PSYCHOSOMATIC SUBJECTS UNDER STRESS: COMPARISONS OF PUPIL, HEART, MUSCLE, AND SKIN RESPONSES

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Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
May, 1977

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ACKNOWLEDGMENTS

I would like to express my appreciation to my major adviser, Dr. Philip J. Murphy, for his constant guidance and assistance in every aspect of this study. Appreciation is also expressed to Dr. Robert F. Stanners, who generously offered his time, and his expertise with pupillometry, as well as his humor and encouragement. Drs. Murphy and Stanners provided all of the equipment used in this project.

My thanks to committee members Dr. H. Stephen Caldwell and Dr. Larry M. Hynson for their participation in the drafting of this manuscript.

Special thanks to Dr. Allen W. Sweet, for his instruction regarding the pupillometric equipment; to Dr. Marge Cowan for her invaluable participation in every area of running the experiment; to Patricia A. Brown, R.N., for her patience and persistence in the seemingly endless task of data-scoring; and to Charlene Fries for her prompt assistance in the format preparation and typing of the manuscript.

My personal appreciation is especially given to my sister and brother-in-law, Deborah and Robert Crawford, for their ready willingness to help in any way possible with the task of scoring and analyzing the data, as well as the preparation of tables. My sister constructed the figures shown in the manuscript.

Most importantly, I would like to thank my parents, Loraine and Wilbur Coulter, for their continual sacrifices, support, and encouragement. My gratitude and love to you both.

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CHAPTER I

INTRODUCTION

Modern society imposes on man stresses quite different from those experienced by his predecessors. There has always been a need to overcome obstacles in living, but these obstacles were consequences of the course of physical nature and the ambitions and dissensions of human nature. In addition, today's man must contend with much more amorphous adversaries: the mechanical revolution and the bureaucratic process. It has become almost impossible to vent frustration appropriately at these ubiquitous systems; consequently, it is often misdirected at others or contained by the person. One possible outcome of containing any stress is a psychophysiological reaction.

Hinsie and Campbell (1970) equate the terms psychophysiological disorders, psychosomatic disorders, and somatization reactions. They state by way of definition that these disorders are disturbances of visceral function secondary to chronic attitudes of long-contained insufficiency of affective discharge. The reactions present themselves as a dysfunction involving any of the organ systems: skin, musculoskeletal, respiratory, cardiovascular, hemic, lymphatic, gastrointestinal, genitourinary, endocrine, nervous systems, or organs of special sense.

The relationship between stress and the psychophysiological reactions of the autonomic response mechanisms is well documented.

Hans Selye (1956) discusses stress in terms of a General Adaption Syndrome involving the pituitary-adrenal system. He cites adrenal enlargement, thymicolymphatic atrophy, and acute gastrointestinal ulcers as possible psychophysiological consequences of stress.

Selye (1973) additionally contends that when faced with a stressful situation, the organism can respond through three essentially distinct mechanisms; nervous, immunologic and phagocytic, and hormonal. The implications are clearly that all systems of the human body can be affected in response to varying stresses.

Specific disorders frequently investigated in relation to stress include, among many others, hypertension (Baumann et al., 1973), colitis (Fullerton, Kollar and Caldwell, 1962), asthma (Miklich et al., 1973), muscle spasticity and rigidity (Boman, 1970) and eczema (Brown, 1967).

In the experimental situation, autonomic changes in relation to stress are almost immediately manifested and able to be measured. Pupillary dilation, heart rate and electrical properties of the skin all show change in response to arousing stimuli (Nunnally, Knott, Duchnowski, and Parker, 1967). Mental arithmetic, threat of electric shock and the presence of a monetary incentive have all been shown to be effective experimental stressors producing physiological arousal (Kahneman et al., 1968; Kahneman and Peaver, 1969; Lorens and Darrow, 1962; Polt, 1960; Tursky, Shapiro and Crider, 1969).

In the daily routine of living, however, what is emotion-arousing or stressful for one person is not necessarily so for another. Some defined quantity of stress may have different consequences for different individuals (Opton and Lazarus, 1967). When an individual who can be categorized as psychosomatic experiences stress, the outcome is a psychophysiological response. The variety of symptomatology which may be expressed, as previously mentioned, can be quite variable. Many symptoms may be expressed, or only one. The degree, duration, and frequency of stress necessary to precipitate the symptoms is also quite variable from person to person. The common factor among individuals considered psychosomatic is the somatic response to stress at such a quantitative or qualitative level as to be physically damaging (Lachman, 1972).

The current study employed two psychosomatic groups, one expressing internal, gastrointestinal disorders such as ulcer or colitis, the other expressing external, skin disorders. These psychosomatic Ss were compared to a normal control group during experimental situations of mental digit transformation problems performed with threat of shock for incorrect responses versus monetary reward for correct responses versus task alone without punishing or rewarding consequences. Four dependent variables involving physiological functioning were examined: pupil response (PR), galvanic skin response (GSR), heart response (HR), and muscle or electromyogram response (EMG). A brief discussion of these dependent variables follows.

Dependent Variables

Pupil Response

The pupil of the eye dilates and constricts due to the opposing actions of the dilator and sphincter pupillae muscles. Both are smooth muscles which are ectodermal in origin, developing from the anterior epithelial layer of the primitive optic cup. The sphincter separates from this layer and develops into true muscle tissue, whereas most of the dilator cells remain in their original position and fail to develop fully, remaining in a state intermediary between true muscle and true epithelial tissue--so--called myoepithelial cells (Davson, 1963).

The sphincter pupillae muscles were first shown to exist in the 1840's. The dilator pupillae, however, retain epithelial pigment cells which made conclusive evidence of muscular qualities more difficult to obtain. It was the pigmentation present in the dilator which obscured much experimentation until modern staining techniques were available. It is now generally agreed upon that the dilator pupillae do exist (Loewenfeld, 1958; Lowenstein and Loewenfeld, 1962). Originally, there were three theories concerning the cause of the dilation of the pupil produced by stimulating the cervical sympathetic: 1) inhibition of the sphincter muscle, 2) action of the sympathetic vasoconstrictor fibers on the blood vessels of the iris, and 3) contraction of a radially arranged muscle. Adler (1959) cites the experiments of Langley and Anderson which showed that changes in the size of the blood vessels could be eliminated as the cause of dilation of the pupil by stimulation of the sympathetic nerve in an animal which had been bled to death first. The pupil dilated as if the animal were normal. Further experimentation by them also disproved that inhibition of the sphincter muscle was responsible; and, contraction of radially arranged muscles, the dilator pupillae, was physiologically shown. As already stated, histological location soon followed when techniques to depigment the epithelial cells were made available.

The dilator pupillae reach from the ciliary border of the sphincter muscle to the root of the iris. They are composed of Bruch's membrane and reinforcement bundles, which are radial fibers of smooth muscle arranged like wheel spokes around the pupil (Lowenstein and Loewenfeld, 1962).

The sphincter is an annular band about one millimeter in width encircling the pupillary aperture. Peripherally, the fibers of the sphincter blend with the fibers of the dilator. In maximum contraction of the pupil, the sphincter muscle is shortened about 87% of its length, which is relatively greater than occurs in any other muscle of the body. Pupil size may be as small as 1.5 mm. during maximum contraction, and as wide as 8.0 mm. with maximum dilation (Adler, 1959). The unusual ability to shorten in the sphincter pupillae had been explained by assuming that the fibers telescope into one another on contraction. The normal diameter of the pupil lies between 2.5 and 4.0 mm. with an average of 3.5 mm. (Duke-Elder, 1938).

The sphincter is innervated by cholinergic, parasympathetic fibers from the third cranial nerve by way of the ciliary ganglion and the short ciliary nerves. The dilator is controlled by the adrenergic cervical sympathetic, the fibers relaying in the superior cervical ganglion; post-ganglionic fibers enter the eye in the short and long ciliary nerves (Lowenstein, 1958; Lowenstein and Loewenfeld, 1962). Adler (1959) contends that the sphincter may be supplied by both cholinergic and adrenergic fibers, however, this is well disputed by Loewenfeld's (1958) comprehensive review of experimental research in which she indicates that parasympathetic innervation alone is responsible for pupillary constriction. Reciprocal action of the sphincter and dilator muscles is also a disputed point with a majority of the research indicating that dilation results from both contraction of the weaker dilator pupillae muscles and inhibition of the stronger sphincter pupillae muscles by means of depression of tonus of pupilloconstrictor cells of the Edinger-Westphal nucleus (Walsh, 1957).

Pupillary reflex dilation is only one of several pupillary reactions, but it is the one of most consequence in the present work. Pupillary reflex dilation can be brought about by sensory stimuli, emotional stimuli, or cognitive processes such as thinking or calculation (Loewenfeld, 1958). Any of four factors can be causative, two of which are neural and two humoral. The neural factors are: 1) general sympathetic arousal resulting in contraction of the dilator pupillae; and, 2) inhibition of the Edinger-Westphal nucleus by sympathetic impulses, which eventuate in relaxation of the sphincter pupillae. The humoral factors are: 1) a release of adrenal epinephrine in an organism which is severely stressed; and, 2) the activation of norepinephrine by sympathetic nerve endings in the heart and arteries in moderately aroused organisms (Lowenstein and Loewenfeld, 1962).

Galvanic Skin Response

Changes in the electrical resistance of the skin have been noted since 1879, when Vigoroux attributed these changes to vasomotor activity. Fere (1888) generally receives credit for demonstrating that emotional stimulation causes fluctuation in skin resistance, also interpreted as vasomotor activity. In 1890, Tarchanoff discovered a skin potential response which occurred between two electrodes placed on dissimilar skin sites even in the absence of an applied current. This potential, indicating a change in permeability of a selective membrane, had as its proposed origin the human sweat gland. The debate over the exact nature of this reflex still continues today.

The galvanic skin reflex can be demonstrated by placing two electrodes on the skin surface and driving a small current between them. The skin acts as a resistor and a voltage develops. Then, using Ohm's law, a measure of apparent resistance can be derived. The unit of apparent resistance is the ohm, or more generally the kilohm or K. The physical unit for conductance is the reciprocal ohm or mho. Ordinary skin resistance is at least $10K \cdot cm^2$, therefore conductance is usually expressed in terms of reciprocal megmhos or micromhos (umho).

Any stimuli causing the subject to orient will result in a rapid decrease in measured voltage about two seconds after the introduction of the stimuli. This voltage drop, indicating a fall in skin resistance is known as the galvanic skin reflex. The characteristic waveform of this reflex takes about 0.5-5 seconds to peak with 1-2 seconds being average. Before return to baseline, a latency of about 1.8 seconds occurs for palmar responses at comfortable room temperature (Edelberg, 1972).

Heart Response

Another index of autonomic arousal is the heart rate. By recording the distance between R waves of the electrocardiogram, the cardiotachometer provides a beat to beat measure of heart rate. Brown (1972) points out that of the five components of the electrocardiogram, the P, Q, R, S and T waves, the R wave is the most important for psychophysiological work. The Q-R-S complex of waves represents the depolarization of ventricular musculature and the R wave is the largest of these waves, making it the most easily identified signal for timing or counting.

Muscle Response

The most frequent method of measuring muscle tension in psychological research is the electromyogram (EMG). Goldstein (1972, pp. 329-330) states that: "Stimulation of the muscle leads to contraction and to the simultaneous electrical, chemical, structural, and thermal changes that result in the muscle action potential (MAP). The record of electrical events of the MAP or a series of MAP's make up the EMG."

When two electrodes are placed on the skin, or inserted into the muscle, and stimulation of the muscle occurs, an electric current flows which is recorded as the EMG. The spread of electrical activity from the summed action potentials of the muscles to the surface of the skin can be large enough to be easily recorded. Muscle fibers maintain a negative intracellular potential of 50-100 mV during their resting state. The most generally accepted explanation of this polarization is the theory of the potassium-sodium pump (Woodburg, 1965). The action potential of the muscle results from a brief depolarization of the resting membrane potential.

Surface electrodes are generally used to record MAP's in psychology because they are sensitive to the action of whole muscles rather than just discrete motor units. Placement of electrodes varies according to the type of experiment and its purpose. Both age and sex factors must be taken into account in comparing MAP's. It has been shown that the same amount of muscular work results in more electrical activity in women, which is indicative of a strength factor between the sexes (Small and Gross, 1958). As age increases there is also a continuous increase in mean action potential duration during slight muscular activity. This increase of MAP duration with increased age has been explained in terms of the fiber density of motor units caused by the decrease in the volume of muscle (Sacco, Buchthal, and Rosenfalck, 1962).

Atmospheric temperature was found to be positively correlated with muscle tension during rest (Balshan, 1962); consequently, restriction of the subject's activity and maintenance of constant room temperature during the experiment are control factors to be considered. Education and level of intelligence have not been found to influence MAP activity (Bartoshuk, 1959).

Voas (1952) examined the test-retest reliability of muscle groups under various experimental situations and found that forearm flexors and frontalis muscles both provided high retest reliabilities. He contends that this finding warrants their usage in measuring differences between individuals.

Independent Variables

Psychosomatic versus Normal Subjects

The degree to which an individual perceives his body as a firm or vague boundary between himself and the world has been frequently explored. Fisher and Cleveland (1968, p. 56) have pointed out that:

> One could conceive of each individual as equating his body with a "base of operations", a segment of the world that is specially his. His body would encompass his private domain and be the cumulative site for all his past integrated experiences. It could be regarded as founding and containing a complex system which has been developed to deal with the world.

In dealing with the world the body must also deal with the stress which may precipitate from the interaction. Psychosomatic symptoms may be a possible consequence of this stress. External psychosomatic symptoms have been found to be representative of definite body boundaries, while individuals with internal symptoms possess uncertain or vague boundaries (Fisher, 1970). In terms of physiological patterns, individuals who show "external" symptoms such as neurodermatitis or arthritis, have been shown to exhibit more physiological reactivity in skin and skeletal muscle areas than in internal areas. Concommitantly, individuals with "internal" disorders such as ulcer or colitis, have higher internal viscera responses such as heart rate (Fisher and Cleveland, 1968). Other research performed in this area will be discussed in the review of the literature in Chapter II.

Some of the present study's expected outcomes are based on this research. The use of normals, internal psychosomatic subjects, and external psychosomatic subjects as categorical independent variables reflects the belief that, when under stress, there will be differences among these subjects in physiological responsivity in the chosen indices.

Digit Transformations, Incentives, and Threat of Shock

All three subject groups were presented with the same nine transformation problems to be performed mentally. The order of presentation was constant: Task alone, task with monetary reward for correct responses, and task with threat of shock for incorrect responses. Problem difficulty increased within all three conditions.

Problem-solving performance has been consistently shown to elicit an activation of the sympathetic nervous system, with pupillary, heart rate, and skin resistance measures showing similar patterns during information intake and processing (Kahneman, Tursky, Shapiro, and Crider, 1969). Electromyogram responses have also been shown to increase during mental work (Voas, 1952). Pupil response has been shown to be significantly increased simply by increasing the amount of the incentive from 1¢ to 5¢ for correct answers, apparently a consequence of increased mental effort (Kahneman and Peavler, 1969). Polt (1970) combined problem-solving tasks with threat of shock and found significantly greater dilation than in the problem-solving performance alone. He interpreted this difference as also being due to increased mental effort.

Proposed Investigation

Hess (1972) has stated that in the mental multiplication problems in his research the increase in pupil size was not influenced by emotional factors, ". . . since galvanic skin response recordings failed to indicate any appreciable degree of autonomic response." When Polt (1970) introduced a fear element, threat of shock, into the problem-sovving situation, he did not record any physiological measures except pupil response; hence, no check on Hess's interpretation was possible.

If it is assumed that threat of electric shock does induce some degree of emotional anticipation or stress, then it could be expected that activation of physiological responses would reflect this additional fear element through greater magnitudes than were present in mental tasks alone or even than in the situation of increased mental effort to gain a reward. Further, it could be expected that the differential handling of stress attributed to psychosomatic subjects would result in increases of responsivity over the level of normal subjects.

The literature review to follow failed to reveal any investigation of psychosomatic subjects performing mental calculations under threat of shock versus incentive, with heart, pupillary, skin and muscle responses being assessed. The present study will combine these factors in order to re-examine the Polt (1970) interpretation of increased pupil dilation as increased mental effort, and in order to extend pupillometric research into the area of psychosomatic investigation.

CHAPTER II

A SELECTED REVIEW OF THE LITERATURE

Early Pupillary Work

References to the observable changes in pupil size under varying conditions can be found as long as the 2nd century B.C. Clark (1970) points out that Archimedes (212-187 B.C.) is believed to have developed a device for measuring pupillary diameter. Roman history indicates that Plinius (23-79 A.D.) and Galen (111-201 A.D.) had used drugs to dilate the pupil before surgery for cataracts. The pupil's reflex to light is cited by the Arabic physician Rhazes (850-933 A.D.), who also described abnormal pupillary conditions in his Encyclopedia of Medicine.

Hess (1972) states that despite the large amount of research involved with the pupil of the eye, relatively little investigation has been carried out on the psychopupil response. Hess references all of the following literature review in his comprehensive article.

An early observation that indicates psychosensory stimuli influences the pupil is Fontana's 1765 finding that there is pupillary dilation upon awakening regardless of the level of illumination. In 1863, the first systematic study of pupil activity due to nonvisual influences was recorded by Westphal, who found that chloroform caused the pupils to constrict but that needle pricks or loud screams in the in the subject's ear resulted in sudden dilation, with gradual return to the constricted state. Gratiolet had mentioned ten years earlier that under conditions of fright the pupil remains dilated even with intense light shone in the eye. Schmidt-Rimpler reaffirmed this finding in 1898.

In 1874 and 1875, Schiff experimented with curarized or chloroformed animals and came to the conclusion that pupillary activity is an index of sensory stimulation, an "esthesiometer" as he called it, because the pupil could be seen to respond to even extremely light touch without any pain involved. He found greater dilation for stronger stimulation such as pressure than for milder stimulation such as touch.

Darwin (1872) commented on the widening and narrowing of the eyes through eyelid and eyebrow movements as being indicators of human emotion. Cognitive influence was also being assessed, as shown by an 1895 report by Mentz that multiplication problems increased pupil dilation in the subject by 15%, and that "just thinking" was equally potent in producing dilation. Hess points out that Heinrich, in 1896, also performed experiments involving mental multiplication and found that dilation was the result. Heinrich's work further elucidated the influence of the factor of where the subject's attention is deployed. He found that fixation in the periphery of the visual field resulted in greater dilation than fixation in the central portion of the visual field. Also, accommodation to far vision results in larger pupil size than accommodation to near vision. In 1900 and 1901, Roubinovitch performed independent studies which yielded essentially the same results.

