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The Reliability of Psychophysiological Assessment: a Comparative Analysis of Two Mental and Two Physical Stressors (Test-Retest Reliability, Physiological Reactivity, Cold Pressor, Blood Pressure, Heart Rate).

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THE RELIABILITY OF PSYCHOPHYSIOLOGICAL ASSESSMENT: A COMPARATIVE ANALYSIS OF TWO MENTAL AND TWO PHYSICAL STRESSORS

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TWO PHYSICAL STRESSORS

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in

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by

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B.A., University of North Carolina, 1980
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ABSTRACT

Extensive research has been conducted assessing psychophysiological reactivity to experimental stressors in various populations. However, there is a paucity of empirical investigations concerning the test-retest reliability of these experimental stressors. Establishment of the relative reliability of specific stressor procedures is important so that results can be compared over time and across studies.

The purpose of this investigation was to compare test-retest reliability of two mental stressors (i.e. Quiz Electrocardiogram, mental arithmetic) and two physical stressors (i.e. cold pressor, isometric challenge). These stressors were presented in a counterbalanced fashion to forty-eight undergraduate and graduate students who returned two weeks later for the same stressor presentation. The experimental conditions comprised a 2 (sessions) x 2 (baseline/test) x 4 (stressors) within-subject design.

The major hypothesis was that physical stressors would have greater univariate and multivariate test-retest reliability since they are a direct function of physical stimuli and result less from cognitive mediation which can vary across sessions. Thus mental stressors were
hypothesized to have lower reliability because they directly result from cognitive involvement which may change across testing sessions. 

The results showed that all four stressors generated significant increases in physiological arousal over baseline. In general, univariate and multivariate test-retest reliability was consistently significant and equivalent across all four stressor conditions. More specifically, univariate reliability as measured by Pearson correlation, was adequate for absolute test values and baseline levels across the physiological variables of skin temperature, skin resistance, vasomotor response, heart rate, systolic and diastolic blood pressure. Forearm electromyogram was the only dependent measure found to be unreliable. Difference scores, which represent change from baseline to test conditions, did not have adequate univariate reliability. Multivariate reliability as indexed by profile of similarity, was found to be adequate across baseline, test and difference scores for all stressors. 

The hypothesis of differential reliability between physical and mental stressors was not supported. In conclusion, the consistent reliability found across stressors provides an empirical basis for the validity of conclusions drawn from these procedures in psychophysiological research.
INTRODUCTION AND REVIEW OF LITERATURE

The clinical application of psychophysiology is a relatively new phenomenon even though the general field is considered to have an extensive history (Mesulm & Perry, 1972). Currently, recordings of psychophysiological measures are often included in comprehensive behavioral assessments. The most extensive use of psychophysiological measurements has been in the clinical areas of behavioral medicine, anxiety disorders and sexual arousal. The recording of physiological responses in these areas have added another dimension to clinical assessment. As such, an improved understanding of these disorders has been obtained. The following section will provide an overview of such clinical applications, focusing upon the areas of behavioral medicine, anxiety and sexual arousal.

Clinical Applications of Psychophysiology

Behavioral medicine. One application of psychophysiological assessment in behavioral medicine has been to evaluate the relationship between level of physiological arousal and symptomatology. Accordingly, most of these investigations have been conducted on disorders considered related to stress reactions and sympathetic arousal. For instance, it has been speculated that tension headache is
related to sustained muscular contractions of the forehead and neck during periods of stress (Blanchard, Ahles & Shaw, 1979). In a similar vein, migraine headaches have been deemed to be a function of cerebral vascular dysregulation which can be precipitated by stress (Dalessio, 1980). Also, peripheral vasoconstriction which is exacerbated by stress has been postulated as the physiological basis of Raynaud's syndrome (Surwit, Pilon & Fenton, 1978). Psychophysiological reactivity has been implicated in the etiology of cardiovascular diseases such as coronary heart disease and essential hypertension (Matthews, Weiss & Detre, 1984; Manuck & Krantz, 1984). Similarly, investigations assessing psychophysiological responding have been conducted on the posited mediation between the Type A behavior pattern and cardiovascular disease (Houston, 1983; Krantz, Glass, Schaeffer & Davia, 1982).

These studies on psychophysiological reactivity have typically employed laboratory stressors from mental and physical modalities. Mental stressors can be defined as stimuli which require cognitive activity and usually a verbal response as in the case of mental arithmetic. Conversely, physical stressors such as the cold pressor task involve presenting a physical stimulus which directly elicits the stress reaction without requiring a mental response. Thus physical stressors only require the subject's physiological abilities to respond to the
stimulus. In general, most of these aforementioned studies have found differential physiological responding in clinical populations compared with normals using these mental and physical stressors. However, as will be discussed later, there is great variability in the findings of behavioral medicine studies in this area.

