7	23.857	8.071
InSw					91.714	29.230
FrSp					13.285	12.365
InSp					31.571	15.417
FrSw	Um	LA	ER	7	27.571	9.431
InSw					82.750	26.657
FrSp					4.571	3.457
InSp					23.721	14.624
FrSw	Lm	HA	ES	7	21.714	6.317
InSw					87.357	13.758
FrSp					11.714	10.980
InSp					31.964	24.768

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
FrSw	Lm	LA	ES	7	26.428	6.629
InSw					91.607	14.246
FrSp					4.428	4.685
InSp					26.250	21.602
FrSw	Lm	HA	ER	7	24.714	5.851
InSw					142.642	68.867
FrSp					5.857	4.140
InSp					18.750	14.807
FrSw	Lm	LA	ER	7	26.142	8.414
InSw					94.007	18.968
FrSp					6.000	4.396
InSp					30.650	12.415
FrSw	Dl	HA	ES	7	22.857	6.841
InSw					126.071	54.595
FrSp					10.000	6.137
InSp					44.785	27.629
FrSw	Dl	LA	ES	7	26.285	7.476
InSw					101.714	14.611
FrSp					5.285	6.183
InSp					39.357	37.668
FrSw	Dl	HA	ER	7	24.000	8.000
InSw					107.678	32.051
FrSp					8.571	5.255
InSp					42.678	34.327
FrSw	Dl	LA	ER	7	27.142	9.856
InSw					122.257	23.693
FrSp					5.285	2.627
InSp					32.035	10.350

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
			Stress			
FrSw	Px	HA	ES	7	17.428	5.255
InSw					65.054	24.479
FrSp					6.571	6.187
InSp					20.321	10.907
FrSw	Px	LA	ES	7	16.428	3.690
InSw					74.285	15.709
FrSp					4.714	5.376
InSp					19.464	20.397
FrSw	Px	HA	ER	7	18.857	7.448
InSw					74.768	14.118
FrSp					8.142	9.856
InSp					19.964	18.399
FrSw	Px	LA	ER	7	22.285	11.382
InSw					72.178	26.023
FrSp					9.000	13.453
InSp					22.142	22.041
FrSw	Um	HA	ES	7	17.428	5.623
InSw					68.964	18.037
FrSp					7.714	8.220
InSp					14.571	9.488
FrSw	Um	LA	ES	7	16.714	3.039
InSw					72.542	33.252
FrSp					5.428	9.180
InSp					16.928	12.879
FrSw	Um	HA	ER	7	18.571	7.502
InSw					90.071	29.285
FrSp					5.714	8.901
InSp					11.785	8.929
FrSw	Um	LA	ER	7	22.000	9.882
InSw					87.214	24.563
FrSp					1.428	2.070
InSp					18.928	15.801
FrSw	Lm	HA	ES	7	16.857	5.014
InSw					101.750	16.726
FrSp					11.714	11.353
InSp					24.821	21.415

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
FrSw	Lm	LA	ES	7	17.285	3.401
InSw					97.650	20.949
FrSp					2.857	4.059
InSp					16.607	16.966
FrSw	Lm	HA	ER	7	18.142	6.644
InSw					122.285	32.817
FrSp					3.571	3.505
InSp					22.785	19.819
FrSw	Lm	LA	ER	7	21.000	9.018
InSw					94.464	17.763
FrSp					5.857	6.618
InSp					37.285	19.239
FrSw	Dl	HA	ES	7	17.142	4.740
InSw					129.964	57.913
FrSp					6.142	8.629
InSp					27.178	39.474
FrSw	Dl	LA	ES	7	13.285	5.618
InSw					92.500	24.632
FrSp					4.857	5.080
InSp					25.392	21.194
FrSw	Dl	HA	ER	7	17.714	6.575
InSw					153.500	47.023
FrSp					3.571	3.408
InSp					31.357	29.685
FrSw	Dl	LA	ER	7	14.857	6.202
InSw					130.785	20.491
FrSp					4.428	6.294
InSp					24.250	13.446