Another variable influencing pupillary dilation was reported by Redlich in studies in 1892, 1897, and 1907, and discussed by Hess: the dilation of the pupil upon muscular effort in the normal, healthy subject. The evidence in this area indicated that muscular contractions, and even the thought of performing them, consistently caused pupillary enlargement. Westphal also found this to be the case in his 1907 and 1920 work. Lowenstein reported the same phenomena in experiments performed with Westphal in 1933. More recent confirmations of the role of muscular effort in producing dilation are indicated by Levine and Schilder (1942), and May (1948).

Studies of psychological abnormality became a popular subject area of pupillary investigation in the early 1900's. Hess cites Bumke's 1911 review book on the study of the pupil as an important review of this area. Hess (1972) states:

> Bumke's book was, in fact, a comprehensive and fascinating review of the work of a veritable multitude of researchers, including himself, who had reported upon pupillary disturbances in mental and nervous illnesses up to his time. These abnormalities not only include special forms of pupillary behavior among these patients but also the absence of pupillary phenomena that regularly appear in normal, healthy persons. A rather wide range of organic and nonorganic conditions have been studied with respect to pupillary behavior even by Bumke's time: tabes dorsalis, paralytic dementia, imbecility, neurosyphilis, senile dementia, arteriosclerotic psychosis, idiocy, multiple sclerosis, tumors of the central nervous system, primary degeneration of motoric apparatus, encephalitis, polioencephalitis, myelitis, poliomyelitis, meningitis, alcoholism, drug addition, dementia praecox, epilepsy, hysteria, neurasthenia, migraine, chorea, and functional psychosis. Bumke summarizes... "in general every active intellectual process, every physical effort, every exertion of attention, every mental image, regardless of content, particularly every affect, just as truly produces pupil enlargement as does every sensory stimulus" (pp. 492-494).

The pupillary abnormalities in these conditions are still being researched today according to Hess, especially by Russian scientists (Leontiev, Luria, Sokolov, Vinogradove and Voronin, 1965).

Interest in pupillary abnormalities in psychiatric populations continued to be strong in the 1920's and 1930's. Westphal (cited by Hess, 1972, p. 494) found that catatonic schizophrenic patients showed a "transitory catatonic pupillary immobility". This condition is characterized by pupils fixedly dilated more than was normal with a failure to respond consistently to light, or to near and far accommodation changes. Westphal's work with Lowenstein later produced results that indicated the catatonic pupil could be observed in schizophrenics upon the suggestion of fear or anxiety. As Gang (1945) has pointed out, this condition could be so reliably reproduced in schizophrenics so as to serve as a differential diagnostic aid, a bedside psychosomatic experiment to distinguish between catatonic stupor and a depressive or other stupor. It was believed that the "loss of lability and spontaneity and the heightening of emotional suggestibility" were possible causes of the dilation problems. In the normal subject, pupillary dilation occurs in relation to the cause of emotional arousal, but returns to normal when that cause is removed.

May (1948) studied the differences between schizophrenic males and normals in terms of pupillary inequality and found that 19% of the schizophrenics exhibited inequality of pupil size compared to 3% of the normals. May also found that 15% of the schizophrenics showed abnormalities in the light reflex while only 1% of the normals did. He added that mentally defective patients also had light reflex impairment.

Many studies have indicated that normal, healthy children have larger pupil sizes than do normal, healthy adults (Birren, Casperson, and Botwinick, 1950; Kumnick, 1954). Rubin confirmed that finding and noted additionally that children with autistic disorders have been shown to have smaller pupils than do normal children, but still larger than those of normal adults (1961; 1962). Rubin et al. (1963) were not able to distinguish between normal children in age group divisions of 6-8 years, 9-11 years, and 12-14 years.

This brief review of early work with pupillary reflexes shows clearly that the study of pupillometrics in psychology was far from a novel approach. However, the heuristic value of Hess's revitalization of interest in the area cannot be denied. By catching the attention of psychologists with his reports, Hess's work has been crucial in stimulating the generation of numerous hypotheses concerning eye-mind relations, some of which will be discussed in the review of recent research.

Recent Pupillary Work

In 1960, Eckhard H. Hess and his associate, James M. Polt, published their findings relating pupil size to the interest value of visual stimuli. As the review of the early pupillometric literature has indicated, the research into the properties of the pupil was quite extensive even before Hess and Polt's work. However, psychology's renewed interest in the area was fortuitously stimulated by their publication at a time when advanced photographic and mechanical techniques made possible more accurate systematic analysis of the pupillary phenomena. Hess and Polt photographed the pupils of four men and two women during the presentation of five slides. Each slide was presented for 10 seconds, with a 19 second control period before each presentation. Using the percentage change in mean pupil area as the dependent variable, they found that there were significant differences between the sexes with respect to the interest value of pictures.

In another study, Hess and Polt (1964) employed four men and one woman as Ss and investigated percentage of change in pupil diameter as a function of mental activity during simple multiplication problems. The results indicated that as an index of mental activity, the pupillary response indicated a close and positive correlation between mental activity and problem difficulty. Beginning with this study and afterward, pupil diameter change was used rather than pupil area because changes in area are a function of the initial diameter.

Extending earlier work on the pupillometric measurement of interest to a specific case, Hess, Seltzer and Schlien (1965) found that normal and homosexual males can be differentiated on the basis of pupillary dilation. All Ss viewed fifteen transparencies, five male, five female, and five art slides. Heterosexual males showed a greater response to the female pictures, while the homosexuals showed larger responses to pictures of males.

In a summary article of his previous work, Hess (1965) states these findings: (1) Constriction is as characteristic in the case of certain aversive stimuli as dilation is in the case of interesting or pleasant pictures. (2) There is a differential pupillary response to different stimuli which are not noticed as being different at the verbal level. (3) Pupillary activity can serve as a measure of motivation. (4) Changes in attitude can be measured with the pupillometric technique.

Hess's work did not go without criticism. Woodmansee (1966) indicated that inadequately controlled light reflexive effects could be the significant confounding variable resulting in constriction of the pupil in Hess and Polt's work. Woodmansee pointed out that the aversion-constriction hypothesis of Hess could not be replicated using non-visual stimuli (music, liquids). He indicated that change in Ss' focus from light to dark areas of the slide could be responsible for some constriction, and that the arousal decrement response to repeated stimuli results in dedilation. Woodmansee warned against lengthy trials and the effect of the near-vision reflex, stating that these factors can also be responsible for constriction. Lehr and Bergum (1966) pointed out that a "pupillary adaption effect" occurs during an experiment, and that this can result in a decrease in absolute pupillary diameter. Peavler and McLaughlin (1967) also failed to find supportive evidence of Hess's conception of the bi-polar pupil response to affect. By introducing novel or arousing stimuli in the presence of increased luminance, they found that the pupil response was always in the direction of increased dilation. They commented that: "Other than the work of Hess . . . [we] . . . know of no evidence for the aversion-constriction hypothesis" (p. 506).

In subsequent research, experimenters have investigated the pupillary response in such areas as memory and cognitive load (Bradshaw, 1968; Kahneman and Beatty, 1966), political preferences (Barlow, 1969), gustatory preferences (Hess and Polt, 1966), sexual preferences (Atwood and Howell, 1971; Hamel, 1974; Schnelle, Kennedy, Rutledge, and Golden, 1974), monetary incentive (Kahneman and Peavler, 1969), general activation (Nunnally, Knott, Duchnowski and Parker, 1967), imagery tasks (Paivio and Simpson, 1966), racial attitudes (Barlow, 1969), commercial advertising (Krugman, 1964), neuroticism (Boddicker, 1972; Francis, 1969; Francis and Kelly, 1969; Rubin, 1965), stimulus content (Fitzgerald, 1968; Polt and Hess, 1968), instructional set (Clark and

Johnson, 1970), paired-associate learning (Colman and Paivio, 1970), information processing (Poock, 1973), mental activities (Schaefer et al., 1968), degree of visual fatigue (Geacintov and Peavler, 1974), and heroin withdrawal versus intoxication (Robinson et al., 1974).

Tryon (1975) has composed the most recent methodological survey of sources of variation in pupilliometry. In his summary article he suggests various experimental procedures to control for the effects of variables that are not themselves the object of the study. Some of the variables that Tryon states are important in various situations are: the darkness reflex, the psychosensory reflex, the consensual reflex, wavelength, and binocular summation. The necessity of controlling factors such as age, absence of alcoholic intake, sexual abnormality, pupillary unrest (hippus) and habituation effects was also cited.

Pupillary Responses Versus Other Physiological Measures

Hess (1972) recognized the importance of comparing pupil responsivity (PR) to concurrent physiological data. He commented: "Ultimately, it appears that the maximal usefulness of the pupil response will be in conjunction with the simultaneous recording of other autonomic measures (p. 510)."

Coleman and Paivio (1969) compared PR and GSR during a task requiring imagery of concrete and abstract nouns. Response magnitudes were measured for the PR by calculating a change score between the largest diameter during the "imaging" period and the diameter in the last frame (.5 sec.) before stimulus presentation. The GSR change score was calculated by subtracting the maximum deflection (decrease in resistance) during the "imaging" period from the resting level during the last one-half second before presentation of the stimulus. It was found that concrete and abstract nouns differed significantly in terms of mean pupillary change scores, with greater dilation occurring to the abstract words. The mean GSR change scores for concrete and abstract words did not differ significantly. Pupillary latency was recorded as the time to maximum dilation after stimulus presentation, and GSR latency was time to maximum deflection. Longer latencies to abstract nouns were significantly present in both measures. Colman and Paivio discussed their results in terms of pupillary dilation appearing more related than GSR to "cognitive difficulty" of the imagery task. They further suggested that latency of either response may be more sensitive indicator than magnitude.

Kahneman et al., (1969) investigated pupil response, skin resistance, and heart rate changes in a paced digit transformation task with time-locked measures. Ten college students, six male, were used as Ss. All three measures were found to follow a similar pattern of response increase during information intake and processing, then a decrease during the report phase. The peak response in each measure was ordered as a function of task difficulty. The sympathetic-like heart response change found in this study during information processing in in agreement with Lacey's (1963) hypothesis of cardiac acceleration during attending to internal cues.

Bankart and Elliot (1974) performed experiments which supported the contention that heart rate and skin conductance increase as probability of receiving electric shock increases. Therefore, if Ss are informed that probability of shock for incorrect response on particular trials is 100%, the heart rate and skin conductance should increase on those trials.

Electromyographic studies discussed by Lader and Mathews (1971, p. 484) indicate: "In normal Ss the EMG level has been found to correlate with behavioral performance and level of motivation...EMG levels are raised in anxious, depressed and schizophrenic patients. This probably reflects general affective over-arousal rather than any more specific mechanism."

Stress has also been indicated as a precipitant of EMG level differences. Martin (1956) could distinguish forearm flexor EMG levels of her patients from controls only during a stressful interview. Eason (1963) measured EMG responses of forearm flexors during a rotary tracking task and found that EMG's appear to reflect degree of effort applied to a task.

This brief overview of pupillometric research since Hess's article in 1960 makes it clear that, although the number and variety of studies performed have been considerable, nevertheless very few of these studies have endeavored to compare the pupil response with other physiological indices. The extension of research into this area should provide a fuller understanding of various contingencies of pupil responsivity.

Psychosomatic Studies

As previously mentioned, psychosomatic Ss with internal symptoms such as ulcer or colitis have been found to have vague boundaries between themselves and the world. Ss exhibiting external symptoms such as skin disorders or arthritis have often formed much more distinct boundaries. Concommitantly, differences in physiological responsivity between these types of Ss have been found. The following investigation into physiological response patterns of Ss with internal versus external disorders provide background support for some of the hypothesis of the present study.

Karush, Hiatt and Daniels (1955) discovered trends for patients with ulcerative colitis (interior symptoms) to respond to stressful activity with the colon, but to show very little response in the peripheral vasculature.

Little (1950) found that ulcer patients have limited reactivity of the skin and peripheral vasculature, but that they were unusually reactive in terms of heart rate. Malmo et al., (1950) have proposed that in its most extreme form, the tendency of some individuals to respond selectively in one particular autonomic or muscular system might lead to specific somatic symptoms centered on that system. Graham (cited in Wolff, 1950) showed that patients with psychosomatic skin disorders had greater skin responses to histamine or pilocarpine than did Ss in a control group.

Fisher and Cleveland (1960) studied 26 male arthritics with a mean age of 36.8 years, and 34 male patients with duodenal ulcers with a mean age of 34.6 years. It was found that, under stress, the arthritic group showed a significantly larger number of GSR responses ($p < .01$, one-tailed test) and a lower heart rate ($p < .001$, one-tailed test) than the ulcer group. The stress in this study was created by dropping a heavy iron bar next to the subject. Moos and Engel (1962) reported higher levels of muscle potential and GSR in Ss with rheumatoid arthritis than in hypertensives.

In 1968, Fisher and Cleveland evaluated college students with minor symptoms and found that external symptoms were shown by Ss with definite body boundaries, (determined by responses to ink blots), while internal symptoms characterized Ss with vague boundaries. Shultz (1966) had earlier found similar differences between patients with skin symptoms and those with stomach symptoms.

These studies represent only a few of the many experiments which have been found to support the belief in a difference between specific types of physiological reactivity to stress by Ss with differing psychosomatic symptoms. Because of such differences, it seems important from a methodological standpoint to begin investigation into the pupil's response in psychosomatic Ss by using distinct symptom groups rather than a collective group containing many types of psychosomatic symptomatology. The use of distinct symptom groups provides a means to assess possible differences in psychosomatic Ss in physiological response combinations in pupil, GSR, HR and EMG reactivity.

Pupil Dilation in Cognition and Affect

In 1970, James Polt studied the effect of threat of shock on pupillary response in a problem-solving situation. The task consisted of two series of three multiplication problems, with increasing problem difficulty in each series. Fourteen female Ss, ages 18 and 19 years, were divided into two groups of seven each. On the second series of problems the experimental group was threatened with shock for an incorrect answer. Response latency, number of correct responses, absolute pupil size and pupillary dilation during problem-solving were compared. The only significant difference between groups was the degree of pupillary dilation while solving the series of problems. This measure was derived by comparing the mean pupil size on the five frames immediately before the problem was presented and the mean of five frames at the peak of pupil dilation during problem-solving.

Polt interpreted his results in the context of greater mental effort being exerted by the Ss under threat of shock. He explained that:

> If the threat of shock created sufficient stress to affect the pupillary response, it would be expected that the anticipation of shock would exist throughout the experimental session and would be evidenced in greater pupil dilation in the experimental Ss during the control as well as during the problem-solving periods (p. 591).

Polt indicated that Lazarus and Opton (1966) have shown that a considerable response increase in skin conductance occurs during the period when Ss are anticipating a scene in a motion picture designed to induce stress. Such evidence leads Polt to believe that it is only the greater cognitive activity level to solve the problem which generates greater pupillary dilation, and not anxiety or emotional arousal in response to the threat. He states:

> It is obvious that the best coping procedure, in terms of behavioral alternatives, would be to avoid the threat by correctly solving the problem and avoiding the shock. It then seems reasonable that more mental effort might be expended in solving the problem to increase the probability of answering correctly. This additional effort had the effect of increasing pupil dilation during problem solving (p. 592).

A possible flaw in Polt's reasoning lies in his failure to correctly parallel the control periods between the Lazarus and Opton study and his own. The control period in Polt's work occurs before the problem is presented. Polt states that there is no PR during this time. However, he then compares his control period with the time before a stressful scene occurs in Lazarus and Opton's study, instead of the time before the movie begins when the S has only been told he is about to see a stressful movie entitled "It Didn't Have to Happen". Although it is true that the Ss in Lazarus and Opton's experiment showed increased GSR as the most stressful scene approached, the fact is that they were being shown a film of a sawmill accident in which they could clearly foresee the likely occurrence of the accident. In actuality, this parallels the period of time between problem presentation and giving of the answer in Polt study, because as the time to give the answer approaches, so does the possibility of shock increase. The pupil does clearly respond more during this period, just as GSR did in Lazarus and Opton's Ss; therefore, the evidence leaves possible affectual contributions to the pupil dilation during threat of shock open to consideration.

Actually, it seems most likely that the pupil dilation response is a part of a more general activation system by which the body deals with thought, orientation to stimuli, anticipation and affect (Nunnally, 1967). Since the pupil is less involved in vegetative functions than GSR, HR, or EMG, it may be in fact a more sensitive indicator of cognitive difficulty; however, this does not preclude the possibility that pupillary dilation is part of the individual's response system to factors such as emotion.

Wenger (1956, p. 343) points out that, operationally, emotion is the "activity and reactivity of the tissues and organs innervated by the autonomic nervous system. It may involve, but does not necessarily involve, skeletal muscle response or mental activity."

It would appear logically that the sympathetically innervated pupil would be quite responsive to threatening stimuli, since vision often plays such a vital role in the individual's locating sources of, and avenues of escape from threat. How can Polt then meaningfully contend that the pupil is responding selectively to increased cognitive effort as a method of escape from threat, rather than to the obvious presence of the threat itself?

Furthermore, it has been shown that the pupil response is affected by the very presence of increased autonomic arousal as reflected by reactions in GSR, HR, and EMG during stress (Lacey, 1967). Hess (1972; p. 509) points out that:

> Increased autonomic activity, as reflected in GSR changes, in itself appears to dilate the pupils. For example, with the shock pictures the pupil dilates strongly when GSR changes are high; but, as the GSR to these pictures drops, the dilation effect of autonomic activity diminishes.

Anticipation of shock can also trigger autonomic arousal which may influence the pupil, as Opton and Lazarus (1967) point out:

> The shock-threat treatment consisted of telling the subject he would receive a shock following the last of a series of seven clicks at 5 second intervals. Actually, the shock was barely perceptible; the threat was in the anticipation. During the shock-anticipation period heart rate, skin conductance, and self-reported anxiety increased for almost all subjects (p. 295).

With regard to possible contributions of muscular tension to the pupil response Nunnally states: "The data relating to lifted weights make it quite clear that pupil size increases with muscle tension and that the size is directly related to the degree of tension" (1967, p. 153).