If it is assumed that the above psychophysiological disorders are due to homeostatic dysregulations, then a treatment goal would be reestablishment of the physiological balance. Therefore, it would follow from this perspective that biofeedback may allow a restoration of the dysfunctional homeostatic process, thus returning the physiological response to a normal level. In fact, biofeedback studies have been conducted on disorders such as Raynaud's disease (Surwit et al., 1978) and chronic headache (Adams, Feuerstein & Fowler, 1980; Blanchard et al., 1979). Overall, the results have supported the efficacy of biofeedback but the actual mechanisms for improvement observed during treatment have not been completely identified (Blanchard, 1979; Williamson, 1981). Comparable effectiveness has been achieved using various relaxation techniques in the treatments of these psychophysiological disorders (Blanchard, Theobald, Williamson, Silver & Brown, 1978; Beaty & Haynes, 1979; Agras & Jacob, 1979; Shapiro & Goldstein, 1982; Keefe, Surwit & Pilon, 1980; Surwit, 1982; Feuerstein & Gainer, 1982). Interestingly, research published up to 1979 on
relaxation training assessed physiological variables as relaxation criterion measures in only 15 percent of the articles, while 70 percent of the studies provided no report of how relaxation was evaluated (Luiselli, Marholin, Steinman & Warren, 1979). The primary use of psychophysiological assessment procedures in biofeedback and relaxation research, however, has been to assess physiological changes during treatment and to relate these changes to treatment outcome (Ray, Raczynski, Rogers & Kimball, 1979; Ray & Raczynski, 1981; Williamson, Monguillot, Jarrell, Cohen, Pratt & Blouin, 1984).

**Anxiety disorders.** Another clinical use of psychophysiological assessment has been in the area of anxiety disorders. Measurement of physiological responses has been useful in both process and outcome evaluations of the systematic desensitization of phobias. Generally, heart rate and skin resistance have been found to be most consistently related to anxiety reduction during desensitization (Mathews, 1971; Ray, Cole & Raczynski, 1983).

While heart rate and skin resistance have been particularly useful in the assessment of anxiety, electromyographic (EMG) measurements have been found to be inconsistent. In a review of studies comparing anxious and normal subjects, EMG differences between groups were less common than heart rate and electrodermal differences (Lader, 1975), and conflicting findings and failed
replications have been common in the EMG anxiety literature (Goldstein, 1972; Nietzel & Bernstein, 1981). EMG assesses muscular activity associated with the somatic rather than the autonomic division of the peripheral nervous system. Hence, sympathetic autonomic arousal related to anxiety may have only an indirect influence upon EMG, perhaps partly explaining inconsistent results in the anxiety literature.

Another disorder which has been assessed using psychophysiological procedures is obsessive-compulsive disorder (Mavissakalian & Barlow, 1981). Research on this disorder has shown increased autonomic nervous system activation, such as elevated heart rate, following exposure to stimuli which elicit compulsive behavior (Boulougouris & Bassiakos, 1973; Boulougouris, Rabavilas & Stefanis, 1977; Rabavilas & Boulougouris, 1974). Following compulsive behavior, there is a general reduction in autonomic nervous system activation. Therefore, measures of ANS physiological reactivity have provided an objective approach for assessing emotional reactions in anxiety disorders.

Sexual arousal. Psychophysiological techniques have also been employed to investigate sexual arousal (Barlow, 1977; Heiman, 1977). This research has improved understanding of the relationship between physiological and cognitive events related to sexual stimulation. After reviewing the literature concerning physiological assessment of
female sexual arousal, Heiman (1978) concluded that vasodilation of the vaginal vascular beds is highly related to subjective reports of arousal. The best psychophysiological techniques for assessing female sexual arousal have been found to be vaginal photoplethysmographic (Hoon, Wincze & Hoon, 1976) and thermister recordings (Henson, 1978). Both of these techniques measure vaginal vascular responses during sexual arousal (Wincze & Lange, 1981).

The male sexual response has been measured using penile circumference and volume which both increase during arousal (Zuckerman, 1971; Barlow, 1977). Although no physiological response has been found to be a totally reliable and valid measure of a specific emotion, these measures of male and female genital responses have been more consistently related to sexual arousal than to other emotional reactions (Hoon et al., 1976).

Assessment of male impotence has involved recordings of nocturnal penile tumescence (NPT) along with measurement of sleep cycles via electroencephalography (EEG). This technique has been found to be very useful for differential diagnoses of psychogenic and organogenic impotence (Karacan, 1978; Freund & Blanchard, 1981). The absence of NPT during REM sleep cycles is suggestive of an organic etiology, indicating a need for further arteriographic and neurological evaluations. Psychophysiological assessments are important in this population since
approximately 40 percent of impotence cases have been diagnosed as psychogenic rather than organogenic (Karacan, Salis & Williams, 1978).