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
		Recovery from Stress				
FrSw	Px	HA	ES	7	17.857	7.312
InSw					66.857	22.129
FrSp					6.000	5.416
InSp					22.750	21.595
FrSw	Px	LA	ES	7	21.428	4.995
InSw					76.785	19.867
FrSp					3.285	2.497
InSp					36.964	35.938
FrSw	Px	HA	ER	7	21.285	5.154
InSw					104.500	32.287
FrSp					6.142	4.740
InSp					43.392	21.886
FrSw	Px	LA	ER	7	25.285	11.279
InSw					77.750	23.616
FrSp					15.714	18.172
InSp					35.892	24.974
FrSw	Um	HA	ES	7	17.000	6.531
InSw					71.071	18.433
FrSp					14.571	10.659
InSp					28.750	18.427
FrSw	Um	LA	ES	7	20.857	5.273
InSw					80.000	33.400
FrSp					10.142	10.447
InSp					43.714	22.731
FrSw	Um	HA	ER	7	20.571	5.623
InSw					91.214	28.670
FrSp					11.571	10.260
InSp					37.142	16.920
FrSw	Um	LA	ER	7	24.142	8.668
InSw					84.107	15.507
FrSp					7.000	7.593
InSp					29.678	12.770
FrSw	Lm	HA	ES	7	17.857	6.938
InSw					91.535	14.009
FrSp					14.571	10.596
InSp					30.035	18.102

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
FrSw	Lm	LA	ES	7	20.571	5.159
InSw					95.142	27.013
FrSp					6.714	5.707
InSp					29.107	19.561
FrSw	Lm	HA	ER	7	20.714	4.956
InSw					131.714	44.141
FrSp					7.428	5.740
InSp					43.571	20.506
FrSw	Lm	LA	ER	7	22.428	7.502
InSw					93.892	20.403
FrSp					11.285	11.146
InSw					40.171	26.899
FrSw	Dl	HA	ES	7	18.285	8.035
InSw					116.535	50.249
FrSp					10.571	8.343
InSp					40.285	54.012
FrSw	Dl	LA	ES	7	21.571	5.593
InSw					120.642	50.323
FrSp					7.285	5.219
InSp					48.857	27.148
FrSw	Dl	HA	ER	7	19.714	6.290
InSw					100.107	26.138
FrSp					6.428	6.451
InSp					27.714	23.443
FrSw	Dl	LA	ER	7	26.285	10.950
InSw					124.392	24.076
FrSp					6.142	4.740
InSp					48.857	20.985

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\overline{X}$	S.D.
			Relaxation			
FrSw	Px	HA	ES	7	13.571	3.866
InSw					70.892	23.862
FrSp					3.142	3.670
InSp					11.214	12.456
FrSw	Px	LA	ES	7	14.000	5.416
InSw					73.392	20.535
FrSp					0.714	0.951
InSp					7.500	12.808
FrSw	Px	HA	ER	7	13.428	2.819
InSw					76.607	19.103
FrSp					1.285	1.380
InSp					22.535	30.540
FrSw	Px	LA	ER	7	14.714	6.183
InSw					77.614	32.037
FrSp					1.142	1.069
InSp					18.892	18.496
FrSw	Um	HA	ES	7	13.428	4.503
InSw					64.821	17.816
FrSp					13.857	14.040
InSp					25.321	20.137
FrSw	Um	LA	ES	7	13.571	5.623
InSw					73.321	32.355
FrSp					4.714	12.037
InSp					8.392	14.338
FrSw	Um	HA	ER	7	13.428	2.439
InSw					89.464	32.128
FrSp					6.714	8.440
InSp					18.714	11.655
FrSw	Um	LA	ER	7	14.571	5.996
InSw					84.142	23.742
FrSp					1.714	3.302
InSp					10.607	13.566
FrSw	Lm	HA	ES	7	13.000	4.082
InSw					86.214	38.253
FrSp					11.142	10.605
InSp					27.642	16.228

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\bar{X}$	S.D.
FrSw	Lm	LA	ES	7	13.714	4.889
InSw					87.857	21.874
FrSp					1.428	2.299
InSp					9.285	11.722
FrSw	Lm	HA	ER	7	13.285	2.214
InSw					117.500	27.041
FrSp					5.142	5.241
InSp					19.971	18.658
FrSw	Lm	LA	ER	7	14.285	5.765
InSw					91.078	13.067
FrSp					3.000	2.886
InSp					19.714	10.213
FrSw	Dl	HA	ES	7	12.714	4.347
InSw					111.035	53.551
FrSp					13.714	13.996
InSp					35.785	27.502
FrSw	Dl	LA	ES	7	17.142	3.579
InSw					103.357	19.712
FrSp					2.714	3.946
InSp					17.107	24.770
FrSw	Dl	HA	ER	7	12.428	1.511
InSw					137.000	27.478
FrSp					9.142	10.056
InSp					36.892	18.006
FrSw	Dl	LA	ER	7	21.142	8.532
InSw					108.757	22.877
FrSp					3.000	4.041
InSp					28.785	19.769