Since the pupil is sensitive to changes in these other response systems, and since these responses occur in the presence of stress, it seems likely that some proportion of the pupil's dilation during threat in Polt's work could very possibly be due to the affective response of the individual being threatened.

Sweet (1974) found evidence which is completely non-supportive of this line of reasoning. He used 24 female Ss between 17 and 20 years who were divided into three groups based on their carefully assessed fear of snakes. The Ss were then told to visually imagine snake scenes which varied in their degree of stressfulness. Pupil dilation during snake-imagery periods and control imagery periods was then compared. No differences were found between groups or between levels of stressfulness. Sweet interpreted these findings as indicative of the pupil's responding selectively to the cognitive load, which he held constant, and not to the affective stimuli. Additional autonomic measures were not taken to see if the affect element was reflected by other indices. If differential responding were found to consistently occur, it would lend strong support to Polt's contention of pupil response being a cognitive effort index.

A possible explanation of Sweet's findings may be given by Janisse's (1973) review of pupil size and affect studies since 1960. Janisse states:

> The most consistent finding relates greater dilation to increases in the intensity of stimulation, whether positive or negative; that is, pupillary activity is linearly related to the intensity continuum and curvilinearly related to the valence (positive-negative) continuum. The most profitable avenue of future investigation lies along the continuum of intensity (p. 311).

Imaging may not provide a sufficiently intense stimulus to bring about significantly different pupil responses. Two studies cited by Janisse, Good and Levin (1970) and Fredericks (1970), found pupil differences in the relative degree of change in dilation responses of subjects who were viewing pictures that varied on the pleasantness-unpleasantness dimension. Perhaps the pictorial presentation of the material in these studies was a more intense visual stimulus than imagery in Sweet's work. Threat of shock in the present study is a more direct source of stress than either imaging or pictures and consequently provides a greater stimulus intensity with which to evaluate pupil response.

One final study will be mentioned in this area, although its experimental arrangement makes it a less relevant source of evidence than the work already discussed. Peavler (1974) arranged information processing tasks so that they ranged from relatively simple to obvious overload dimensions. He hypothesized that the _Ss_ would have the greatest dilation to the overload situation, thereby indicating anxiety due to the fact that more material was being presented than one could process. Instead, he found that information overload resulted in a leveling of the dilation pattern suggesting a voluntary suspension of processing effort when an impending overload was perceived. Peavler interpreted this finding as a lack of emotional factors influencing dilation since the overload task did not precipitate the predicted anxiety. It would appear that an equally viable interpretation could be made in terms of a sophisticated human organism choosing to defend itself by "giving up" in the face of obvious overload. This would imply an automatic reduction in anxiety, since the "choice" to reduce effort had been made. It may have been possible that the anxiety in the overload condition would have been present if some consequence, such as threat of electric shock, would have been attached to failure in Peavler's study. Physiological measures other than pupil response were not taken in his work.

In summary, it appears that the evidence marshalled thus far regarding cognitive and affective influences on pupillary dilation has failed to definitively answer all questions concerning this issue. Support has been reliably found to show that the pupil response is a highly sensitive indicator of cognitive difficulty and load factors; however, as the preceding discussion has indicated, it would be unwarranted and premature at this time to reject the possibility of affectual factors also precipitating increased dilation. Additional physiological response measures, infrequently used in the past, may prove to be effective tools with which to examine these factors.

Problem and Hypotheses

The research literature in pupillometry has shown that emotional, incentive and thought stimuli can all result in pupillary dilation (Hess, 1972; Kahneman and Peavler, 1969; Tryon, 1975). During cognitive activity, the pupil has been shown to respond in a pattern similar to GSR and HR (Kahneman et al., 1969), but to be a more sensitive indicator of cognitive difficulty and load factors than these other physiological measures (Colman and Paivio, 1969). GSR and HR were shown to increase in response to threat of shock in Opton and Lazarus's study (1967); however, pupil response was not included in the measures and so the opportunity to see if it would continue to parallel the GSR and HR patterns was not available. It seems likely that PR would continue its pattern with other measures in this situation, because Nunnally et al., (1967) found that the stress of gunshot threat produced dilation increases even in the absence of a mental task.

In 1970, Polt combined a stress stimulus, threat of shock, with a mental task and the expected increase in dilation over mental task alone was found. Instead of interpreting the increased dilation as a function of the added variable, threat of shock, causing additional stress, Polt chose the interpretation of increased cognitive work to avoid the stress. Why increased cognitive effort to avoid the threatened stress rather than a response to the threat itself? Polt bases his interpretation, as discussed earlier, on a questionable comparison between his study and that of Lazarus and Opton (1966).

A more consequential source of evidence for the possibility of cognitive factors being more influential than affective factors over the pupil response was provided by Sweet (1974). This study used mental imagery as stimuli, and the intensity of the stimuli may have been lower than necessary to produce significant differences (Janisse, 1972). Nevertheless, the imagery did produce very regular pupil increases that simply were not differential ones across the affects conditions.

The present study explores the information gap between Kahneman et al.'s (1969) study measuring GSR, HR, and PR during a mental task but without a threat of shock condition, and Polt's (1970) work which provided a mental task with threat of shock, but without additional physiological measures being taken.

It has been suggested by Hess (1972) and Janisse (1973) that pupillary change in conjunction with other physiological measures and with variation of individual differences may be useful parameters to investigate. Consequently, by comparing PR, GSR, EMG, and HR measures in psychosomatic and normal individuals in a paradigm with combined features of Polt's (1970) and Kahneman's (1969) work, the present study attempts to re-examine previous conclusions regarding cognitive and affectual influences on the pupil.

The following hypotheses were investigated:

I. That pupillary dilation is influenced by the interaction of cognitive and affective factors if they are simultaneously present.

Specific predictions under this hypothesis were:

(1) Response magnitude would be significantly greater in the task with incentive condition than in the task alone, and greatest in the task with threat of shock condition.

(2) All measures will decrease significantly in the control period.

II. That subjects with psychosomatic disorders would show greater physiological reactivity on one or more of the four selected measures than normals when problem-solving under stress.

Specific predictions under this hypothesis were:

(1) Pupillary dilation would be greater for psychosomatic Ss than normals in the task with threat of shock condition.

(2) Those Ss with internal psychosomatic disorders would respond with greater heart activity than normals or external disorder Ss in the task with threat of shock condition.

(3) Those Ss with external psychosomatic disorders respond with greater GSR and/or EMG activity than normal or internal disorder Ss in the task with threat of shock condition.

III. That all physiological indices would be higher in the threat of shock without mental task, or countdown condition, than in the threat of shock during mental task condition.

The pupil, as indicated in Hypothesis I, is predicted to respond to the interaction of both task and threat of shock (cognitive and affective factors) if they are simultaneously present. In fact, all four measures are expected to increase during task with threat, with differences being predicted based on psychosomatic classifications. This is not meant to imply, however, that there is an additive relationship occurring, resulting in task plus threat having a greater magnitude than either separately. Instead, it is a subtractive model that is being proposed by the third hypothesis. When the threat of shock is present during problem-solving, it is expected that the mental work will bring about a lowering of the impact of the threat of shock below what would occur if only a threat of shock were present. This prediction is based partly on the speculation that problem-solving forms a "distraction" for the subject which prevents him from focusing attention fully on the threat; and partly on the research discussed by Seligman (1975), which indicates that lessened control over a situation results in increased psychophysiological symptoms. Problem-solving to avoid shock does provide more of an element of control than is possible when the threatened shock is based on chance.

CHAPTER III

METHODOLOGY

Subjects

A modified Cornell Medical Index (Appendix A) was distributed to undergraduate classes at a south central United States university, with a total of 124 questionnaires distributed before thirty subjects (Ss) fitting the necessary criteria were found. The ten Ss for the normal group were recruited on the basis of all negative replies to the questionnaire, while the ten internal and ten external psychosomatic Ss were selected after responding affirmatively to one or more of the questions in the appropriate symptom categories. Appendix E shows the items responded to affirmatively by each of the psychosomatic groups. The Ss received extra credit for their participation. All Ss were male since, as previously mentioned, gender has been found to be an influencing factor in magnitude of response in electromyogram recordings (Small and Gross, 1958). The age range of the Ss was 18 to 30 years, with a mean age of 20.4 years.

All Ss were informed of the possibility of mild electric shock being involved before they consented to participate in the experiment. One subject in the normal group had to be replaced when he changed his mind and left the experiment at the beginning of the threat of shock trial. Four other Ss were replaced due to various problems in the equipment which resulted in loss of data.

Apparatus

Pupillometric data was obtained with equipment essentially similar to that employed in all recent research in pupillometry (see Hess, 1965). The pupillometer used in this experiment consists of a 1.27 cm plywood rectangular viewing box with inside dimensions of 57.15 cm x 57.15 cm x 123.19 cm. The front, or S's end of the box, was enclosed except for an opening in the center to provide for viewing the rear of the box and to allow for photographing of the S's eyes. This opening was provided with a stationary eyepiece that incorporated a red lighting system to provide a red light source for the infrared film and an adjustable chin rest. The opening extended far enough downward to allow Ss to speak unimpeded. The rear end of the box was opened and fitted with a tight fitting polyethylene screen with a black fixation cross (1.905 cm high with 1.27 cm arms) positioned in the center. All interior surfaces were painted flat black to minimize reflectance.

A Beaulieu R16 movie camera was positioned on the side of the box to the S's right. The camera was mounted on a fully adjustable support which provides for precise adjustments of camera position and focus. The lens of the camera extends approximately .3175 cm into the interior of the box through a tight fitting aperture in a system of sliding panels designed to allow adjustment in camera position.

A half-silvered mirror was positioned adjacent to the S's end of the pupillometer which extends from top to bottom and from side to side, thus completely subtending the field of view within the box. The mirror was positioned at a 45 degree angle to both the S's forward line of vision and the central axis of the camera lens. This positioning of the mirror allows the subject a clear view of the fixation cross on the rear of the screen and also allows a reflected image of the right eye to strike the camera lens system.

The camera used was a Beaulieu R16ES equipped with a Vemar 135 mm f/2.8 telephoto lens, a Vemar "C" mount adapter and a 30mm extension tube to provide for precise focusing at a lens to subject distance of 60.96 cm. Camera speed was set and calibrated to 2 frames/second (exposure duration of .2 seconds per frame) driven by a regulated power supply to prevent speed fluctuations (Raytheon VR6114). Kodak High Speed Infrared Type 2481 film was used and developed with Kodak Microdol X developer, Kodak Rapid Fix and Kodak Photo-Flo solutions. Each roll was processed individually in a Superior Color Reel 16mm bulk film developing tank. The processed film was scored by displaying the pupil image in a microfilm reader, Xerox Microforms Reader Model 2240, which produced an image magnification of forty times the film size. The combination of lens on the 16mm camera and the magnification of the microfilm reader produced an image ten times the actual size of the pupil. Pupil diameter was measured directly from the screen of the microfilm reader with a transparent ruler, to the nearest millimeter, which would correspond to the nearest tenth millimeter of actual pupil diameter change.

All trials were run in the same room under constant lighting and temperature conditions. Windows were covered with an opaque black paper to eliminate variation in external light conditions.

The rear projection screen was illuminated by a 200 watt incandescent bulb in a flexible desk lamp positioned behind the fixation cross. The eyepiece contains five miniature 12 volt bulbs powered by a variable transformer set to provide illumination at S's eye of approximately 16-18 ft.-c.

All instructions and stimulus items were presented over a tape recorder (Uher Royal de Luxe) equipped with headphones for the S. One channel of the tape recorder controlled camera operation. Cues placed on the control channel activated a sound-operated relay within the tape recorder which is connected by cable to start and stop by automatic control.

Connected to the audio output of the tape recorder was an external sound-operated relay (Grason-Stadler, Model E7300A-1) which controls a frame marker. The onset of stimuli activates a pinhole light source mounted inside the eyepiece and out of the S's line of sight. It served to identify the sequence of stimulus events on the developed film.

The basic recording system for GSR, EMG, and HR was the Physiograph Six (Narco Bio-Systems, Inc., Houston, Texas) which permits six channels of recording and an event marker. Heart rate was monitored by a silver disc electrode placed on the upper left area of the S's chest, with a ground electrode located on the lower right side of the chest. Heart rate was measured in beats per minute by multiplying the number of beats contained in a 25mm length of responses by twelve, which is equivalent to multiplying the number of beats in 5 seconds times 12 to equal the seconds contained in a minute. In this way a second by second measure of heart rate was available, since each consecutive 5mm space on the recording paper represented one second of time.

Electromyographic recording was monitored by two silver disc electrodes placed on the skin above the forearm flexors on the right arm at a distance of approximately 10 cm. from each other. This was fed into a Hi-Gain Preamplifier (MK III) prior to its amplification

(Amplifier CA200) for visual display. This yielded a channel of raw EMG. The output from this channel was then fed into an integrator (EMG Integrator MK III) which permitted an integrated display on an adjacent channel. This measure of EMG was integrated microvolts. Redux Creme (Hewlett-Packard Medical Electronics Div., Mass.) was used to provide the medium between the skin and the electrode.

All skin surfaces for the various electrode placements were cleansed initially with alcohol and lightly scrubbed with fine sandpaper to scrape off the exterior corny layers of the skin and permit better electrode pick-up.

GSR was monitored by two silver-silver chloride cup electrodes placed on the palm and ventral wrist of the S's left hand. This was fed into a GSR Preamplifier (MK II) prior to its amplification for visual display on a fourth channel. This yielded a measure of skin resistance in ohms, which was converted numerically to its reciprocal, conductance in mhos. Redux Creme was again used to provide the medium between the skin and the electrodes.

Stimuli

The S performed a mental task which increased in difficulty within each condition by requiring that he add 0, 1, or 3 to each of four serially presented digits and to respond with the transformed series after a two second pause. The task was repeated under three conditions: the first one in which the task was performed without consequence, then an equivalent task with a 5¢ reward for each correct response, then a final task with threat of mild electric shock for incorrect responses.

Table I shows the numbers actually presented in each difficulty level of each condition.

TABLE I

DIGITS TO BE TRANSFORMED

Task			Reward			Threat		
Add			Add			Add		
0	1	3	0	1	3	0	1	3
0582	6973	1864	3691	2470	7285	8024	6153	9307

Correct Transformations

	Task	Reward	Threat
Add 0:	0, 5, 8, 2	3, 6, 9, 1	8, 0, 2, 4
Add 1:	7, 10, 8, 4	3, 5, 8, 1	7, 2, 6, 4
Add 3:	4, 11, 9, 7	10, 5, 11, 8	12, 6, 3, 10

In the final part of the experiment the mental task was removed and the S was presented with a series of ten clicks through his earphones, with a 50% probability of shock on the tenth click. The S was told that the shock would be delivered if he was incorrect in his calling of a coin-toss.

All stimuli were presented by tape recorder. Physiological recordings of pupil, heart, GSR, and EMG changes were made during all parts of the experiment.

Procedure

The S was seated before the pupillometer while all recording equipment was attached. After a ten minute habituation period, during which the recording equipment was being adjusted, the heart rate baseline was taken. The average number of beats per minute during a single 30 second epoch was used as the baseline, with the heart rates reported throughout the experiment being change scores from this baseline. All EMG scores reported are based on absolute change from zero, in terms of integrated microvolts. Both GSR and pupil measurements were taken from a running baseline. The responses during the three seconds prior to the ready signal for each sequence of trials were averaged to provide a baseline for that particular series. The running baseline was used as an attempt to correct for the expected marked habituation in these measures during the experiment. A tape recorded set of instructions was then played (Appendix B). Three practice trials without recordings were run to allow the S to become familiar with the equipment and task. The author served as experimenter (E) for all Ss.

After the practice trials were completed the S was allowed to ask any questions which he had before starting the experiment.

The experiment was paced by 1/sec. pulses of 10 msec. duration recorded on magnetic tape along with the digits. The "ready" signal coincided with the first pulse, the instructions to add 0, 1, or 3 were given on pulses 3 and 4, the digits were presented on pulses 6-9, and S was instructed to respond with the transformed series of digits on pulse 11. The S was told to relax on the 24th second. Rest periods of ten seconds each were allowed between the trials in all three conditions. The S could close his eyes at that time, but was asked to remain in the headrest until the end of each condition, at which time he could sit back and relax while listening to the next set of instructions (Appendix B).

Reward and threat conditions were carried out in the same format as the first condition. Immediately after the reward trial the S was paid the amount he had earned through correct responses, so as to increase the credibility that the mild electric shock would also be immediately given. At the start of the threat condition an electrode was attached to the right side of tht S's neck. He was told that an incorrect response outside of the undisclosed permissible range of error would result in an electric shock, and that about 50% of the people who try these problems get them all correct. No shocks were actually given.

After the threat condition was completed, the S was told to relax. The final experimental condition then began. The S was told that many people make errors when they are concerned about shocks and that he did very well. He was told further that some measurements of responses to shock from Ss who had not made any errors were needed, and that the decision of which Ss to choose of those who had not made large errors would be determined by a coin-toss. He was then told to place his head back into the rest, and then to call "heads" or "tails." He was then instructed to listen to the final set of instructions (Appendix B).

Ten clicks at a rate of one click each two seconds were sounded, with the subject informed that he may or may not receive a shock on the tenth click, depending on the outcome of the coin toss. In this manner, the S's expectancy of shock was approximately 50% on both the threat of shock trials and the threat alone, and the element of uncertainty was therefore held more constant. The S received no shocks in this final condition. Each S was completely debriefed as to the purpose of the experiment and his full cooperation in not discussing it was requested.

Design and Analyses

Three repeated measures analyses of variance (ANOVA) were used in this study to evaluate the effects of the various independent variables on each of the dependent variables.

In the first part of the experiment, a 3x3x3x24 repeated measures analysis of variance with repeated measures on three of the four factors was employed for each of eight dependent variables: the response magnitude and latency of pupil, heart, muscle, and skin conductance changes. The between Ss factor (A) included three levels: normal, internal psychosomatic, and external psychosomatic groups. Factors B, C, and D were the within-Ss factors. Factor B had three levels: task alone, task with reward, and task with threat of shock. Factor C had three levels: the three degrees of digit transformation difficulty. Factor D had 24 levels: the 24 seconds during each sequence.

For the shock countdown, a 3x20 repeated measures ANOVA was used to investigate how the three symptom groups (Factor A) respond on ten consecutive two second trials approaching the time of possible shock and ten two second trials immediately after the time of possible shock in the absence of a mental task. This 3x20 ANOVA was computed for four dependent variables: pupil, heart, muscle, and skin conductance magnitudes.