Several autonomic variables have been used in attempts to differentiate sexual and nonsexual arousal. Electrodermal measures have not been able to make such a discrimination because they are also responsive to emotional states other than sexual arousal (Tollison & Adams, 1979; Barlow, Leitenberg & Agras, 1969). Further, heart rate, facial temperature, finger pulse volume, blood pressure and respiration rates have not reliably discriminated responses to sexually relevant stimuli from neutral presentations (Bernick, King & Borowitz, 1968; Bancroft & Mathews, 1971). Along these lines, Zuckerman (1971) has commented that autonomic responsivity to sexual stimuli may be inconsistent since such responding could indicate an orienting response to novelty rather than actual sexual arousal. As such, measures recorded during presentation of sexual material may not be comparable to responses assessed during coitus.

In sum, clinical applications of psychophysiological procedures have added another assessment dimension to the areas of behavioral medicine, anxiety disorders and sexual functioning. However, further research efforts are necessary on issues related to the reliability and stability of psychophysiological assessment procedures since inconsistent findings are a frequent occurrence.
and such basic methodological research is needed to help explain these conflicting results. In the area of headache, for example, some investigators have reported abnormal vasomotor responses (e.g. Bakal & Kaganov, 1977; Gannon, Haynes, Safranek & Hamilton, 1983) while others have failed to replicate these findings (e.g. Sturgis, 1980; Andrasik, Blanchard, Arena, Saunders & Barron, 1982). In addition, some researchers have successfully discriminated among headache diagnostic groups using psychophysiological methods (e.g. Cohen, Williamson, Monguillot, Hutchinson, Gottlieb & Waters, 1983) while others have not (e.g. Andrasik et al., 1982). In a review of psychophysiological assessment of headache, Andrasik et al. (1982) reported that three out of six studies found no frontal EMG differences between headache patients and controls. These inconsistent psychophysiological findings could result from unreliable assessment procedures. Therefore, the following section will discuss this crucial issue of reliability in psychophysiological assessments.

Reliability of Psychophysiological Measurement

The concept of test-retest reliability is central to any assessment procedure. The repeatability or stability of assessment results are necessary so that meaningful comparisons can be made over time. Without a reliable assessment procedure, it is not clear whether different values are legitimate changes due to an experimental manipulation or are a result of an unstable measurement.
Also, the failure to distinguish among groups using psychophysiological measures may be due to a lack of differences among groups or to increased error variance due to unreliable measurement. Thus reliability of an assessment procedure must be established before conclusions are made regarding the meaning of any subsequent data. Unfortunately, evaluations of reliability for psychophysiological procedures have not been adequately conducted.

There is a surprising paucity of reliability research in the area of psychophysiological assessment. One early study assessed test-retest reliabilities of EMG measures over a period of nine days (Voas, 1952). The muscle groups that were evaluated included frontal and forearm flexors. Test-retest correlations for the frontal EMG during relaxation, mental arithmetic and stress/frustration conditions were .81, .91 and .92 while forearm flexor EMG had test-retest correlations of .46, .94 and .80. Although more details from this unpublished study are not available, it can be concluded that good overall reliability was observed. Similar results have been reported between two rest periods where respective correlations of .81 and .52 were found for frontal and forearm muscle groups (Martin, 1956; 1958). These early studies, therefore, demonstrated good reliability for EMG measurements.

A comprehensive review has been reported concerning the reliability of electrodermal measures (Freixa i Baque,
He concluded that electrodermal responses were fairly consistent during short (i.e. days) and long (i.e. months) term assessments. However, additional research is needed to specify what stimulus situations differentially affect reliability. That is, comparative evaluations of the relative reliability of different stressors are necessary. Investigations are also needed to discern the interrelationships among psychophysiological variables including electrodermal measures.

The only recently published work on reliability of psychophysiological variables assessed 15 normal subjects on the multiple occasions of days 1, 2, 8 and 28 (Arena, Blanchard, Andrasik, Cotch & Myers, 1983). After analyzing all possible combinations of these sessions using Pearson correlations, the authors noted four important findings: (1) absolute frontal EMG had excellent reliability during mental arithmetic but not during stressful imagery or cold pressor tasks; (2) absolute heart rate and forearm flexor EMG were inconsistently reliable in these conditions; (3) absolute skin temperature was reliable when sessions occurred within one week; and (4) absolute skin resistance was not found to be reliable. Moreover, Arena et al. (1983) calculated correlations using difference scores where baseline values were subtracted from the levels during a test procedure. Difference scores for frontal EMG demonstrated satisfactory reliability during mental arithmetic, cold pressor and stressful imagery. However,
for other psychophysiological responses (skin resistance, skin temperature, forearm EMG and vasomotor response) difference scores were found to be unreliable. These investigators concluded that their data cast doubt upon the reliability of many psychophysiological variables, with the possible exception of frontal EMG. This study was the first to systematically investigate the reliability of clinical psychophysiological procedures. However, the findings of this study conflict with that of earlier investigations. It should be noted that the methodology of the Arena et al. (1983) study was problematic in that a small sample size (N = 15) was employed. Also, only simple correlations were calculated, thus failing to assess multivariate psychophysiological response patterns across test conditions.