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\bar{X}$	S.D.
			Recovery from Relaxation			
FrSw	Px	HA	ES	7	17.142	4.845
InSw					69.714	21.965
FrSp					6.714	3.450
InSp					33.500	35.849
FrSw	Px	LA	ES	7	19.142	6.121
InSw					78.392	21.086
FrSp					4.142	4.140
InSp					26.785	21.321
FrSw	Px	HA	ER	7	19.714	4.889
InSw					88.750	21.866
FrSp					8.714	7.454
InSp					42.321	31.061
FrSw	Px	LA	ER	7	26.571	11.645
InSw					81.971	26.481
FrSp					9.000	15.132
InSp					30.585	29.202
FrSw	Um	HA	ES	7	16.857	5.080
InSw					70.678	16.012
FrSp					19.428	13.464
InSp					30.107	14.432
FrSw	Um	LA	ES	7	19.571	6.320
InSw					82.938	34.269
FrSp					7.428	8.580
InSp					35.714	29.010
FrSw	Um	HA	ER	7	20.000	4.898
InSw					90.535	31.753
FrSp					12.428	8.753
InSp					32.678	12.268
FrSw	Um	LA	ER	7	26.285	10.965
InSw					81.757	18.743
FrSp					5.000	4.898
InSp					34.714	28.670
FrSw	Lm	HA	ES	7	17.857	5.843
InSw					90.214	19.608
FrSp					13.714	12.134
InSp					31.678	12.638

Table 12-(Continued)

Variable[a]	Site[b]	Group[c]	Order[d]	N	$\bar{X}$	S.D.
FrSw	Lm	LA	ES	7	19.285	6.499
InSw					93.928	30.168
FrSp					5.571	4.429
InSp					37.678	35.542
FrSw	Lm	HA	ER	7	21.000	3.415
InSw					115.678	32.591
FrSp					10.428	5.968
InSp					32.857	15.439
FrSw	Lm	LA	ER	7	26.000	11.430
InSw					92.714	18.417
FrSp					8.000	6.879
InSp					37.828	28.731
FrSw	Dl	HA	ES	7	16.714	5.822
InSw					121.321	46.979
FrSp					12.714	8.459
InSp					48.500	26.589
FrSw	Dl	LA	ES	7	20.714	4.956
InSw					100.178	30.524
FrSp					7.285	5.437
InSp					32.071	19.515
FrSw	Dl	HA	ER	7	18.714	4.386
InSw					141.785	34.752
FrSp					11.142	4.879
InSp					47.357	31.782
FrSw	Dl	LA	ER	7	23.285	7.040
InSw					115.642	26.809
FrSp					7.000	6.271
InSp					33.071	15.830

Key

[a]Variable:
- FrSw = Frequency of Swallow-related contractions
- InSw = Intensity of Swallow-related contractions
- FrSp = Frequency of Spontaneous contractions
- InSp = Intensity of Spontaneous contractions

[b]Esophageal Site:
- Px = Proximal
- Um = Upper-mid
- Lm = Lower-mid
- Dl = Distal

[c]Group:
- HA = High Anxiety
- LA = Low Anxiety

[d]Order:
- ER = Early Relaxation
- ES = Early Stress

APPENDIX G

Table 13

Physiological Variable Means by
Treatment Situation and Group By Order Combinations

Variable[a]	Group[b]	Order[c]	N	$\overline{X}$
		Baseline		
EMGM	HA	ES	7	2.857
EMGSD				1.552
SCLM				15.760
SCLSD				2.964
TEMPM				90.665
TEMPSD				0.208
EMGM	LA	ES	7	3.777
EMGSD				2.431
SCLM				13.960
SCLSD				2.191
TEMPM				89.831
TEMPSD				0.497
EMGM	HA	ER	7	3.895
EMGSD				2.261
SCLM				21.871
SCLSD				2.857
TEMPM				89.530
TEMPSD				0.705
EMGM	LA	ER	7	2.518
EMGSD				1.477
SCLM				11.572
SCLSD				2.031
TEMPM				88.937
TEMPSD				0.325