To compare the responses of the three symptom groups under the threat of shock when they have a task to complete and when they have no

To compare the responses of the three symptom groups under the threat of shock when they have a task to complete and when they have no task to undertake, a 3x2 repeated measures ANOVA was employed for each of four dependent variables: pupil, heart, muscle, and skin conductance magnitudes. Specifically, on the repeated measures factor, the measure that was used for the response on the threat plus task condition was the peak response on problem number three, the most difficult digit transformation task. The measure which was used for the response in the threat without task condition was obtained from the peak response occurring in the time space from the fifth trial prior to possible shock to the fifth trial after possible shock, during the shock countdown condition.

Pupil Response

Four analyses of variance were concerned with pupil response. The first ANOVA evaluated pupil response magnitude in the task alone, task with reward, and task with threat of shock. If the pupil response is sensitive to level of affect, then changes in pupil magnitude would be expected to be greater in the threat condition than in either the task alone or reward conditions, and the reward condition should have higher response magnitude than the task alone. Also, a significant group x condition interaction would be expected of the form that psychosomatic Ss should give larger pupillary dilation responses than normals in the threat of shock condition. Planned comparisons were used to evaluate this prediction and also to see if the internal and external psychosomatic Ss differed from each other.

The second ANOVA compared pupil latencies in the task conditions. Latencies were expected to be longer with increases in task difficulty, and planned comparisons evaluated this expectancy. There was insufficient information to make further predictions.

An ANOVA on pupil response in the threat alone, or countdown condition, was done to see if there were differences between normal and psychosomatic Ss, and between the two types of psychosomatic Ss. Planned comparisons were again used to evaluate the differences.

The final ANOVA regarding magnitude of pupil response was a comparison of the threat plus task and countdown conditions. The peak pupil response for problem No. 3 of the task plus threat conditions was compared to the peak response in the countdown condition. It was expected that the countdown would produce more dilation in all Ss and, again, that psychosomatic Ss in general would have increased dilation over normals when evaluated by planned comparisons.

Galvanic Skin Response and Electromyogram

The analyses for GSR and EMG were the same as for the pupil, with the exception that the external psychosomatic groups were expected to respond with greater magnitude than either the normal or internal groups in both threat situations, with and without task.

Heart Rate

Again, the analyses to be performed were the same as described for the pupil, but in this case the internal psychosomatic group was expected to respond with greater magnitude than either the normal or external groups in both threat situations, with and without task.

CHAPTER IV

RESULTS

Change scores were calculated for each of the four dependent variable measures. For the electromyogram (EMG) responses, the change consisted of the number of integrated microvolts of deflection from the zero baseline. For the heart, the rate of change in beats per minute from the prestimulus resting heart rate level was used. For both the pupil and skin conductance measures, the changes were from a running baseline consisting of the average of the three seconds prior to the ready signal for each sequence of trials. Pupillary measures were in millimeters of change from baseline, while skin conductance was measured in micromhos.

Baseline averages were: 70 beats per minute for heart rate; 4.3 mm for pupil; and, 10.32 micromhos for skin conductance. As shown in Appendix D, the differences among the groups for baseline responses were not significant for any of the three measures. EMG baselines were not available, since the change scores were taken from the zero point of an integrated response measure.

The conventional .05 level of probability was used as the minimum for an effect to be considered significant. A conservative F test (Geisser and Greenhouse, 1958) with reduced degrees of freedom was used to determine significance, due to the increased possibility of Type I error introduced by the large number of degrees of freedom associated with the trials factor, and to compensate for possible violations of the symmetrical matrix assumption underlying the statistical model.

Main Effects

Group

The overall analyses of variance are provided in Appendix E. They show that the group to which the subject belonged, whether external, internal or normal, accounted for significant differences in the magnitude of a bodily response only for the muscle response during tasks (Table V). Post hoc analysis with a Tukey HSD Test, presented in Table XLIV, showed that, as predicted, subjects with external psychosomatic symptoms had the highest amount of muscle response with differences significantly higher (p < .05) than either the internals or the normals. The internals had the least response, but the differences between internals and normals were not significant.

Dunn's Multiple Comparison Tests (Tables XXIV through XXVII) inspected the specific prediction that, when threatened with shock for an incorrect task solution, the groups would show individual differences in physiological responding. In this specific condition, as with the overall task experiment, the group effect was significant only for the muscle response, with external Ss averaging 52.46 microvolts compared to 23.02 and 17.63 for normals and internals respectively. The external group responded with the largest amount of pupil dilation also, when evaluated by planned comparisons (Table XXVII) in the task situation with threat of shock; however, the differences were not significant. For both the heart and skin conductance measures, the planned comparisons (Tables XXV and XXIV) indicated that it was the normal subjects who responded the highest while solving problems under the stress of threat of shock. In both cases the internal group had the second largest amount of response, but again the differences were not significant. This tendency for the normal group to respond with higher heart rate and skin conductance than the psychosomatics in the task with threat of shock condition did not actually match-up with the average for the three task sequences combined. The internal group had the highest overall response for both of these measures, with the normals and then externals lowest for the heart, and the reverse order for skin conductance. The differences were not significant.

The group effect was not significant in any of the analyses of countdown, countdown versus task with threat, or latency of response, as can be seen in Tables VII through XIX.

In summary, it appears that the external group reliably produced the expected significantly higher amounts of muscle tension throughout all parts of the experiment. At the same time, the external group also was lowest in heart rate, but with differences that did not reach significance. Pupillary dilation appears to follow a pattern quite similar to the EMG, with external subjects showing the highest amounts of dilation of the three groups; again, however, the differences were not significant. The internal subjects displayed the highest heart rate for task alone, reward, and countdown; but, it was the normal group that edged the internal group out of the highest position in the task with threat of shock situation. While EMG, heart rate, and pupillary dilation displayed some consistent differences due to the effect of group, the skin conductance response failed to show any particular pattern.

Condition

The condition factor consisted of task alone, reward, task with threat of shock, and countdown, the threat without task condition. As shown in Table IV, only the heart rate was significantly influenced by the condition in the task sequence. In order to more closely examine this effect, a Tukey HSD Test was used (Table XLV). It showed that the threat of shock condition with task present was significantly higher ($p < .01$) in rate of heart response than either the reward or task alone conditions, the two of which did not differ significantly. The reward condition produced the least heart rate.

For both pupil and skin conductance, the task condition produced the highest response, followed by the threat and then the reward. For EMG, the order of response magnitude showed threat to be highest and task alone lowest. Differences for pupil, skin conductance and muscle were not significant.

When the task with threat of shock was compared to the countdown condition, both the pupil and the heart showed significant differences (Tables XIV and XII). In both cases the task with threat condition had significantly higher ($p < .001$) response measurements than the countdown. This trend is repeated for both the muscle and skin conductance measures, although the differences are not significant. This is the opposite of the expected outcome. It had been hypothesized that, when there was no task present to allow the subject some control over the delivery of the shock, then the subject would respond with higher physiological responses.

When the latency of response was analyzed, as shown in Tables XV through XIX, there were significant differences ($\underline{p} < .025$) between the skin conductance latencies for the condition factor. A Tukey HSD Test was used to examine these differences (Table XLVI). It showed that the task with threat of shock condition had a significantly longer period of seconds to peak response in skin conductance than the reward condition ($\underline{p} < .01$). The task alone and task with threat were not significantly different. The task with threat condition resulted in the longest EMG and pupil latencies also, although not significant. Latency differences were extremely small for the three conditions for heart rate, with reward resulting in a slightly longer latency than task or threat, in that order.

In summary, it appears that the task with threat of shock condition, while significantly higher than the other two conditions only in heart rate, does produce consistently higher responses than the countdown condition. For the most part, the effect of offering a reward of 5¢ per correct response was negligible or non-existent.

Difficulty Level and Trials

For both the pupil and skin conductance measures, the difficulty level of the task, to add 0, 1, or 3 to each of the four digits presented, interacted with the trials, the seconds during the experiment. This is shown in Tables III and VI for the overall analyses of variance, and will be discussed further in the next section.

The EMG showed slight differences in muscle responding according to difficulty level, with adding 0 having the least response magnitude, and adding 3 the most, but without significant differences. The trial effect was also non-significant for EMG.

Heart rate varied significantly due to the main effects of both the difficulty level ($p < .001$) and the trial ($p < .001$), but without significant interaction between them. A Tukey HSD Test (Table XLVII) showed that there were significant differences ($p < .01$) in heart rate between add 0 and add 1, add 0 and add 3, and add 1 and add 3. The add 0 condition was lowest in heart rate, and the add 3 highest.

One of the predictions in this study dealt specifically with trials and stated that all four measures would decrease significantly when the subject was not involved in a stimulus sequence. These non-stimulus times between sequences are called "control" periods in the prediction. The first and last trials of each sequence are used to represent the control period. The eleventh trial, when the subject was instructed to respond, was chosen to represent the stimulus sequence. A Dunn's Multiple Comparison Test was performed on each of the four dependent measures to see if this prediction was supported. As shown in Tables XXXVI through XXXIX, all four of the measures have the expected significantly lower magnitude of response ($p < .05$ or less) in the control period.

In order to see if the countdown condition also had a significant decrease in responding in the control periods, Dunn's Multiple Comparison Tests were again used for all four measures. The three trials compared in this instance were: the first trial, or beginning of the countdown; the tenth trial, or time of possible shock; and, the final trial when the condition was ending. Tables XL through XLIII show the results of the planned comparisons. For all measures, the highest response level occurs at trial ten, the time the shock was expected, and the lowest level is at trial twenty, as the countdown was ending. Trial ten was significantly higher than trial twenty for all four measures ($p < .05$ for EMG and heart; $p < .01$ for pupil and GSR). In other words, there was a significant change in response simply due to the fact that the subject was anticipating a shock. When no shock occurred and the period of threat was ending, there was significantly less physiological activity. The differences between trial one, at the beginning of the countdown, and trial ten, the time of expected shock, were significantly different for skin conductance and pupil only.

When response latency was analyzed (Tables XV through XIX), it was shown that all four dependent variables had a significant difficulty main effect. In general, GSR latency was significantly longer than the other three measures, and pupil, with the shortest overall latency, was significantly shorter than both GSR and EMG latencies (Table LIII). It was predicted that latency would increase as difficulty increased, and so Dunn's Multiple Comparison Tests (Tables XXVIII through XXXI) were used to investigate this prediction. As expected, response latencies did increase for all four physiological measures as a consequence of increasing the difficulty of the task. The increase in latency was uniformly significant at the $p < .01$ level for all measures for differences between add 0 and add 3. The pupil and skin conductance showed significantly longer latencies ($p < .01$ and $p < .05$, respectively) between adding 0 and adding 1, while the EMG had a significantly ($p < .01$) longer latency for add 3 than for add 1.

To summarize, for both the pupil and skin conductance, the difficulty level and trials interacted, and will be discussed in the next section. For the muscle response, neither difficulty level nor trial effects were significant, although the response measure increased in step with the difficulty level. The heart had significant main effects for both difficulty levels and trials, without an interaction between them. All four measures displayed significant increases in trials during stimulus periods over trials approaching control periods for both task conditions and countdown. Increases in the difficulty level resulted in increases in the latency of the response for all four indices.

Interactions

As shown in Table VI and illustrated in Figure 1, there was a significant difficulty level by trials interaction ($p < .001$) for the pupil response. Simple effects tests (Table XX) were performed to specify more clearly the relationships within the interaction. They showed that there was a significant difference between pupil responses for difficulty levels at all except the first, second, and fourth trials of the task experiment. Figure 1 illustrates the nature of these differences and shows that the add 1 and add 3 difficulty levels respond in an essentially similar pattern until after the response was given by the subject, at which time the reduction in pupil dilation was more rapid for add 1 than for add 3. The add 0 difficulty level followed the same general pattern of changes, at an obviously lesser magnitude of response than add 1 or add 3. Simple effects tests also indicate that the change in magnitude of pupil dilation within each individual difficulty level over trials was significant ($p < .001$).

There was also a significant difficulty level by trials interaction ($p < .05$) for skin conductance (Table III). Figure 2 illustrates this interaction. Simple effects tests (Table XXI) showed that significant

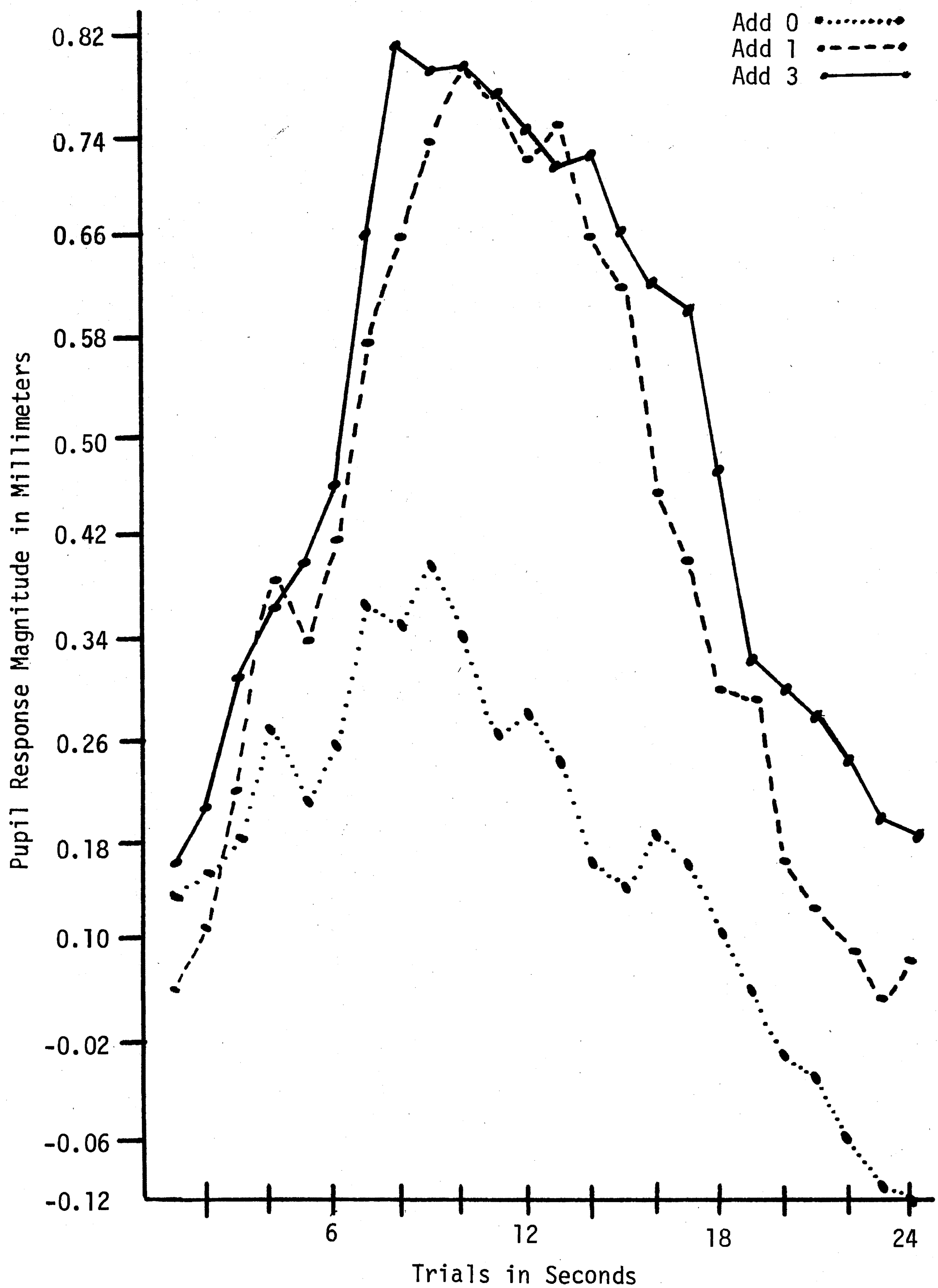

Figure 1. Pupil Dilation Over Trials at Each Difficulty Level

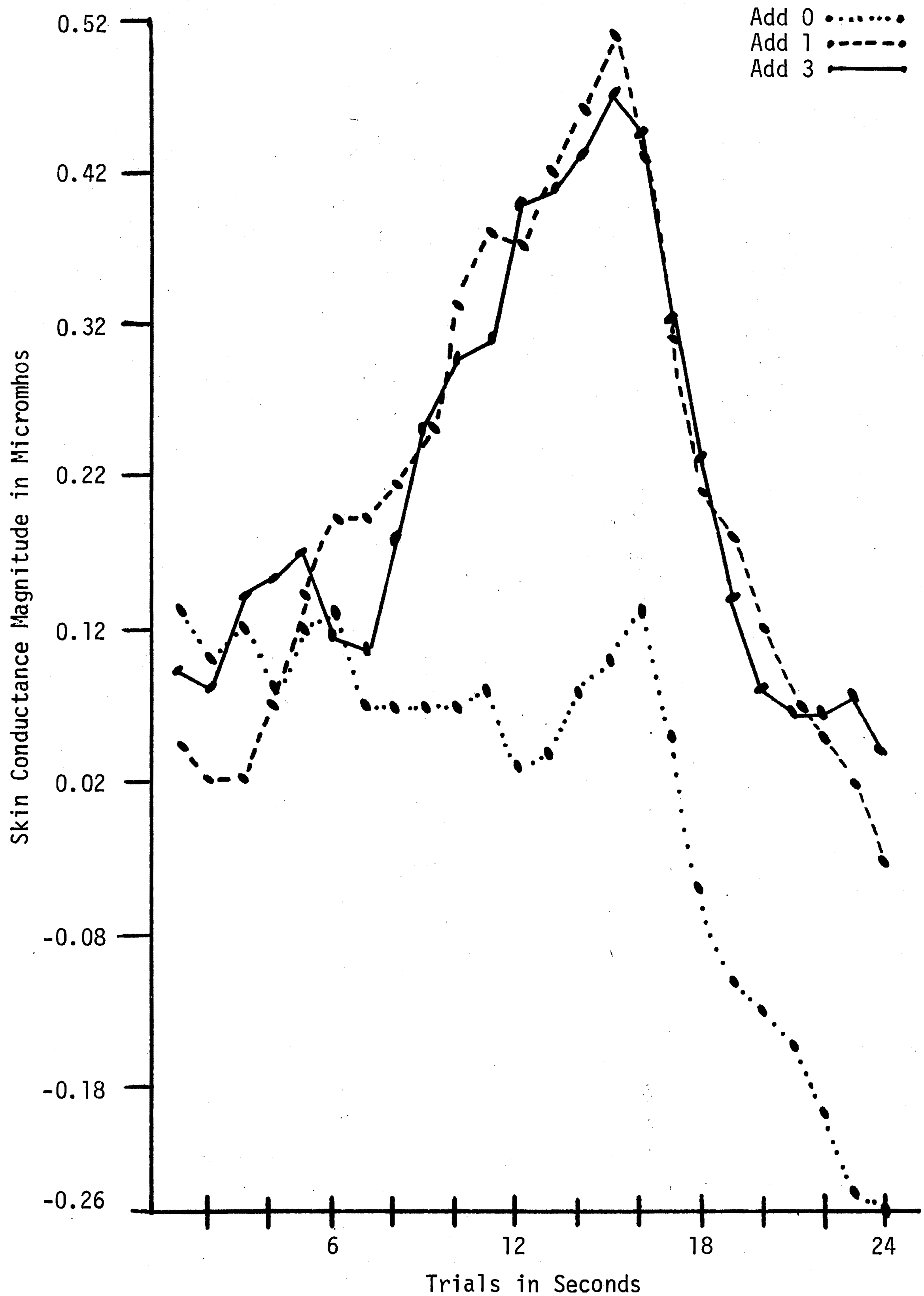

Figure 2. Skin Conductance Over Trials at Each Difficulty Level

differences between difficulty levels were found for trials 10 through 24, with the exception of trial 21. Inspection of Figure 2 indicates that, as with the pupil interaction of difficulty level and trials, there was very little difference between magnitude of responding for add 1 and add 3 over each of the trials, while obviously large differences existed between add 0 and the other two difficulty levels. Significant levels of magnitude change during trials occurred for both the add 1 ($p < .025$) and the add 3 ($p < .005$) difficulty levels, but not for the add 0 level.