A study similar to that of Arena et al. (1983) has been completed by Williamson, Waters, Bernard, Faulstich and Blouin (1985). This project evaluated 30 normal subjects in a pair of identical sessions separated by two weeks. Subjects were exposed to: a series of tones (habituation task), a mental stressor—the Quiz Electrocardiogram (Schiffer, Hartley, Schulman & Abelman, 1976) stressful imagery, stressful slides and a startle stimulus. Each test period was preceded by a three minute baseline. The physiological variables of this study were skin temperature, heart rate, blood pressure, skin conductance, respiration, finger vasomotor response and frontal and
forearm EMG. These data were analyzed to assess the degree to which psychophysiological measures were stable over time. Both correlational and inferential statistics were used. All testing procedures, except the habituation task and startle stimulus, produced significantly lower levels of arousal at the second session, suggesting that mental stress such as the Quiz Electrocardiogram, imagery and stressful slides may have lost their "potency" in the second session due to habituation. A comparison of specific responses across sessions showed that absolute levels of skin temperature, heart rate, respiration rate and skin conductance were consistently positively correlated during baseline and testing procedures. In contrast to these findings with absolute values, the use of difference scores from baseline demonstrated poor reliability. Furthermore, profiles of similarity on individual subjects were conducted holding out 15 subjects to develop a covariance matrix. According to this analysis on absolute values, most of the subjects exhibited significantly similar response patterns across time, providing evidence for stability of responding for some individual subjects or individual response stereotypy. As opposed to the Arena et al. (1983) study, this investigation by Williamson et al. (1985) employed multivariate response profile analyses and found considerably greater reliability for absolute psychophysiological scores. These data suggest that certain
procedures, mental stressors, may not produce levels of physiological responding which are comparable from the first to second session, but do produce similar response profiles (as indicated by correlational and profile of similarity analyses). If this hypothesis is correct, then one must differentiate types of stressors (e.g. mental or physical) when interpreting research using psychophysiological methods. Further research on this question is needed. This point will be discussed in more detail in the problem section.

Most of the stressors employed in these reliability investigations result in sympathetic activation and physiological arousal. As such, the next section will present a general overview on models of arousal. These conceptualizations of physiological reactivity can provide a theoretical framework for most of the research on psychophysiological assessment.

Models of Psychophysiological Arousal

An early theory regarding physiological arousal was the "fight or flight" theory of Cannon (1915, 1939). It posited a generalized physiological arousal which occurred during moments of danger. This "fight or flight" response prepared the organism for defensive behavior or energy for escape by ANS and endocrine activation that provided for great expenditures of energy. The physiological arousal was considered to increase across physiological variables and provided energy necessary for survival of
the organism. This early notion of arousal provided a theoretical foundation for modern psychophysiological research.

This "fight or flight" concept of arousal was later refined and extended to explain the relationship between level of arousal or activation and performance of all behavior (Duffy, 1957). Specifically, an inverted U-shaped curve was considered to characterize this relationship. Thus when activation is low, quality of performance is low. Maximum performance is thought to occur at an intermediate level of activation while performance quality returns to a low level as arousal is further increased. These concepts of a unidimensional activation continuum and inverted U-shaped curve were helpful in conceptualizing some psychophysiological data (e.g. Lindsley, 1952; Malmo, 1959). Yet, this activation theory was criticized on the grounds that arousal is not unidimensional but consists of at least three modalities (Lacey, 1967). Namely, it is thought autonomic, cortical and behavioral forms of arousal exist and each respond in complex patterns, frequently independent of one another. For example, research has demonstrated that arousal can occur in one general area (e.g. cognitive) but not in another (e.g. behavioral) (Borkovec, 1976; Davidson & Schwartz, 1976). Lang's (1968, 1969, 1971, 1979) tripartite model can also account for these data. Lang has postulated that self-report, behavioral and psychophysiological systems
may not necessarily covary and can evidence different levels of arousal (Borkevec, Weerts & Berstein, 1977; Borkevec, 1979; Eysenck, 1976, 1979; Rachman, 1974, 1976, 1978). This multimodal approach to the assessment of arousal is currently a popular procedure.