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\bar{X}$
		Standard Manometry		
EMGM	HA	ES	7	3.348
EMGSD				1.671
SCLM				17.131
SCLSD				1.721
TEMPM				88.504
TEMPSD				0.332
EMGM	LA	ES	7	2.008
EMGSD				1.937
SCLM				14.834
SCLSD				1.628
TEMPM				87.901
TEMPSD				0.388
EMGM	HA	ER	7	3.820
EMGSD				2.191
SCLM				26.627
SCLSD				1.878
TEMPM				86.748
TEMPSD				0.488
EMGM	LA	ER	7	3.338
EMGSD				3.015
SCLM				14.402
SCLSD				1.867
TEMPM				87.420
TEMPSD				0.320

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\overline{X}$
		Recovery from Manometry		
EMGM	HA	ES	7	2.487
EMGSD				1.675
SCLM				17.620
SCLSD				1.892
TEMPM				88.617
TEMPSD				0.387
EMGM	LA	ES	7	3.268
EMGSD				2.538
SCLM				18.154
SCLSD				2.038
TEMPM				88.497
TEMPSD				0.365
EMGM	HA	ER	7	3.042
EMGSD				2.205
SCLM				26.502
SCLSD				2.464
TEMPM				87.505
TEMPSD				0.434
EMGM	LA	ER	7	2.921
EMGSD				2.438
SCLM				14.001
SCLSD				1.275
TEMPM				86.917
TEMPSD				0.402

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\bar{X}$
		Stress		
EMGM	HA	ES	7	3.388
EMGSD				1.911
SCLM				20.421
SCLSD				1.297
TEMPM				88.262
TEMPSD				0.335
EMGM	LA	ES	7	2.300
EMGSD				2.037
SCLM				21.672
SCLSD				1.497
TEMPM				88.347
TEMPSD				0.300
EMGM	HA	ER	7	3.815
EMGSD				2.507
SCLM				30.882
SCLSD				2.184
TEMPM				88.284
TEMPSD				0.412
EMGM	LA	ER	7	2.924
EMGSD				2.488
SCLM				18.850
SCLSD				1.315
TEMPM				87.370
TEMPSD				0.468

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\bar{X}$
		Recovery from Stress		
EMGM	HA	ES	7	3.247
EMGSD				2.315
SCLM				19.180
SCLSD				1.914
TEMPM				87.625
TEMPSD				0.497
EMGM	LA	ES	7	2.788
EMGSD				2.677
SCLM				18.542
SCLSD				2.237
TEMPM				87.272
TEMPSD				0.255
EMGM	HA	ER	7	3.385
EMGSD				2.752
SCLM				29.597
SCLSD				1.851
TEMPM				86.835
TEMPSD				0.537
EMGM	LA	ER	7	2.972
EMGSD				2.622
SCLM				18.671
SCLSD				1.685
TEMPM				87.157
TEMPSD				0.254

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\bar{X}$
		Relaxation		
EMGM	HA	ES	7	3.031
EMGSD				1.591
SCLM				17.615
SCLSD				1.341
TEMPM				87.600
TEMPSD				0.881
EMGM	LA	ES	7	1.734
EMGSD				1.405
SCLM				16.375
SCLSD				2.197
TEMPM				87.112
TEMPSD				0.271
EMGM	HA	ER	7	2.782
EMGSD				1.080
SCLM				22.141
SCLSD				2.650
TEMPM				88.270
TEMPSD				0.375
EMGM	LA	ER	7	1.805
EMGSD				1.544
SCLM				12.744
SCLSD				1.192
TEMPM				87.080
TEMPSD				0.477

Table 13-(Continued)

Variable[a]	Group[b]	Order[c]	N	$\bar{X}$
		Recovery from Relaxation		
EMGM	HA	ES	7	3.534
EMGSD				2.304
SCLM				19.105
SCLSD				2.120
TEMPM				87.898
TEMPSD				0.220
EMGM	LA	ES	7	2.804
EMGSD				2.625
SCLM				19.125
SCLSD				2.781
TEMPM				87.440
TEMPSD				0.472
EMGM	HA	ER	7	3.204
EMGSD				2.417
SCLM				25.820
SCLSD				3.362
TEMPM				88.860
TEMPSD				0.270
EMGM	LA	ER	7	2.620
EMGSD				2.458
SCLM				14.490
SCLSD				1.570
TEMPM				88.002
TEMPSD				0.215