A significant interaction between groups and conditions occurred in the muscle response when the task with threat condition was compared to the countdown condition (Table XIII). Figure 3 illustrates this interaction, showing that while magnitude of EMG was higher in the external group, the internal group was responding in a different way than either externals or normals by being more responsive to the countdown than to the task with threat. Simple Effects Tests in Table XXII showed that there was a significant difference between groups at countdown condition, and between conditions for the internal group. The difference between conditions for the internal group is self-explanatory, since only two conditions were being compared. The internal group had significantly higher ($p < .025$) muscle response during the countdown than when doing a task under threat of shock. A Tukey HSD Test was used to make the differences between the groups during the countdown clearer. As shown in Table XLVIII, the internal group and external group reacted in a significantly different manner during the task plus threat condition, with the internal group lower. The differences between the

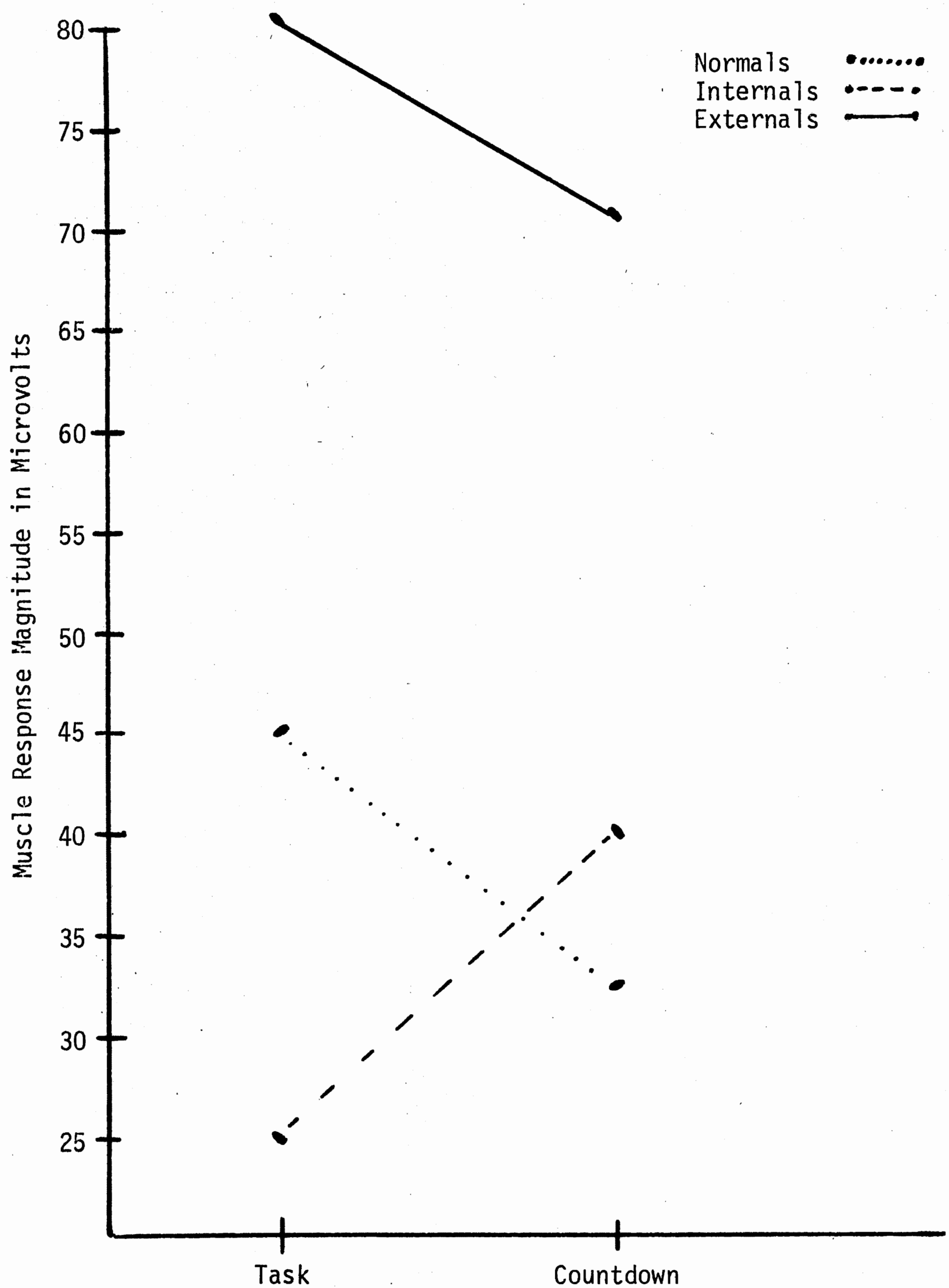

Figure 3. Muscle Response of Groups in Task With Shock Versus Countdown

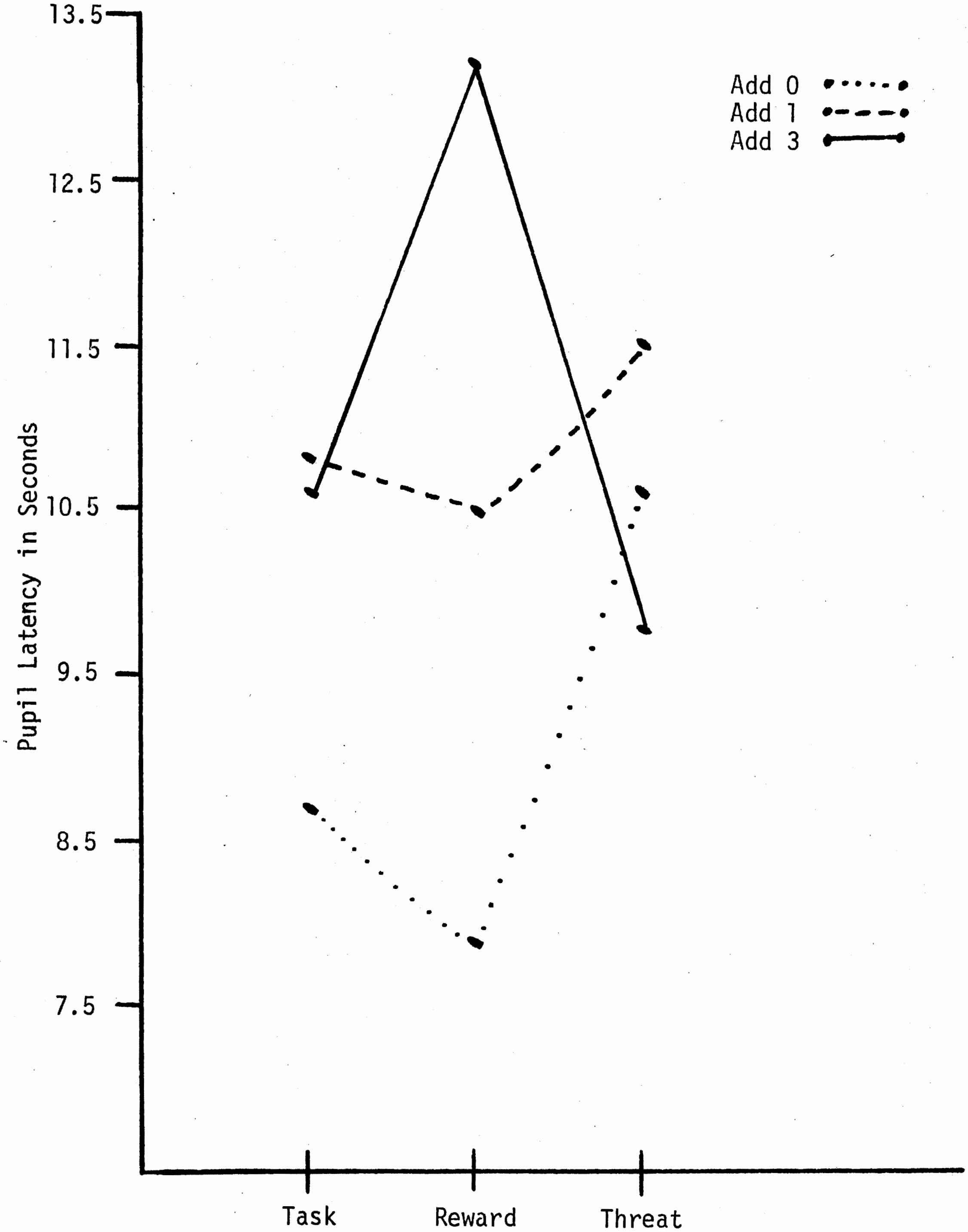

Figure 4. Pupil Latency: Conditions by Difficulty Levels

internal group and the normal, and between the external group and the normal, were not significant.

A significant interaction in pupil latency of response took place between conditions and difficulty levels, as illustrated in Figure 4 and presented in Table XIX. Simple Effects Tests (Table XXIII) showed that the significant differences existed between conditions at difficulty level add 0, and difficulty level add 3 ($p < .01$ and $p < .001$, respectively) and between difficulty levels at conditions of task alone and reward ($p < .025$ and $p < .001$, respectively). Tukey HSD Tests were used to define these differences more clearly in Tables XLIX through LII. During the add 0 difficulty level, the threat condition was shown to be significantly longer in latency than either the reward condition ($p < .01$) or the task condition ($p < .05$). During the add 3 difficulty level, the reward condition had the longest latency, significantly longer ($p < .01$) than either the task alone or task with threat conditions ($p < .01$ each). The task alone condition had significantly longer latencies for add 3 ($p < .05$) and add 1 ($p < .01$) than for the add 0 level, but the add 1 and add 3 difficulty levels were not significantly different. The reward condition showed significant differences ($p < .01$) between each of the three difficulty levels, with the add 3 difficulty level producing the longest latency, and add 0 the shortest. In this instance, the addition of a threat of shock condition appeared to have interfered with the pupil latency's discrimination of difficulty levels. Whether this represents an affectual influence on the pupil may be open to speculation; however, two factors in the present experiment might refute this. First, the results in the overall experiment tend to support the view of the pupil as primarily sensitive to cognitive load and effort.

This will be reviewed further in the discussion section. Second, there is a possibility that the way the difficulty task set-up may have resulted in a subject having some choice in the way he applied mental effort. The subject can increase his effort to rehearse the numbers so as not to accidentally forget one, and this effort would reveal itself in a heightening of response closer to the time that the digits are all received, on second nine. The mean peak pupil response for threat of shock with the most difficult task was at 9.7 seconds. Certainly the threat of shock would provide some motivation to increase effort sooner on a more difficult task. Also, the pupil peaked a second time on the 13th second, at a magnitude only .05 mm less than the earlier maximal response, and at a time one would have expected the maximal response to have occurred for the most difficult task. This could suggest that, for this particular type of difficulty task, the effect of threat of shock on more difficult tasks is a more sustained mental effort, which reflects itself in a short latency. The much longer latency seen for the add 3 task in the reward condition coincided also with reduced magnitude of responding when compared to task alone or task with shock. Since the reward condition in general appeared to be influenced by habituation, it may be that the subject felt confident in his ability to do the task and had little to lose with such a small reward being offered. Consequently, he may have shown maximal dilation when he was actually responding rather than in any effort prior to that time.

Figure 5 displays the changes in each of the four measures over trials at each of the various conditions. This illustration allows some general overview of the trends for the experiment as a whole.

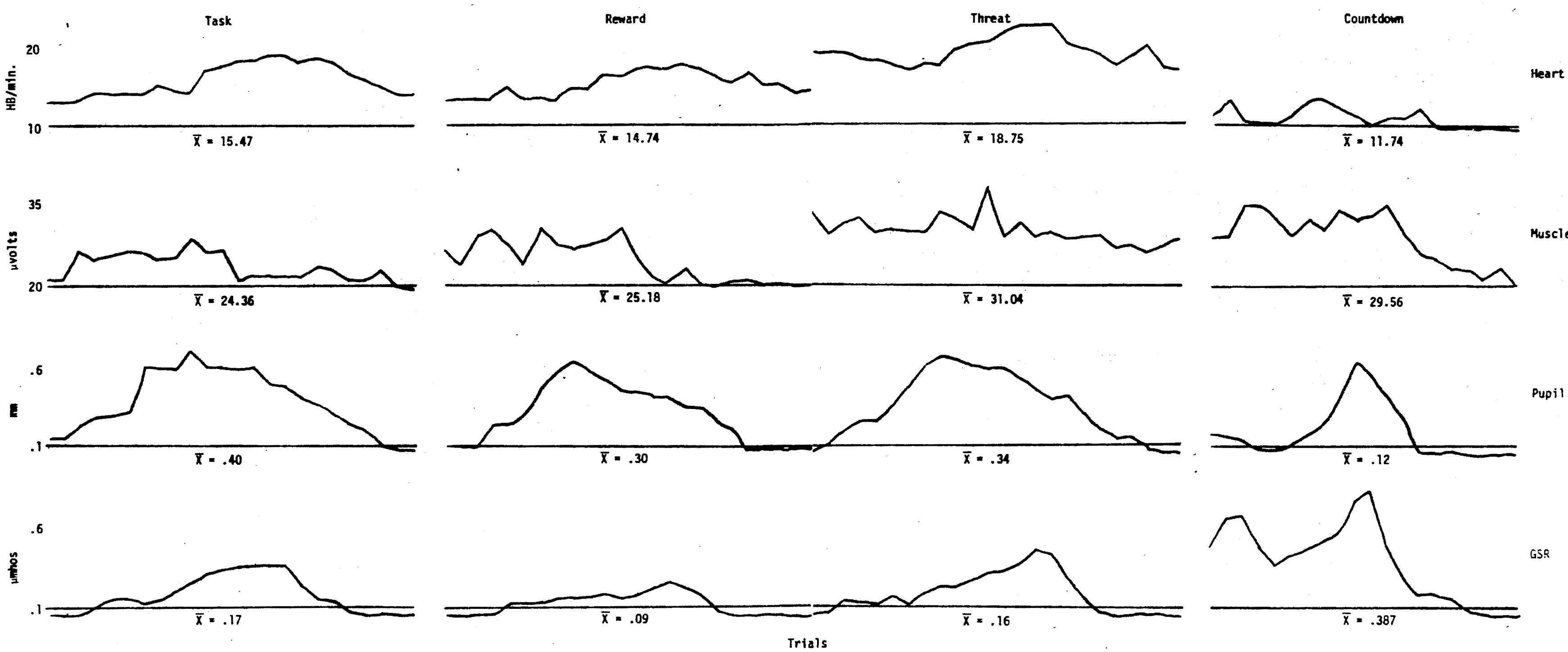

Figure 5. Conditions by Trials for All Measures

CHAPTER V

DISCUSSION AND SUMMARY

Discussion

The hypotheses for this study were designed to provide some insight into four main questions: Does the same stress situation result in different responses for different kinds of psychosomatic subjects? Does a threat result in more arousal when it is based on "chance" than when problem-solving can avoid it? How do responses to problem-solving vary when an incentive or a threat are included? Do some physiological indices, such as pupillary dilation, reflect mental work more accurately while others respond more to emotional arousal? The three hypotheses which these questions dealt with were advanced in Chapter II (pp. 32-33). Mixed support was found for the first two, while the third hypothesis was, for all but one exception, not supported.

Does the same stress situation result in different responses for different kinds of psychosomatic subjects? For subjects classified as external, those expressing symptoms of skin disorders such as itching, rashes or frequent acne, the answer was yes. The external people showed muscle tension at a level significantly higher than either of the other two groups throughout the time that they were performing mental tasks, and continued to be highest in the countdown, although the difference was not significant during that sequence. For subjects classified as internal, those expressing gastro-intestinal distress, the answer is a much more qualified yes. The internal subjects had the highest heart rate in all conditions except performance of a task while under threat. This is curious since the threat of shock for incorrect problem-solving did produce the highest responses for all three groups. Yet it appears that the internal subject responds to having a problem to solve with a heart rate moderated mainly by task difficulty, with less concern for threat of shock than the other subjects. When there was no problem to solve, then the heart rate dropped significantly for all groups despite the fact that a threat was still being issued in the countdown. What did happen, however, was that the internal subject then responded with significantly higher muscle tension than he had shown during problem-solving. Exactly why this happens is open to interpretation, but to some extent it may reflect another attempt on the part of the ulcer patient to problem solve or cope. Since he has agreed to participate and is hence taking his chances on receiving a shock, the best thing to do may be to "brace" for it muscularly, much in the same manner that one grips the dentist's chair a little as the drill starts. Such a bracing easily shows itself in EMG responding. Since the internal group had the lowest EMG in the task with threat condition, the increase in muscle tension would be more likely to show significance for this group in the comparison of task with threat versus countdown.