One important principle of psychophysiological assessment is stimulus-response specificity which attempts to account for complex physiological responding without positing a unidimensional activation continuum. Instead, this principle contends that certain stimulus situations result in specific response patterns, rather than an overall increase or decrease in physiological reactivity. Along these lines, Ax (1953) has reported data indicative of a physiological distinction between anger and fear. In addition, sensory "intake" (i.e. attentive observation of the environment) and sensory "rejection" (i.e. internal concentration) have reportedly resulted in differential physiological patterns (Lacey, 1959; Lacey & Lacey, 1970; Williams, in press). These distinctions between anger or fear and sensory "intake" or "rejection" provide examples of stimulus-response specificity. Thus, anger and fear provoking stimuli may result in differential physiological response patterns. Similarly, stimulus situations related to sensory "intake" and "rejection" seem to result in different types of physiological responding. Therefore, these data support the notion of stimulus-response specificity in that certain
stimulus conditions seem to elicit unique physiological
dactivity across individuals. Definitive statements,
however, cannot be made since these findings need further
replication.

Another related principle of psychophysiology is
individual response stereotypy, which refers to idio-
syncratic physiological responding. This principle holds
that an individual will respond to various stressors with
a similar physiological pattern while other individuals
may react with a different stereotypic pattern. In a
classic example of this principle, psychiatric patients
with head and neck pain were compared to patients with
frequent heart palpitations (Malmo & Shagrass, 1949).
During experimentally induced stress, head and neck
complainers had significantly more muscle activity at
these sites and the group with heart palpitations reacted
with increased heart rate. It was suggested that these
patients' individual response stereotypy during life
stressors may have eventually led to their related
symptomatology. In other research, normal subjects have
been found to each have idiosyncratic physiological
activity in the same response system across several
different experimental stressors (e.g. Lacey, Bateman
& Van Lehn, 1952; Lacey & Lacey, 1958; Wenger, Clemens,
Coleman, Cullen & Engel, 1961). Although not conclusive,
these data suggest that individuals may react with similar
response patterns to different environmental and
psychosocial stressors. However, some individuals have been termed "random" responders because they do not exhibit repeatable idiosyncratic physiological responding across sessions. Currently, it is not possible to determine the degree to which unreliable psychophysiological assessment can account for the occurrence of such "random" responding. Nevertheless, unreliable or unstable psychophysiological assessments could be a factor in this phenomenon.

In summary, stimulus-response specificity and individual response stereotypy are principles which seem to have some empirical support. These two concepts are not mutually exclusive and both must be taken into consideration during psychophysiological research (Engel, 1960; Roessler & Engel, 1977). As such, physiological responding can be a result of both the response tendencies of the individual and the characteristics of the stimulus situation (e.g. mental or physical stressors). These models of arousal can assist in the conceptualization of psychophysiological response patterns over time by explaining why responding may vary across stressors and individuals.
PROBLEM

Based on the literature review, there appears to be a need for further examination of the reliability of different types of clinical psychophysiological assessment procedures for evaluating stress reactions. As previously mentioned, assessment procedures must be repeatable in order for meaningful conclusions to be drawn. An example of where reliable physiological measures are important is in treatment outcome research. The repeated measurement of physiological variables during experimentally induced stress has been employed in behavioral medicine and anxiety disorder outcome research. If unstable measurements occur and differential responsivity exists independent of any treatment effect, then psychophysiological assessment is of little value. The study proposed here will address this problem by attempting to identify stimulus conditions that may bring about reliable assessments.

A clarification in definition is needed with respect to the notion of reliability. In the present context, reliability will refer to the repeatability of physiological responding as a function of a particular experimentally presented stressor. That is, a response's reliability will be considered in the context of each stressor. It
follows then that responding of a physiological variable may be consistently repeated during presentations of stressor A but perhaps not for stressor B. Thus, stressor A would be considered reliable for that variable, while stressor B would be deemed unreliable. Therefore, test-retest reliability of specific experimental stressors will be evaluated in this study with regard to the repeatability of consequent physiological responses.

In general, psychophysiological stress tests can be divided into mental or physical modalities. For example, stressful stimuli can require mental activity such as answering challenging questions or solving mathematical problems. Conversely, stressful stimuli can come from a physical modality like exposure to cold temperature or sustaining a muscular contraction. Regarding mental stressors, physiological responding may vary according to an individual's response set to the task. Therefore, the degree of a person's volitional involvement in a particular task may vary from session to session. Consequently, this differential response set across sessions may lower test-retest reliability. Also, some individuals may be more task-involved and exert more effort during mental stressors than other individuals. Similarly, individuals' level of concern regarding evaluation and their quality of performance might differ across testing sessions. As such, physiological reactions to mental stressors could be mediated by cognitive
appraisals and volitional involvement which may change over time.