Key

[a]Variable:
EMGM = Mean Forehead EMG
EMGSD = Forehead EMG Standard Deviation
SCLM = Mean Skin Conductance Level
SCLSD = Skin Conductance Level Standard Deviation
TEMPM = Mean Skin Temperature (^{o}F)
TEMPSD = Skin Temperature Standard Deviation (^{o}F)

[b]Group:
HA = High Anxiety
LA = Low Anxiety

[c]Order:
ER = Early Relaxation
ES = Early Stress

NOTE

1. O'Neil, H. F., Jr., Hansen, D. N., & Spielberger, C. D. The effects of state and trait anxiety on computer-assisted learning. Unpublished paper, Florida State University, 1969.

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BIOGRAPHICAL SKETCH

Kathleen Shea Abrams was born in Lackawanna, New York, in Our Lady of Victory Parish on December 28, 1941, the Feast of the Holy Innocents. She spent her childhood ignorant of the esophagus and of most of the rest of the world outside Lackawanna. The smoke from the mighty stacks at Lackawanna's Bethlehem Steel Plant prevented her from seeing more than a few feet beyond the city limits. Kathleen, her brother Michael, and her sisters Nan and Carolyn attended Franklin Elementary School, where they caught colds, earaches, measles, and impetigo. Her mother, Mary Ann Yerkovich Shea, a Lackawanna native, often urged Kathleen to leave her books in order to play in the yard. Instinctively protective of her lungs, little Kathleen invariably refused her mother's urgings except one time. In the summer of 1952, at the tender age of ten, little Kathleen went out of town, off to Girl Scout Camp deep in the hills south of Lackawanna. She looked up at the sky, saw that it was blue, much to her surprise and delight, and decided that from that day forward a way out of Lackawanna would be her goal. For beginners, she earned a pathfinder's badge at Girl Scout camp. Her father, Edmond J. (Mike) Shea, wrote her long, chatty letters which she read aloud to her cabinmates.

Later, when she went away to Syracuse University, her father wrote her long, chatty letters which she read aloud to her roommates. When she graduated in 1963, she took and passed the Federal Civil Service Exam and, finally, against all odds, received her senior explorer's badge. Her score on the exam qualified her to be an administrative assistant in the Brooklyn Navy Yard. Kathleen refused to work in the Yard. Instead, she and a college roommate followed the blue sky to the University of Florida where they both took a master's degree in rehabilitation counseling. Her father wrote her long, chatty letters which she read aloud to her friends. The smokeless southern air alarmed her roommate, who returned North. Kathleen went to Miami-Dade Community College as a college counselor. She encountered sex, violence, a hurricane, and her first car. Despite her new experiences, she remained ignorant of the esophagus. Her mother worried about her living on her own in the deep and fungal South. Kathleen thought that her mother might be right. She decided to live on her own in the deep and dirty North. She drove her first car to Minneapolis where it died in October of hypothermia. On her first night in town, she met her husband-to-be, Harvey, in a cheap restaurant across from the University of Minnesota. He said to her, with his mouth full of hamburger, "Ya new in town, honey?" She was immediately attracted by his sophistication and wit. She took her master's degree in clinical child psychology and married Harvey in 1968. She encountered love, warmth, islands, and cats. Harvey and Kathleen moved to Ann Arbor, Michigan, that year where Harvey pursued and caught a Master of Social Work degree while Kathleen worked as a psychologist with adolescents at Ypsilanti State Hospital for one year too many and with physically disabled adults at Parkview Rehabilitation Center for three years too few. She encountered death, despair, fear, friends, trees, and birds. Kathleen returned to Miami in 1972 with Harvey and the cats. Unable to find employment at the Miami Navy Yard as a psychologist or rehabilitation counselor, she experienced political campaigns, art, rivers of grass, camping, beaches, birds, and endless sky. She returned to the University of Florida with Harvey in 1976 to pursue a Ph.D. in clinical psychology. Harvey continued to teach college in Miami and till gardens in Gainesville. Kathleen encountered fireplaces, blueberries, the esophagus and Mark Kane Goldstein.

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.

Mark Kane Goldstein, Chairman
Associate Professor of Psychology

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.

Cynthia D. Belar
Associate Professor of Clinical Psychology

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.

Yvonne Brackbill
Graduate Research Professor of Psychology

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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This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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