The external group's muscle response, although showing some variations in accordance with the conditions, for example, responding highest when problem-solving under threat or when doing a more difficult problem, did not really vary all that much. The general response to all stresses, from simple problem to threats of shock, was to have a relatively uniform, higher level of muscle response than the other subjects.

In posing the question about the same stress situation resulting in different responses in different psychosomatic subjects certain outcomes had been predicted, based on such studies as Little (1950), Fisher and Cleveland (1968), and Moos and Engel (1962). The second hypothesis was that subjects with psychosomatic disorders would show greater reactivity than normals when problem-solving under stress. Both psychosomatic groups were expected to respond with more pupil dilation than normals, and they did, but not significantly; externals were expected to respond with higher EMG and/or GSR, and they did respond with significantly higher EMG in all of the task conditions; and, internals were expected to respond with increased heart rate, which was not supported for the particular condition of task with threat, although they did show a higher heart rate generally.

The outcomes in this study thus provide mixed support for the second hypothesis, with a clear suggestion that external psychosomatic subjects tend to display more muscle tension generally, and a trend toward ulcer-type subjects responding with a heart rate higher than other subjects, and muscle tension less than other subjects, during mental work. It had been predicted that mental tasks would help distract the subject from the threat of shock and thus result in lower responding than in the countdown. Although this prediction was largely unsupported, it does appear that for the internal group the mental work provided some distraction sufficient enough to reduce muscle tension below what they expressed in the countdown.

Does threat result in more arousal when it is based on "chance" than when problem-solving can avoid it? Hypothesis III contended that such would be the case: that all physiological indices would be higher in the threat of shock without mental task, or countdown condition, than in the threat of shock during mental task condition. That hypothesis was almost completely non-supported by the results, the only exception being the internal group's increase in muscle response during countdown, as was just discussed. Despite the finding that there was no increase in responding in the countdown when compared to the task with threat, some suggestion of differences between the physiological measures was given by the significant decrease in two of the measures, the pupil and the heart. Both the EMG and skin conductance measures continued to respond at a similar magnitude as was present when the subject was solving a problem under threat, even when there was no task present but the pupil and the heart decreased. The pupil decrease is no surprise due to the absence of mental work. Why did the heart decrease?

Rogers Elliott (1974) discusses changes in heart rate that may provide some understanding of why heart rate responded as in the mental tasks versus the countdown situation. He writes:

> When doing mental arithmetic, subjects are busily talking to themselves. . . . the degree of activity of the organism as a result of task requirements can serve to account reasonably well for the results (higher heart rate). In discussing their experiment on looking at pictures varying in pleasantness, the Lacey's (1967) deal with the apparent heart rate deceleration to very unpleasant pictures. I think they are correct in noting that subjects must frequently be fascinated (orient steadily and without interruption) by pictures of, for example, homicide victims. But to say that subjects intend "to note and detect" fascinating stimuli is only really to observe that subjects do note and detect, usually very quietly, fascinating pictorial stimuli. The relative somatic quieting suits pretty well as an explanation, without reference to states of mind. These remarks would apply to important incentive stimuli, such as shocks. There is little question that most subjects would orient quietly to the source of such stimuli, with accompanying low heart rate (pp. 515-516).

Such a lowered heart rate, below the task conditions although not below the resting baseline, accompanied the countdown condition when the subjects sat waiting for a possible shock.

Seligman (1975) expresses some ideas that may also help explain the lowering of heart rate in the countdown. In his book Helplessness (1975) Seligman relates many cases of animal experiments in which loss of control over outcomes results in stomach ulcers in various animals tested. One would, of course, expect that increased internal responding facilitated the ulcer development. If extrapolated to humans in the present experiment, one might also expect that threat of shock by chance, without problem-solving as a means of avoidance, would also lead to increased internal responding, namely heart rate. As already noted, this did not occur. Instead, there was a quieting of heart rate. Why? Seligman suggests the answer himself. The factors most often attributed by him to helplessness are loss of controllability and loss of predictability. The subjects in the present experiment knew of the possibility of shock in advance and were free to go at any time, in fact one did. They knew the nature of the shock was described as mild, and could predict that, if the shock came at all, it would occur on the number ten. In short, they did have control and the ability to predict many things even though the delivery of the shock was based on chance factors. This is not undermining of the role of the possible shock as a mild stressor, since its effects are clearly visible in the experiment; however, the area of the body to be affected was the external skin surface, so it is hardly surprising that skin conductance and skeletal muscle responses would remain active.

How do responses to problem-solving vary when an incentive or a threat are included? In this instance, the incentive produced no visible effect in any of the dependent measures. In fact, the EMG measure was the only one which remained essentially at the same magnitude as in the task alone sequence; the other three measures dropped. Kahneman and Peavler (1969) had found that greater pupil dilation occurred on high reward trials (5¢) than on low reward trials (1¢) on a paired-association learning task. They concluded that the significant response difference was a function of the amount of mental effort expended in recalling the response item rather than the degree of arousal elicited by the 5¢ reward. It appears that in the present study, a 5¢ incentive for each correct series (15¢ total) did not provide any real cause for increased effort, probably because of the small amount of money involved. Perhaps a more substantial reward would have shown different results.

The series of conditions from task alone to reward to task with threat provides a built-in element of conservativism, since it can be assumed that the Ss' responses would naturally decrease as the familiarity with the task increased. The occurrence of lower pupil response, for example, with continuous experience with the same stimulus or in the same stimulus situation has been alluded to by Hess (1965), Kahneman and Beatty (1967), and Kahneman and Peavler (1969) and has been categorized under "habituation and practice effects" by Kahneman and Peavler (1969). It can therefore be assumed that, without the threat of shock, the third experience with the tasks would have approximated the level of the reward condition or lower. Instead, there is an increase in response magnitude in all four dependent measures. The increase is smallest for the pupil which, although responding higher than in the reward condition, does not approach the same magnitude as in the task alone, when the task was still somewhat unfamiliar. Polt (1970) reported pupillary increases when Ss were threatened with shock for incorrect responses to arithmetic tasks. The Ss in that study were given a five-minute break after a single series of three problems, before the shock series was started. The Ss in the present study performed two series of problems and then, with time in-between only for instructions, they began the threat of shock series. This difference in procedure may provide some clue as to the difference in pupillary response reported in the two studies. The habituation processes could have been sufficiently interrupted by the rest period so that the representation of arithmetic problems in the new series was a more novel occurrence than was possible in continuous tasks.

Do some physiological indices, such as pupillary dilation, reflect mental work more accurately, while others respond more to emotional arousal? The results of this study suggest yes. The experiment was designed so as to be able to compare task with threat to each of them separately. The reward condition was intended as a "positive" motivation, in contrast to the "negative" motivation of shock, but the size of the reward resulted in the condition becoming only a display of habituation with decreasing physiological responding. The task alone, task with threat, threat alone design, however, did allow some differences in responding to become evident. With "affect" operationally defined as responding to threat alone, i.e., the countdown condition, one can see that both skin conductance and EMG display more affective arousal in the present study than pupil or heart. Additionally, the pupil and the heart rate are both more accurate indicators of the level of difficulty of the task than EMG or skin conductance. Both the pupil and the heart rate decrease significantly when the task is removed and the countdown to possible shock is present. The EMG and skin conductance continue to respond at the same high magnitudes of response as in the task with shock, and they maintain the high level of responding longer. The heart rate increases during mental work and decreases during countdown appear to follow closely the patterns already described by Elliott (1974), i.e., changing as a function of activity level requirements, in this case mental activity.

Both the question just discussed, and the previous question regarding how responses to problem-solving change with reward and threat, deal with the first hypothesis: that pupillary dilation is influenced by the interaction of cognitive and affective factors if they are simultaneously present. This hypothesis predicted an increase in pupil responding in reward above task, and task with threat above both task alone and reward. It was unsupported by the results. The slight recovery in pupil response during task with threat above the level in reward is probably best explained as increased mental effort, as Polt (1970) had contended.

This hypothesis dealt specifically with the pupil for several reasons. There is no lack of evidence regarding the dual role of EMG, GSR and heart rate in reflecting both mental task and emotional factors. Goldstein (1972) points out that high EMG levels characterize responsive and emotional individuals. Lader and Mathews (1971) state that high EMG levels correlate with performance in reaction-time tasks, vigilance tasks, and mirror-drawing tasks. GSR and heart rate have been shown to respond in a pattern very similar to the pupil during performance of a mental task (Kahneman et al., 1969) yet they are still closely linked to emotional factors. Lazarus et al. (1963) state: "There is abundant evidence that most autonomic indicators, including skin conductance, heart rate and respiration, are responsive to heightened emotional states."

Despite the dual role for these other measures, the pupil has been reported as more of an index of cognitive load and task difficulty, and as less sensitive to emotional factors (Kahneman et al., 1969; Polt, 1970; Sweet, 1974). The present study attempted to sort out the mental effort and the emotional factors in order to see more clearly the effect of their simultaneous presence.

Polt (1970) believed that if it were emotional stress causing greater pupil dilation in his tasks with threat than in task alone, then one should expect to see greater pupil dilation even between problems in the control periods, since the anticipation of shock would still exist. He states that Lazarus and Opton (1966) "using another autonomic measure, skin conductance, showed that a considerable response occurs during the period when Ss are anticipating a scene in a motion picture designed to induce stress" (p. 592). The present study has contended that the control period before the problems are presented cannot be considered comparable to the GSR increase while the movie is approaching a stressful scene. The significant decrease in all four measures in this study's control periods supports this point. Additionally, none of the four measures responds diffusely to the introduction of threat of shock during task as Polt had conjectured would happen with skin conductance. Instead, there appears to be a heightening of the response magnitudes while the basic pattern of response is maintained. Despite this disagreement with how Polt arrived at his final premise of pupil dilation reflecting increased mental effort to avoid shock, the results of the present study do support his conclusion.

Kahneman and Beatty (1966) and Kahneman et al. (1969) had reported that the significant difference they found in time of peak response as a function of difficulty was unique to the pupil. In the report by Kahneman et al. (1969) the heart had unexpectedly peaked prior to the pupil, while skin conductance peaked last, probably due to its longer latency. In the present study the pupil had the shortest amount of time to maximal change, peaking during the pause between receiving the digit series and responding. The heart and EMG then peaked, in that order, as the responding began; and the skin conductance peaked two seconds after the beginning of responding. The significant difference in time of peak response as a function of difficulty was not unique to the pupil in the present study. Both the pupil and skin conductance had significant differences between all three difficulty levels, while heart rate showed a significant difference between add 0 and add 3, and EMG had significant differences between both add 0 and add 3, and add 1 and add 3. This is essentially similar to Kahneman et al.'s (1969) study, since the peak response in each measure was ordered as a function of task difficulty, but the differences were not significant in their work. In the present study, latency of response was found to be more sensitive to changes in difficulty level than magnitude of response for the skin conductance and muscle response measures, while heart rate magnitude was more sensitive than latency, and pupil responses were equally sensitive in both.

Additional research into psychosomatic responses to stress is certainly warranted, since the types of problems in the current living times contribute substantially to both physical and psychological stress. Increasing the understanding of how individual physiological measures respond in psychosomatic subjects can be a useful line of research to follow and, as the present study suggests, specifying the types of psychosomatic symptoms allows a much clearer idea of which physiological measures are more pertinent for development of different symptoms.

The present study lends strong support to past findings that the pupil is more responsive to cognition than to affect. The factorial arrangement that was used provided a means of comparing pupillary changes to mental task difficulty and affect separately, as well as in combination. The presence of a realistic affectual influence could be discerned by the simultaneous recording of heart, muscle, and skin responses, each of which displayed some variation attributable to the presence of the affect variable. In contrast, the pupil was responsive only to changes in mental effort and task difficulty levels. This appears to make the pupil a particularly useful tool with which to further study memory, mental fatigue, and cognitive effort.

Summary

The purpose of the present study was twofold: to study the responses of different types of psychosomatic subjects to a stress situation; and to re-examine pupillary responses to mental and emotional stimuli. Specifically, it was hoped that the experiment would help to investigate the questions of whether over-stimulation of a particular bodily system during stress contributes to physical disorders; and whether the pupil primarily reflects mental processes. It has been previously suggested (Hess, 1972; Janisse, 1973) that pupillary change in conjunction with other physiological measures and with variation of individual differences could be useful parameters to investigate. The Ss performed a mental arithmetic task with three levels of difficulty and with conditional reward and threat while time-locked measures of pupil diameter, heart rate, skin conductance, and muscle responses were taken. Additional recordings were taken when there was no mental task to perform, and a threat of shock could be delivered by the outcome of a coin-toss.

Analyses of variance were performed on the response magnitudes and latencies. It was found that Ss with external psychosomatic disorders responded to the experimental situation with significantly higher muscle tension. Heart rate was unique in being equally sensitive to the difficulty of the task as well as the shock contingency when both were present; yet, like the pupil, it was not very responsive to the threat of shock during countdown when the mental task was absent. Skin conductance and muscle response showed patterns of response similar to pupil and heart rate during problem-solving, but also were responsive to affective stimuli alone in the countdown. Only the pupil measures were equally sensitive to task difficulty levels in both response magnitude and latency, supporting previous findings that the pupil is primarily sensitive to mental load and effort factors.

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APPENDIX A

HEALTH QUESTIONNAIRE

MODIFIED CORNELL MEDICAL INDEX

HEALTH QUESTIONNAIRE

Name ______________________________ Age ___ Phone _______

Circle the most accurate answer for you. Answer all questions.

1. Do your eyes continually blink or water? Yes No
2. Do you often suffer from an upset stomach? Yes No
3. Do you suffer badly from frequent severe headaches? Yes No
4. Is your skin very sensitive or tender? Yes No
5. Do you have frequent loose bowel movements? Yes No
6. Are you often bothered by severe itching? Yes No
7. Does your skin often break out in a rash? Yes No
8. Are you frequently ill? Yes No
9. Do you have frequent problems with acne? Yes No
10. Does your thinking get mixed up when you have to do things quickly? Yes No
11. Do you suffer from constant stomach trouble? Yes No
12. Has a doctor ever said you have stomach ulcers? Yes No
13. Has a doctor ever said you had colitis? Yes No
14. Are you often troubled with boils? Yes No
15. Do you suffer from any chronic disease? Yes No
16. Do you frequently have arthritis pains? Yes No
17. Do you frequently have problems with eczema, psoriasis, or other skin disorders? Yes No

Note for Appendix: External items: 4,6,7,9,14,16,17; Internal items: 2,3,5,11,12,13; Screening items: 1,8,10,15.

APPENDIX B

INSTRUCTIONS

INSTRUCTIONS TO SUBJECTS

The following tape-recorded instructions were played for each subject.

In this experiment we will be measuring changes in body responses as you do some mental tasks. You will hear the word "Ready." This is a signal to you to look directly at the small black cross inside the box. Now place your chin in the chinrest in a comfortable position and look directly at the small black cross. Try to keep as still as possible during the experiment. You will be told to add some number to each digit in a series you are given, and then to reply with the new series when you hear the word "Respond." For example, you may be told to add 3, and then, after several seconds be given the series 1-4-2-5; then when you are told to respond, your answer should be 4-7-5-8. If you do not understand, you may now ask the experimenter to explain further. (Tape stopped for questions.)

Now you will be given some practice problems. Remember to remain as still as possible, blink as little as possible, and look directly at the small black cross. After your response you will be told to relax. The relax time will last ten seconds. At this time you may close your eyes, but please remain in the headrest. (The following problems were then given to each subject.)

Attention	. . .	Ready	. . .	Add 0	. . .	8-6-5-1	. . .	Respond
"	. . .	"	. . .	" 1	. . .	7-5-0-3	. . .	"
"	. . .	"	. . .	" 3	. . .	9-1-2-4	. . .	"

You may now ask the experimenter if you have any further questions. (Tape stopped for questions.)

The experiment will now begin. You will be given problems like the ones you have just completed. Please look into the box again, look directly at the black cross, and move as little as possible.

Attention	. . .	Ready	. . .	Add 0	. . .	0-5-8-2	. . .	Respond
"	. . .	"	. . .	" 1	. . .	6-9-7-3	. . .	"
"	. . .	"	. . .	" 3	. . .	1-8-6-4	. . .	"

You may now sit back and relax. The next set of problems will again be similar to the ones you have just finished except that this time you will have a chance to earn some money. For each problem that you answer correctly you will be given five cents. Get into position.

Attention	. . .	Ready	. . .	Add 0	. . .	3-6-9-1	. . .	Respond
"	. . .	"	. . .	" 1	. . .	2-4-7-0	. . .	"
"	. . .	"	. . .	" 3	. . .	7-2-8-5	. . .	"

You may now sit back and relax. You will again be presented with problems on the next trial, but this time you will be punished with a mild electrical shock to your neck if your response is incorrect beyond a certain range of error. (Electrode fastened to subject.) About 50% of the people who try these problems answer them correctly. Get into position.

Attention . . .	Ready . . .	Add 0 . . .	8-0-2-4 . . .	Respond
" . . .	" . . .	" 1 . . .	6-1-5-3 . . .	"
" . . .	" . . .	" 3 . . .	9-3-0-7 . . .	"

You may now sit back and relax. If you received an electric shock due to some error you made, then your participation in the experiment is now over. We appreciate your volunteering for the experiment and apologize for the discomfort of the shock.

If you have answered all problems within our range of error and have not yet been shocked, then it is necessary for you to take part in the final session of the experiment. The experimenter will now discuss this with you further.

S was told that he had answered all questions within the required range of error and was told to call "heads" or "tails" in a coin-toss. S was then instructed to get into position and told that if his guess in the coin toss was wrong he would receive a mild electric shock on the number ten of the countdown.

The countdown to possible shock will now begin. If you have lost the heads-tails toss, the shock to your neck will occur on the number ten: one, two, three, four, five, six, seven, eight, nine, ten. Please remain in the headrest and continue to look directly at the black cross. You may now sit back and relax. (15 seconds of recording.)