While reactions to mental stressors may be significantly affected by cognitive sets, responses to physical stressors might be less likely to result from such cognitive mediation. The presentation of physical stressors, such as cold temperature or muscular contraction, involve direct exposure to a noxious stimulus without requiring a mental response. On the other hand, mental stressors assume certain cognitive requirements like attention and interest in the task, and often require the subject to respond verbally. Thus, it could be hypothesized that physical stressors may have a more reliable effect across sessions if they are less contingent upon: volitional task involvement, degree of effort, or concerns regarding performance quality. Mental and physical stressors may therefore have differential reliability as a function of the amount of elicited cognitive mediation across testing sessions. In this regard, it was concluded that a direct comparison of test-retest reliability is needed between mental and physical stressors.

It was expected that brief mental stressors (i.e. 30 seconds) will be more reliable than a relatively longer mental stressor (i.e. 3 minutes) since subjects might be able to maintain a more consistent degree of task involvement over the shorter time period. During the longer mental stressor, subjects' degree of involvement
and effort may vary across sessions, in turn lowering reliability. Yet, duration may not affect reliability of physical stressors since they are less likely to be affected by cognitive sets.

The purpose of this study was to evaluate the stability of several mental and physical stressors across a two week period. The research design was a 2 x 2 x 4 structural design (see Figure 1) with all three factors as repeated measures. The independent variables were session number (test 1 or test 2), baseline/test conditions and stressor type (cold pressor, isometric challenge, mental arithmetic, Quiz EKG). This design allowed an evaluation of the respective reliabilities of mental and physical stressors across a two week period.

The physical stressors employed were: (1) the cold pressor test (30 seconds), which involved hand immersion in cold water approximately 2 degrees Celsius (Lovallo, 1975), and (2) isometric challenge (3 minutes) where an individual maintained a hand grip at 15 percent of maximum voluntary contraction (Ewing, Irving, Kerr and Kirby, 1973). The mental stressors were: (1) mental arithmetic (30 seconds) which required a subject to count aloud backwards from 200 by 7's (Arena et al., 1983), and (2) the Quiz Electrocardiogram (3 minutes) in which individuals orally responded to a series of general information/I.Q.-type questions (Schiffer et al., 1976). According to previous data, three minute durations of
Figure 1. A representation of the $2 \times 2 \times 4$ structural design showing the three repeated measures.
the isometric challenge and Quiz Electrocardiogram (EKG) should result in equivalent levels of physiological responding (e.g. Manuck & Proietti, 1982; Williamson et al., 1985). Likewise, the thirty second cold pressor and mental arithmetic tasks should elicit approximately similar physiological reactions (e.g. Engel, 1960).

In summary, the primary hypothesis was that physical stressors should result in better test-retest reliability than mental stressors. Duration of stressors were also experimentally controlled with stressors lasting either three minutes or thirty seconds. It was hypothesized that the thirty second mental stressor would result in more reliable responding than the three minute mental stressor but duration would not differentially affect the physical stressors. The mental stressors are considered likely to be influenced by duration since degree of involvement and effort may vary less during a brief thirty second stressor compared to a longer three minute duration. However, direct comparisons of a "duration variable" cannot be made since stressors vary across the thirty second/three minute modality. Therefore, the major hypotheses concerned physical versus mental stressors and not duration.
METHOD

Subjects

Forty eight undergraduate and graduate subjects were recruited and randomly assigned to a counterbalanced order of the four stressors. Two subjects were assigned to each of the twenty four possible orders. Only healthy subjects were included in the study. The health problems shown in Appendix A were used as exclusion criteria and no subjects were excluded due to presence of these physical problems. Subjects read and then signed the consent form presented in Appendix B which asked them to return in exactly two weeks in order to repeat the stressor presentation. Three subjects failed to return for the second session and were subsequently replaced by an additional three subjects.

Apparatus and Laboratory Environment

A two room laboratory was used to isolate subjects from the recording equipment during the experimental sessions. Subjects were seated in a room with an ambient temperature of 72 degrees Fahrenheit. All physiological responses were recorded by a Grass model 7 polygraph, including DC preamplifiers (model 7 P1) and AC preamplifiers (model 7 P5). The physiological responses monitored were
electrocardiogram (EKG), frontal electromyogram (EMG),
vasomotor response (VMR), skin temperature, skin resistance
level, systolic and diastolic blood pressure. Silver/silver
chloride electrodes were used to record skin resistance
and frontal EMG. Skin resistance was recorded from the
first or distal phalange of the middle and fourth fingers
of the left hand. Frontal EMG was recorded with electrodes
placed approximately 2.5 cm above each eyebrow in line
with the pupil of the eye (Lippold, 1967). The VMR was
measured from the left thumb by a reflecting photo-
plethysmograph. The R wave of the raw EKG was counted
automatically by a Med Associates Threshold comparator
(ANL-300). Skin temperature from the left index finger
was measured using a Yellow Springs (#409-A) thermister
and a Med Associates Differential/Absolute Temperature
Signal Conditioner (ANL-410). Frontal EMG and skin
temperature were mechanically recorded via Med Associates
analogue-to-digital converters (ANL-940). Using these
components, heart rate, frontal EMG, skin temperature,
skin resistance and VMR were automatically recorded by
an IBM - PC computer system which was interfaced to the
Med Associates equipment. Systolic and diastolic blood
pressure were measured via an automatically inflatable
sphygmomanometer (Marshall Electronics, #88) which provided
digital readings of blood pressure using Korotkoff sounds
detected by microphone in the occluding cuff from the
right arm. The timing of all phases of the experiment
and presentation of instructional stimuli were controlled by Med Associates solid-state logic and programming equipment and the computer system.

**Procedure**

All subjects participated in two sessions separated by two weeks and lasting approximately thirty eight minutes each time. Prior to electrode attachment and initiation of the experiment, maximum voluntary contraction (MVC) was determined using the procedure suggested by Ewing et al., (1973). More specifically, the MVC was the highest of three brief maximum grips of the handgrip dynamometer (Lafayette Instruments, #76618). Fifteen percent of this MVC was the level subjects were asked to maintain on the handgrip dynamometer during the three minute isometric challenge. Fifteen percent MVC was used since available data indicate this level generates physiological responding comparable to the other stressors in this project (e.g. Manuck & Proietti, 1982; Williamson et al., 1985).

After electrode placement, a ten minute adaptation phase was begun, followed by a one minute baseline phase. Order of presentation for the four stressors was counterbalanced across subjects. Based on previous research (e.g. Manuck & Proietti, 1982; Arena et al., 1983), there was a one minute baseline (BL) before each stressor and a four minute return to baseline (RTB) after each stressor. Taped instructions related to each task
were presented to the subject and these are presented in Table 1 along with an example of one order of stressor presentation.

Special precautions and procedures were employed with respect to subject's compliance to experimental tasks. Any necessary communication between experimenter and subject was conducted by a two-way intercom. As previously mentioned, the mental arithmetic task entailed subjects counting backwards aloud from two hundred by 7's for thirty seconds. If a subject stopped counting, the next correct number was provided by the experimenter via intercom. The thirty second cold pressor task involved subject's immersing their right hand in water 2 degrees Celsius. Subjects were requested to keep their hands in the water until instructed to remove them and were observed through a one-way mirror to insure task compliance. Regarding the isometric challenge, subject's maintenance of hand grip tension levels were also checked by observation through the one-way mirror. No subject was found to be noncompliant to these experimental instructions. Finally, the items that comprise the Quiz EKG are shown in Appendix C. Since the questions are of variable difficulty, subject exclusion did not occur due to incorrect or "no reply" answers.

Statistical Analysis

All three factors within the 2 x 2 x 4 design were repeated measures and the data was initially subjected
Table 1

Instructions for Experimental Conditions Using An Example of One Order of Stressor Presentation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adaptation</td>
<td>10 min.</td>
<td>Please sit quietly, avoiding unnecessary movement for the next several minutes.</td>
</tr>
<tr>
<td>Baseline 1</td>
<td>1 min.</td>
<td></td>
</tr>
<tr>
<td>Quiz</td>
<td>3 min.</td>
<td>Detailed instructions in Appendix C.</td>
</tr>
<tr>
<td>EKG</td>
<td>3 min.</td>
<td></td>
</tr>
<tr>
<td>Return-to-baseline</td>
<td>4 min.</td>
<td>Please sit quietly avoiding unnecessary movements for the next several minutes.</td>
</tr>
<tr>
<td>Baseline 2</td>
<td>1 min.</td>
<td></td>
</tr>
<tr>
<td>Mental Arithmetic</td>
<td>30 sec.</td>
<td>Please count aloud backwards from 200 by 7's. When I say begin, count as quickly and accurately as possible. Continue counting even if you think you have made an error. Any questions? O.K. Begin counting.</td>
</tr>
<tr>
<td>Return-to-baseline</td>
<td>4 min.</td>
<td>Please sit quietly, avoiding unnecessary movements for the next several minutes.</td>
</tr>
<tr>
<td>Baseline 3</td>
<td>1 min.</td>
<td></td>
</tr>
<tr>
<td>Isometric Challenge</td>
<td>3 min.</td>
<td>Please pick up the handgrip device with your right hand. When I say begin, hold the tension level indicated on the handgrip. Please continue this tension until I instruct you to stop. Any questions? O.K. Begin the tension.</td>
</tr>
<tr>
<td>Return-to-baseline</td>
<td>4 min.</td>
<td>Please sit quietly, avoiding unnecessary movements for the next several minutes.</td>
</tr>
<tr>
<td>Baseline 4</td>
<td>1 min.</td>
<td></td>
</tr>
</tbody>
</table>
Table 1 (continued)