APPENDIX C

PROFILE OF SUBJECT'S PSYCHOSOMATIC SYMPTOMS

External Subjects

Ss	Sensitive Skin No. 4	Itch-ing No. 6	Rash No. 7	Acne No. 9	Boils No. 14	Arth-ritis No. 16	Skin Disorders No. 17
	Question Number						
1)	X	X		X			
2)	X	X		X			X
3)	X	X	X				X
4)				X			
5)	X	X		X		X	X
6)					X		
7)	X		X				X
8)				X		X	
9)							X
10)			X	X			

Internal Subjects

Ss	Upset Stomach No. 2	Head-aches No. 3	Loose Bowel Movements No. 5	Constant Stomach Trouble No. 11	Stomach Ulcers No. 12	Colitis No. 13
	Question Number					
1)					X	
2)				X		
3)					X	
4)					X	
5)					X	
6)					X	
7)	X			X		
8)	X			X		
9)	X		X	X		
10)					X	

APPENDIX D

BASELINE ANALYSES OF VARIANCE

TABLE II

BASELINE ANALYSES OF VARIANCE

Source	df	MS	F
Pupil			
Groups	2	.0620	.2288
Subj. W. Groups	27	.2702	
Heart			
Groups	2	100.6000	1.6542
Subj. W. Groups	27	60.8150	
Skin Conductance			
Groups	2	94.6500	2.897
Subj. W. Groups	27	32.6700	

APPENDIX E

OVERALL ANALYSES OF VARIANCE

TABLE III

SUMMARY OF THE ANALYSIS OF VARIANCE OF GSR MAGNITUDE DURING TASKS

Source	df	MS	*F*
<u>Between Subjects</u>			
Group (A)	2	3.2144	0.2780
Subj. W. Groups	27	11.5615	
<u>Within Subjects</u>			
Condition (B)	2	4.5997	0.9212
A x B	4	3.6131	0.5933
B x Subj. W. Groups	54	4.9929	
Difficulty (C)	2	27.3046	4.9873*
A x C	4	3.9481	0.7211
C x Subj. W. Groups	54	5.4748	
Trial (D)	23	4.1242	12.0276†
A x D	46	0.2827	0.8244
D x Subj. W. Groups	621	0.3428	
B x C	4	1.9672	0.4569
A x B x C	8	2.5917	0.6019
B x C x Subj. W. Groups	108	4.3055	
B x D	46	0.1473	1.3249
A x B x D	92	0.1360	1.2230
B x D x Subj. W. Groups	1242	0.1112	
C x D	46	0.6677	4.7324*
A x C x D	92	0.1558	1.1048
C x D x Subj. W. Groups	1242	0.1410	
B x C x D	92	0.1197	0.9339
A x B x C x D	184	0.1221	0.9524
B x C x D x Subj. W. Groups	2484	0.1282	

(Corrected df; see text.)

*$p < .05$.

†$p < .005$.

TABLE IV

SUMMARY OF THE ANALYSIS OF VARIANCE OF HEART MAGNITUDE DURING TASKS

Source	df	MS	*F*
Between Subjects			
Group (A)	2	2589.7290	0.27844
Subj. W. Groups	27	9300.9908	
Within Subjects			
Condition (B)	2	11471.0440	8.58247*
A x B	4	1709.0075	1.27866
B x Subj. W. Groups	54	1336.5664	
Difficulty (C)	2	30102.2861	32.78592†
A x C	4	989.4079	1.07761
C x Subj. W. Groups	54	918.1469	
Trial (D)	27	1248.6587	15.22094†
A x D	54	74.1877	0.90434
D x Subj. W. Groups	729	82.0356	
B x C	4	906.0647	3.41569
A x B x C	8	165.3829	0.62346
B x C x Subj. W. Groups	108	265.2654	
B x D	54	62.2377	1.53575
A x B x D	108	46.5379	1.14885
B x D x Subj. W. Groups	1458	40.5259	
C x D	54	188.6016	3.85959
A x C x D	108	32.6440	0.66803
C x D x Subj. W. Groups	1458	48.8658	
B x C x D	108	54.4296	1.38874
A x B x C x D	216	32.8610	0.83843
B x C x D x Subj. W. Groups	2916	39.1936	

(Corrected df; see text.)

*$p < .005$.

†$p < .001$.

TABLE V

SUMMARY OF THE ANALYSIS OF VARIANCE OF MUSCLE MAGNITUDE DURING TASKS

Source	df	MS	F
Between Subjects			
Group (A)	2	679388.042	4.6835*
Subj. W. Groups	27	145059.218	
Within Subjects			
Condition (B)	2	28610.372	3.1456
A x B	4	1074.595	0.1181
B x Subj. W. Groups	54	9095.341	
Difficulty (C)	2	3677.022	1.5303
A x C	4	1549.595	0.6449
C x Subj. W. Groups	54	2402.753	
Trial (D)	23	2249.220	3.4074
A x D	46	710.121	1.0757
D x Subj. W. Groups	621	660.095	
B x C	4	1177.064	0.5366
A x B x C	8	1893.312	0.8631
B x C x Subj. W. Groups	108	2193.453	
B x D	46	290.292	1.0245
A x B x D	92	328.283	0.9450
B x D x Subj. W. Groups	1242	283.326	
C x D	46	295.360	0.9984
A x C x D	92	279.588	0.9450
C x D x Subj. W. Groups	1242	295.833	
B x C x D	92	355.178	1.4173
A x B x C x D	184	250.166	0.9982
B x C x D x Subj. W. Groups	2484	250.597	

(Corrected df; see text.)

*$p < .01$.

TABLE VI

SUMMARY OF THE ANALYSIS OF VARIANCE OF PUPIL MAGNITUDE DURING TASKS

Source	df	MS	*F*
Between Subjects			
Group (A)	2	7.2973	0.9006
Subj. W. Groups	27	8.1023	
Within Subjects			
Condition (B)	2	4.7265	3.5966
A x B	4	0.5309	0.4040
B x Subj. W. Groups	54	1.3141	
Difficulty (C)	2	61.2125	65.2843*
A x C	4	1.0100	1.0772
C x Subj. W. Groups	54	0.9376	
Trial (D)	23	11.0079	97.6678*
A x D	4	0.1135	1.0078
D x Subj. W. Groups	621	0.9376	
B x C	4	3.1760	2.5979
A x B x C	8	1.2622	1.0324
B x C x Subj. W. Groups	108	1.2225	
B x D	46	0.1442	2.4431
A x B x D	92	0.0607	1.0296
B x D x Subj. W. Groups	1242	0.0590	
C x D	46	0.8356	15.5681*
A x C x D	92	0.0405	0.7555
C x D x Subj. W. Groups	1242	0.0536	
B x C x D	92	0.1499	2.8346
A x B x C x D	184	0.0532	1.0055
B x C x D x Subj. W. Groups	2484	0.0529	

(Corrected df; see text.)

*$p < .001$.

TABLE VII

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
GSR MAGNITUDE DURING COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	.87520	.8249
Subj. W. Groups	27	1.06090	
Within Subjects			
Trials (B)	19	1.77099	14.0500*
A x B	38	.23220	1.8420
B x Subj. W. Groups	513	.12604	

(Corrected df; see text.)

*$p < .001$.

TABLE VIII

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
HEART MAGNITUDE DURING COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	1369.62	1.2789
Subj. W. Groups	27	1070.87	
Within Subjects			
Trials	19	97.91	3.2099
A x B	38	18.93	.6205
B x Subj. W. Groups	513	30.50	

TABLE IX

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
MUSCLE MAGNITUDE DURING COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	48714.8000	2.1868
Subj. W. Groups	27	22276.0170	
Within Subjects			
Trials	19	701.2070	3.0880
A x B	38	164.6827	.7252
B x Subj. W. Groups	513	227.0707	

TABLE X

SUMMARY OF THE ANALYSIS OF VARIANCE FOR
PUPIL MAGNITUDE DURING COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	.1310	.4114
Subj. W. Groups	27	.3184	
Within Subjects			
Trials	19	1.5709	28.4141*
A x B	38	.0242	.4370
B x Subj. W. Groups	513	.0553	

(Corrected df; see text.)

*$p < .001$.

TABLE XI

SUMMARY OF THE ANALYSIS OF VARIANCE OF GSR MAGNITUDE IN TASK WITH THREAT VERSUS COUNTDOWN

Source	df	MS	F
Between Subjects			
Group (A)	2	.72120	.7044
Subj. W. Groups	27	1.02380	
Within Subjects			
Condition (B)	1	.04004	.0996
A x B	2	.00593	.0147
B x Subj. W. Groups	27	.40214	

TABLE XII

SUMMARY OF THE ANALYSIS OF VARIANCE OF HEART MAGNITUDE IN TASK WITH THREAT VERSUS COUNTDOWN

Source	df	MS	F
Between Subjects			
Group (A)	2	120.600	.8610
Subj. W. Groups	27	140.066	
Within Subjects			
Condition (B)	1	3197.400	45.2036*
A x B	2	29.400	.4157
B x Subj. W. Groups	27	70.730	

(Corrected df; see text.)

*$p < .001$.

TABLE XIII

SUMMARY OF THE ANALYSIS OF VARIANCE OF MUSCLE MAGNITUDE IN TASK WITH THREAT VERSUS COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	10707.7770	2.51430
Subj. W. Groups	27	4258.6890	
Within Subjects			
Condition (B)	1	71.2860	.33449
A x B	2	1057.7265	4.96309*
B x Subj. W. Groups	27	213.1186	

(Corrected df; see text.)

*$p < .025$.

TABLE XIV

SUMMARY OF THE ANALYSIS OF VARIANCE OF PUPIL MAGNITUDE
IN TASK WITH THREAT VERSUS COUNTDOWN

Source	df	MS	*F*
Between Subjects			
Group (A)	2	.084470	.92878
Subj. W. Groups	27	.090949	
Within Subjects			
Condition (B)	1	2.265900	20.66800*
A x B	2	.008200	.07490
B x Subj. W. Groups	27	.109600	

(Corrected df; see text.)

*$p < .001$.

TABLE XV

SUMMARY OF THE ANALYSIS OF VARIANCE OF LATENCY OVER ALL MEASURES

Source	df	MS	F
Between Subjects			
Group (A)	2	0.4860	0.03630
Subj. W. Groups	27	13.3970	
Within Subjects			
Measure (B)	3	230.6145	17.42530*
A x B	6	7.4700	0.56448
B x Subj. W. Groups	81	13.2345	
Condition (C)	2	15.0394	1.47100
A x C	4	12.9280	1.26450
C x Subj. W. Groups	54	10.2240	
Difficulty (D)	2	277.1194	40.08800*
A x D	4	12.7722	1.84760
D x Subj. W. Groups	54	6.9130	
B x C	6	19.6280	3.28650
A x B x C	12	9.4900	1.58900
B x C x Subj. W. Groups	162	5.7357	
B x D	6	9.7290	1.69600
A x B x D	12	7.6930	1.34000
B x D x Subj. W. Groups	162	5.7357	
C x D	4	23.7710	3.64400
A x C x D	8	15.4230	2.36390
C x D x Subj. W. Groups	108	6.5242	
B x C x D	12	28.3204	4.51800†
A x B x C x D	24	7.4020	1.18090
B x C x D x Subj. W. Groups	324	6.2680	

*$p < .001$.

†$p < .05$.

TABLE XVI

OVERALL ANALYSIS OF VARIANCE
FOR GSR LATENCY

Source	df	MS	*F*
Between Subjects			
Group (A)	2	9.1000	.4466
Subj. W. Groups	27	20.3750	
Within Subjects			
Condition (B)	2	57.2770	6.5474*
A x B	4	14.0287	1.6036
B x Subj. W. Groups	54	8.7480	
Difficulty (C)	2	82.6778	7.6364*
A x C	4	17.1110	1.5804
C x Subj. W. Groups	54	10.8268	
B x C	4	16.5539	2.2095
A x B x C	8	14.4311	1.9261
B x C x Subj. W. Groups	108		

(Corrected df; see text.)

*$p < .025$.

TABLE XVII

OVERALL ANALYSIS OF VARIANCE
FOR HEART LATENCY

Source	df	MS	F
Between Subjects			
Group (A)	2	4.45930	.4730
Subj. W. Groups	27	9.42670	
Within Subjects			
Condition (B)	2	4.63700	1.0740
A x B	4	3.29260	.7627
B x Subj. W. Groups	54	4.31687	
Difficulty (C)	2	29.62590	7.4740*
A x C	4	6.06480	1.5300
C x Subj. W. Groups	54	3.96378	
B x C	4	8.44259	1.9203
A x B x C	8	6.31480	1.4363
B x C x Subj. W. Groups	108	4.39650	

*$p < .025$.

TABLE XVIII

OVERALL ANALYSIS OF VARIANCE
FOR MUSCLE LATENCY

Source	df	MS	*F*
Between Subjects			
Group (A)	2	4.2396	.3939
Subj. W. Groups	27	10.7620	
Within Subjects			
Condition	2	2.9233	.3938
A x B	4	12.0222	1.6195
B x Subj. W. Groups	54	7.4230	
Difficulty (C)	2	77.8084	16.0550*
A x C	4	8.8057	1.8170
C x Subj. W. Groups	54	4.8463	
B x C	4	4.6360	.7540
A x B x C	8	6.1437	.9992
B x C x Subj. W. Groups	108	6.1484	

(Corrected df; see text.)

*$p < .001$.

TABLE XIX

OVERALL ANALYSIS OF VARIANCE
FOR PUPIL LATENCY

Source	df	MS	*F*
Between Subjects			
Group (A)	2	5.2110	.40964
Subj. W. Groups	27	12.7210	
Within Subjects			
Condition (B)	2	9.8110	1.27490
A x B	4	12.3889	1.60990
B x Subj. W. Groups	54	7.6950	
Difficulty (C)	2	119.4778	26.15620*
A x C	4	4.4220	.96810
C x Subj. W. Groups	54	4.5678	
B x C	4	78.9889	11.03050†
A x B x C	8	9.1583	1.27890
B x C x Subj. W. Groups	108	7.1609	

*$p < .001$.

†$p < .005$.

APPENDIX F

SIMPLE EFFECTS SUMMARY TABLES

TABLE XX

SIMPLE EFFECTS TEST FOR PUPIL RESPONSE MAGNITUDE: DIFFICULTY X TRIALS INTERACTION

Source	SS	df	MS	F
Bet. C at d_1	.5413	2	.2706	2.9900
Bet. C at d_2	.4364	2	.2182	2.4109
Bet. C at d_3	.7892	2	.3946	4.3599*
Bet. C at d_4	.6480	2	.3240	3.5798
Bet. C at d_5	1.6850	2	.8427	9.3111†
Bet. C at d_6	2.3008	2	1.1504	12.7106**
Bet. C at d_7	4.2284	2	2.1142	23.3594††
Bet. C at d_8	9.7955	2	4.8978	54.1144††
Bet. C at d_9	7.9983	2	3.9991	44.3990††
Bet. C at d_{10}	12.0092	2	6.0046	66.3442††
Bet. C at d_{11}	15.7940	2	7.8970	87.2526††
Bet. C at d_{12}	11.8573	2	5.9290	65.5044††
Bet. C at d_{13}	14.3320	2	7.1660	79.1759††
Bet. C at d_{14}	16.9285	2	8.4643	93.5201††
Bet. C at d_{15}	14.6712	2	7.3356	81.0498††
Bet. C at d_{16}	6.0085	2	3.0043	33.1935††
Bet. C at d_{17}	8.5990	2	4.2995	47.5045††
Bet. C at d_{18}	6.3578	2	3.1789	35.1231††
Bet. C at d_{19}	3.6673	2	1.8336	20.2597††
Bet. C at d_{20}	3.8258	2	1.9129	21.1353††
Bet. C at d_{21}	3.5715	2	1.7858	19.7304††
Bet. C at d_{22}	3.9086	2	1.9543	21.5928††

TABLE XX (Continued)

Source	SS	df	MS	F
Bet. C at d_{23}	3.8300	2	1.9150	21.1587††
Bet. C at d_{24}	4.1707	2	2.0854	23.0409††
Error C at d_1	117.2970	1296	.0905073	
Bet. D at c_1	43.0707	23	1.8726	25.5291††
Bet. D at c_2	139.3628	23	6.0592	82.6039††
Bet. D at c_3	109.1523	23	4.7458	64.6974††
Error D at c_k	136.6819	1863	.0733531	

(Corrected df; see text.)

*$p < .05$.

$^{\dagger}p < .01$.

**$p < .005$.

$^{\dagger\dagger}p < .001$.

TABLE XXI

SIMPLE EFFECTS TEST FOR SKIN CONDUCTANCE MAGNITUDE:
DIFFICULTY X TRIALS INTERACTION

Source	SS	df	MS	F
Bet. C at d_1	.3160	2	.1580	.4349
Bet. C at d_2	.3112	2	.1556	.4283
Bet. C at d_3	.7480	2	.3740	1.0294
Bet. C at d_4	.3391	2	.1696	.4668
Bet. C at d_5	.1017	2	.0509	.1401
Bet. C at d_6	.3150	2	.1575	.0267
Bet. C at d_7	.7270	2	.3635	1.0005
Bet. C at d_8	.9420	2	.4710	1.2963
Bet. C at d_9	1.9384	2	.9692	2.6676
Bet. C at d_{10}	3.3243	2	1.6622	4.5749*
Bet. C at d_{11}	4.3473	2	2.1737	5.9827*'
Bet. C at d_{12}	7.5237	2	3.7619	10.3540**
Bet. C at d_{13}	8.2637	2	4.1319	11.3724**
Bet. C at d_{14}	7.7164	2	3.8582	10.6190**
Bet. C at d_{15}	8.2614	2	4.1307	11.3691**
Bet. C at d_{16}	5.5117	2	2.7559	7.5851*'
Bet. C at d_{17}	4.1108	2	2.0554	5.6571*'
Bet. C at d_{18}	4.5087	2	2.2544	6.2049*'
Bet. C at d_{19}	4.4356	2	2.2178	6.1041*'
Bet. C at d_{20}	3.2951	2	1.6476	4.5347*
Bet. C at d_{21}	2.8093	2	1.4047	3.8662
Bet. C at d_{22}	4.2109	2	2.1055	5.7950*'

TABLE XXI (Continued)

Source	SS	df	MS	F
Bet. C at d_{23}	5.6815	2	2.8408	7.8188†
Bet. C at d_{24}	4.5465	2	2.2733	6.2560*'
Error C at d_1	470.8736	1296	.36333	
Bet. D at c_1	7.2120	23	.3136	1.5050
Bet. D at c_2	35.7730	23	1.5550	7.4630*'
Bet. D at c_3	51.0360	23	2.2190	10.6497**
Error D at c_k	388.1737	1863	.20836	

(Corrected df; see text.)

*p < .05.

*'p < .025.

†p < .01.

**p < .005.

††p < .001.

TABLE XXII

SIMPLE EFFECTS TEST FOR MUSCLE MAGNITUDE IN TASKS WITH THREAT VERSUS COUNTDOWN: GROUP X CONDITION INTERACTION

Source	SS	df	MS	F
Bet. A at b_1	8108.120	2	4054.060	1.900
Bet. A at b_2	15422.880	2	7711.440	3.615*
Error A at b_j	11519.770	54	2133.290	
Bet. B at a_1	429.660	1	429.660	2.016
Bet. B at a_2	1058.513	1	1058.513	4.967*'
Bet. B at a_3	698.562	1	698.562	3.277
Error B at a_i	5754.200	27	213.119	

(Corrected df; see text.)

*$p < .01$.

*'$p < .025$.

TABLE XXIII

SIMPLE EFFECTS TEST FOR PUPIL LATENCY:
CONDITION X DIFFICULTY INTERACTION

Source	SS	df	MS	F
Bet. B at c_1	116.071	2	58.036	7.9067*
Bet. B at c_2	17.432	2	8.716	1.1875
Bet. B at c_3	201.801	2	100.900	13.7467†
Error B at c_k	1181.740	161	7.340	
Bet. C at b_1	81.014	2	40.507	6.4338*'
Bet. C at b_2	428.072	2	214.036	33.9960†
Bet. C at b_3	46.508	2	23.254	3.6935
Error C at b_j	1013.656	161	6.296	

(Corrected df; see text.)

*p < .01.

*'p < .025.

p < .001.

APPENDIX G

DUNN'S MULTIPLE COMPARISON TESTS

TABLE XXIV

DUNN'S MULTIPLE COMPARISON TEST ON GSR MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE TASK WITH THREAT OF SHOCK CONDITION

Groups	Means	$\bar{X}_1$	$\bar{X}_3$	$\bar{X}_2$
Externals	$\bar{X}_1$ = .0889	--	.0971	.1231
Normals	$\bar{X}_3$ = .1860		--	.0260
Internals	$\bar{X}_2$ = .2120			--

d, $p < .05$ = .3375.

TABLE XXV

DUNN'S MULTIPLE COMPARISON TEST ON HEART RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE TASK WITH THREAT OF SHOCK CONDITION

Groups	Means	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$
Externals	$\bar{X}_1$ = 17.157	--	1.6	3.172
Internals	$\bar{X}_2$ = 18.757		--	1.572
Normals	$\bar{X}_3$ = 20.329			--

d, $p < .05$ = 7.3676.

TABLE XXVI

DUNN'S MULTIPLE COMPARISON TEST ON MUSCLE RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE TASK WITH THREAT OF SHOCK CONDITION

Groups	Means	$\overline{X}_2$	$\overline{X}_3$	$\overline{X}_1$
Internals	$\overline{X}_2$ = 17.63	--	5.357	34.83*
Normals	$\overline{X}_3$ = 23.02		--	29.44*
Externals	$\overline{X}_1$ = 52.46			--

d, $p < .05$ = 29.37

*$p < .05$.

TABLE XXVII

DUNN'S MULTIPLE COMPARISON TEST ON PUPIL RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE TASK WITH THREAT OF SHOCK CONDITION

Groups	Means	$\overline{X}_3$	$\overline{X}_2$	$\overline{X}_1$
Normals	$\overline{X}_3$ = .27383	--	.06787	.15221
Internals	$\overline{X}_2$ = .34517		--	.08087
Externals	$\overline{X}_1$ = .42604			--

d, $p < .05$ = .238283.

TABLE XXVIII

DUNN'S MULTIPLE COMPARISON TEST ON GSR LATENCY FOR DIFFICULTY LEVELS

Diff. Level	Means	$\overline{X}_1$	$\overline{X}_2$	$\overline{X}_3$
Add 0	$\overline{X}_1 = 11.57$	--	1.34*	1.85†
Add 1	$\overline{X}_2 = 12.91$		--	.51
Add 3	$\overline{X}_3 = 13.42$			--

d, $p < .05 = 1.212$.

d, $p < .01 = 1.506$.

*$p < .05$.

†$p < .01$.

TABLE XXIX

DUNN'S MULTIPLE COMPARISON TEST ON HEART RESPONSE LATENCY FOR DIFFICULTY LEVELS

Diff. Level	Means	$\overline{X}_1$	$\overline{X}_2$	$\overline{X}_3$
Add 0	$\overline{X}_1 = 10.52$	--	.50	1.15*
Add 1	$\overline{X}_2 = 11.02$		--	.65
Add 3	$\overline{X}_3 = 11.67$			--

d, $p < .05 = .73289$.

d, $p < .01 = .91085$.

*$p < .01$.

TABLE XXX

DUNN'S MULTIPLE COMPARISON TEST ON MUSCLE RESPONSE LATENCY FOR DIFFICULTY LEVELS

Diff. Level	Means	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$
Add 0	$\bar{X}_1$ = 10.56	--	.64	1.87*
Add 1	$\bar{X}_2$ = 11.20		--	1.23*
Add 3	$\bar{X}_3$ = 12.43			--

d, $p < .05$ = .8112.

d, $p < .01$ = 1.0080.

*$p < .01$.

TABLE XXXI

DUNN'S MULTIPLE COMPARISON TEST ON PUPIL RESPONSE LATENCY FOR DIFFICULTY LEVELS

Diff. Level	Means	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$
Add 0	$\bar{X}_1$ = 9.09	--	1.85*	2.11*
Add 1	$\bar{X}_2$ = 10.94		--	.26
Add 3	$\bar{X}_3$ = 11.20			--

d, $p < .05$ = .7873.

d, $p < .01$ = .9784.

*$p < .01$.

TABLE XXXII

DUNN'S MULTIPLE COMPARISON TEST ON GSR MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE COUNTDOWN CONDITION

Groups	Means	$\bar{X}_1$	$\bar{X}_2$	$\bar{X}_3$
Externals	$\bar{X}_1$ = .3223	--	.0616	.1322
Internals	$\bar{X}_2$ = .3839		--	.0706
Normals	$\bar{X}_3$ = .4545			--

d, $p < .05$ = .2629.

TABLE XXXIII

DUNN'S MULTIPLE COMPARISON TEST ON HEART RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE COUNTDOWN CONDITION

Groups	Means	$\bar{X}_1$	$\bar{X}_3$	$\bar{X}_2$
Externals	$\bar{X}_1$ = 7.83	--	3.66	5.07
Normals	$\bar{X}_3$ = 11.49		--	1.41
Internals	$\bar{X}_2$ = 12.90			--

d, $p < .05$ = 8.34.

TABLE XXXIV

DUNN'S MULTIPLE COMPARISON TEST ON MUSCLE RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE COUNTDOWN CONDITION

Groups	Means	$\overline{X}_1$	$\overline{X}_2$	$\overline{X}_3$
Normals	$\overline{X}_3$ = 16.77	--	8.18	30.18
Internals	$\overline{X}_2$ = 24.95		--	22.00
Externals	$\overline{X}_1$ = 46.95			--

d, $p < .05$ = 38.10.

TABLE XXXV

DUNN'S MULTIPLE COMPARISON TEST ON PUPIL RESPONSE MAGNITUDE OF PSYCHOSOMATIC AND NORMAL Ss IN THE COUNTDOWN CONDITION

Groups	Means	$\overline{X}_3$	$\overline{X}_2$	$\overline{X}_1$
Normals	$\overline{X}_3$ = .1072	--	.0031	.0458
Internals	$\overline{X}_2$ = .1103		--	.0427
Externals	$\overline{X}_1$ = .1530			

d, $p < .05$ = .1439.

TABLE XXXVI

DUNN'S MULTIPLE COMPARISON TEST ON GSR MAGNITUDE DURING TRIALS WITH TASK PRESENT

Trials	Means	$\bar{X}_3$	$\bar{X}_1$	$\bar{X}_2$
Relax	$\bar{X}_3$ = -.0816	--	.1663*	.3357*
Ready	$\bar{X}_1$ = .0847		--	.1694*
Resp.	$\bar{X}_2$ = .2541			--

d, $p < .01$ = .1482.

*$p < .01$.

TABLE XXXVII

DUNN'S MULTIPLE COMPARISON TEST ON HEART MAGNITUDE DURING TRIALS WITH TASK PRESENT

Trials	Means	$\bar{X}_3$	$\bar{X}_1$	$\bar{X}_2$
Relax	$\bar{X}_3$ = 12.00	--	3.33*	7.68*
Ready	$\bar{X}_1$ = 15.33		--	.47*
Resp.	$\bar{X}_2$ = 19.68			--

d, $p < .01$ = 2.29.

*$p < .01$.

TABLE XXXVIII

DUNN'S MULTIPLE COMPARISON TEST ON MUSCLE MAGNITUDE DURING TRIALS WITH TASK PRESENT

Trials	Means	$\overline{X}_3$	$\overline{X}_1$	$\overline{X}_2$
Relax	$\overline{X}_3$ = 23.19	--	5.3*	9.59†
Ready	$\overline{X}_1$ = 28.49		--	4.29
Resp.	$\overline{X}_2$ = 32.78			--

d, $p < .05 = 5.2850$.

d, $p < .01 = 6.4974$.

*$p < .05$.

†$p < .01$.

TABLE XXXIX

DUNN'S MULTIPLE COMPARISON TEST ON PUPIL MAGNITUDE DURING TRIALS WITH TASK PRESENT

Trials	Means	$\overline{X}_3$	$\overline{X}_1$	$\overline{X}_2$
Relax	$\overline{X}_3$ = .0477	--	.0694*	.5527†
Ready	$\overline{X}_1$ = .1171		--	.4833†
Resp.	$\overline{X}_2$ = .6004			--

d, $p < .05 = .0691$.

d, $p < .01 = .0850$.

*$p < .05$.

†$p < .01$.

TABLE XL

DUNN'S MULTIPLE COMPARISON TEST ON GSR MAGNITUDE DURING SELECTED TRIALS IN COUNTDOWN

Trials	Means	$\overline{X}_3$	$\overline{X}_1$	$\overline{X}_2$
Trial 20	$\overline{X}_3$ = .0357	--	.4503*	.7063†
Trial 1	$\overline{X}_1$ = .4860		--	.2560†
Trial 10	$\overline{X}_2$ = .7420			--

d, $p < .05 = .208$.

d, $p < .01 = .295$.

*$p < .05$.

†$p < .01$.

TABLE XLI

DUNN'S MULTIPLE COMPARISON TEST ON HEART MAGNITUDE DURING SELECTED TRIALS IN COUNTDOWN

Trials	Means	$\overline{X}_3$	$\overline{X}_1$	$\overline{X}_2$
Trial 20	$\overline{X}_3$ = 6.60	--	4.4*	4.4*
Trial 1	$\overline{X}_1$ = 11.00		--	0.0
Trial 10	$\overline{X}_2$ = 11.00			--

d, $p < .05 = 3.24$.

*$p < .05$.

TABLE XLII

DUNN'S MULTIPLE COMPARISON TEST ON MUSCLE MAGNITUDE DURING SELECTED TRIALS IN COUNTDOWN

Trials	Means	$\bar{X}_3$	$\bar{X}_1$	$\bar{X}_2$
Trial 20	$\bar{X}_3$ = 20.40	--	8.78	11.85*
Trial 1	$\bar{X}_1$ = 29.18		--	3.07
Trial 10	$\bar{X}_2$ = 32.25			--

d, $p < .05$ = 8.84.

*$p < .05$.

TABLE XLIII

DUNN'S MULTIPLE COMPARISON TEST ON PUPIL MAGNITUDE DURING SELECTED TRIALS IN COUNTDOWN

Trials	Means	$\bar{X}_3$	$\bar{X}_1$	$\bar{X}_2$
Trial 20	$\bar{X}_3$ = -.193	--	.367*	.821*
Trial 1	$\bar{X}_1$ = .174		--	.454*
Trial 10	$\bar{X}_2$ = .628			--

d, $p < .01$ = .1956.

*$p < .01$.

APPENDIX H

TUKEY HSD TESTS

TABLE XLIV

TUKEY HSD TEST OF MUSCLE RESPONSE MAGNITUDE FOR GROUP WITH TASK PRESENT

Groups	Means	$\overline{X}_2$	$\overline{X}_3$	$\overline{X}_1$
Internals	$\overline{X}_2$ = 15.059	--	q = .3921	q = 3.93*
Normals	$\overline{X}_3$ = 18.272		--	q = 3.54*
Externals	$\overline{X}_1$ = 47.257			--

$q_{.05;\ 3,27} = 3.49.$

*$\underline{p}$ < .05.

TABLE XLV

TUKEY HSD TEST OF HEART MAGNITUDE DURING CONDITIONS WITH TASK PRESENT

Condition	$\overline{X}_2$	$\overline{X}_1$	$\overline{X}_3$
Reward $\overline{X}_2$ = 14.739	--	q = 1.012	q = 5.504*
Task $\overline{X}_1$ = 15.476		--	q = 4.492*
Threat $\overline{X}_3$ = 18.748			--

$q_{.01;\ 3,54} = 4.28.$

*$\underline{p}$ < .01.

TABLE XLVI

TUKEY HSD TEST OF SKIN CONDUCTANCE LATENCY FOR CONDITIONS

Condition	Means	$\overline{X}_2$	$\overline{X}_1$	$\overline{X}_3$
Reward	$\overline{X}_2$ = 11.84	--	q = 2.66	q = 5.10*
Task	$\overline{X}_1$ = 12.67		--	q = 2.44
Threat	$\overline{X}_3$ = 13.43			--

$q_{.05;\ 3,54} = 3.40.$

$q_{.01;\ 3,54} = 4.28.$

*$\underline{p}$ < .01.

TABLE XLVII

TUKEY HSD TEST OF HEART MAGNITUDE DURING DIFFICULTY LEVELS WITH TASK PRESENT

Diff. Level	Means	$\overline{X}_1$	$\overline{X}_2$	$\overline{X}_3$
Add 0	$\overline{X}_1$ = 12.67	--	q = 6.7760*	q = 11.3810*
Add 1	$\overline{X}_2$ = 16.76		--	q = 4.6056*
Add 3	$\overline{X}_3$ = 19.54			--

$q_{.01;\ 3,54} = 4.28.$

*$\underline{p}$ < .01.

TABLE XLVIII

TUKEY HSD TEST OF MUSCLE MAGNITUDE OF GROUPS AT TASK WITH THREAT CONDITION

Groups	Means	$\overline{X}_{22}$	$\overline{X}_{32}$	$\overline{X}_{12}$
a_2 (Internal) at b_2	$\overline{X}_{22} = 25.51$	--	q = 1.34	q = 3.75*
a_3 (Normal) at b_2	$\overline{X}_{32} = 45.09$		--	q = 2.41
a_1 (External) at b_2	$\overline{X}_{12} = 80.31$			--

$q'_{.05;\ 3,54} = 3.39.$

*$\underline{p} < .05$.

TABLE XLIX

TUKEY HSD TEST OF PUPIL LATENCY FOR ADD 0 TASK AT EACH CONDITION

Condition	Means	$\overline{X}_{21}$	$\overline{X}_{11}$	$\overline{X}_{31}$
b_2 (Reward) at c_1	$\overline{X}_{21} = 7.93$	--	q = 1.560	q = 5.459*
b_1 (Task) at c_1	$\overline{X}_{11} = 8.70$		--	q = 3.900†
b_3 (Threat) at c_1	$\overline{X}_{31} = 10.63$			--

$q'_{.05;\ 3,108} = 3.36.$

$q'_{.01;\ 3,108} = 4.19.$

*$\underline{p} < .01$.

†$\underline{p} < .05$.

TABLE L

TUKEY HSD TEST OF PUPIL LATENCY FOR ADD 3 TASK AT EACH CONDITION

Condition	Means	$\overline{X}_{33}$	$\overline{X}_{13}$	$\overline{X}_{23}$
b_3 (Threat) at c_3	$\overline{X}_{33}$ = 9.77	--	q = 1.617	q = 7.076*
b_1 (Task) at c_3	$\overline{X}_{13}$ = 10.57		--	q = 5.459*
b_2 (Reward) at c_3	$\overline{X}_{23}$ = 13.27			--

$q'_{.01;\ 3,108} = 4.19.$

*$\underline{p}$ < .01.

TABLE LI

TUKEY HSD TEST OF PUPIL LATENCY FOR TASK ALONE AT EACH DIFFICULTY LEVEL

Difficulty Level	Means	$\overline{X}_{11}$	$\overline{X}_{31}$	$\overline{X}_{21}$
c_1 (Add 0) at b_1	$\overline{X}_{11}$ = 8.70	--	q = 4.08*	q = 4.650†
c_3 (Add 3) at b_1	$\overline{X}_{31}$ = 10.57		--	q = .568
c_2 (Add 1) at b_1	$\overline{X}_{21}$ = 10.83			--

$q'_{.05;\ 3,108} = 3.40.$

$q'_{.01;\ 3,108} = 4.28.$

*$\underline{p}$ < .05.

†$\underline{p}$ < .01.

TABLE LII

TUKEY HSD TEST OF PUPIL LATENCY FOR REWARD AT EACH DIFFICULTY LEVEL

Difficulty Level	Means	$\overline{X}_{12}$	$\overline{X}_{22}$	$\overline{X}_{32}$
c_1 (Add 0) at b_2	$\overline{X}_{12}$ = 7.93	--	q = 5.55*	q = 11.66*
c_2 (Add 1) at b_2	$\overline{X}_{22}$ = 10.47		--	q = 6.11*
c_3 (Add 3) at b_2	$\overline{X}_{32}$ = 13.27			--

$q'_{.01;\ 3,108} = 4.28.$

*$\underline{p}$ < .01.

TABLE LIII

TUKEY HSD TEST OF LATENCY OF MEASURES

Measure	Means	$\overline{X}_1$	$\overline{X}_3$	$\overline{X}_2$	$\overline{X}_4$
Pupil	$\overline{X}_1$ = 10.42	--	q = 2.940	q = 4.065*	q = 9.982†
Heart	$\overline{X}_3$ = 11.07		--	q = 1.355	q = 7.046†
Muscle	$\overline{X}_2$ = 11.37			--	q = 4.517*
Skin	$\overline{X}_4$ = 12.63				--

$q_{.05;\ 4,81} = 3.71.$

$q_{.01;\ 4,81} = 4.55.$

*$\underline{p}$ < .05.

†$\underline{p}$ < .01.

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