<table>
<thead>
<tr>
<th>Condition</th>
<th>Duration</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold Pressor</td>
<td>30 sec.</td>
<td>When I say begin, please place your right hand in the water next to you. Please do not remove your hand until instructed to do so. Any questions? O.K. Begin.</td>
</tr>
<tr>
<td>Return-to-baseline</td>
<td>4 min.</td>
<td>Please sit quietly, avoiding unnecessary movements for the next several minutes.</td>
</tr>
</tbody>
</table>
to a multivariate analysis of variance (MANOVA) followed by
univariate analyses of variance (ANOVA) for significant
MANOVA effects. All post-hoc comparisons were conducted
using Scheffe's comparison. This series of statistical
analyses evaluated the absolute physiological values
across experimental conditions. Manipulation checks
were provided by these analyses since comparisons of
baseline and test values were made for all stressors.
If test values were significantly higher in arousal than
baseline levels, then the stressor was considered
successfully manipulated. Also, main effects and
interactions across sessions for stressor type were
discerned by these analyses.

Difference scores for each physiological response
were calculated where each immediately preceding baseline
was subtracted from the following stressor's test value.
One exception to this approach was VMR which was computed
using a percent change from baseline procedure (mean mm
pen deflections during stressor minus the mean deflections
during baseline divided by mean baseline deflections,
then multiplied by one hundred). Pearson product-moment
correlations were then calculated between sessions one
and two for these difference scores as well as baseline
and absolute stressor values. Thus, correlations were
conducted on the absolute and relative physiological
values. These analyses determined the test-retest
reliabilities of individual physiological variables as
a function of experimental conditions.

Lastly, profile of similarity analyses were utilized to evaluate the degree of correspondence for absolute and relative values between the two sessions. Twenty four subjects were held out to form a covariance matrix and the profile of similarity analyses were performed on the remaining twenty four subjects. All possible combinations of stressor presentations were represented in both the holdout and experimental groups. Separate profiles of similarity were conducted on each of the four stressor conditions. These multivariate analyses assessed the similarity of psychophysiological response profiles from each session during baseline and test periods using difference scores and absolute values. The profile of similarity evaluates patterns of physiological responding between sessions in a correlative rather than differential manner. That is, this analysis will identify baselines and stressors which have reliably dissimilar response patterns over time taking into account levels and patterns. Therefore, this statistical procedure answered questions regarding what stressors resulted in reliably dissimilar overall physiological arousal. This statistical technique was used to assess similarity of physiological responding for the subjects together as a group as well as on an individual basis for each subject. Thus, it has relevance to the issue of individual response stereotypy in that it evaluates the extent to which individual subjects
respond with similar physiological response patterns to
test procedures from session one to session two.

Hypotheses

As mentioned previously, the primary hypothesis of
this study was that the physical stressors will be more
reliable over time than the mental stressors. In reference
to the statistical analyses described in the last section,
the following statements can be made as formal hypotheses:

(1) According to MANOVA and ANOVA analyses,
all four stressors will produce significantly
higher levels of arousal than preceding
baseline values during both sessions.

(2) According to MANOVA and ANOVA analyses,
physical and mental stressors will not
be significantly different at the first
session. However, at the second session,
mental stressors will result in significantly
lower physiological responding than physical
stressors.

(3) According to Pearson correlations, each
specific physiological variable will have
stronger test-retest correlations across
sessions for physical rather than mental
stressors.

(4) According to the profile of similarity
analyses, group and individual overall
physiological response patterns will be
more reliable between sessions for physical stressors than mental stressors.

(5) According to profiles of similarity, physiological responding will be more reliable for the thirty second mental stressor than the three minute mental stressor. Finally, no difference is expected between the two physical stressors due to differential duration.
RESULTS

Findings related to the hypotheses of this investigation are addressed in the following sections: Physiological Reactivity to Stressors, Level Changes Across Sessions, Univariate and Multivariate Test-Retest Reliability Analyses. Multivariate analysis of variance (MANOVA) using Wilk's criterion, univariate analysis of variance (ANOVA), and Scheffe's post-hoc comparison were employed to identify group differences across the repeated measurement of stressors, sessions, and baseline/test conditions. Also, Pearson product-moment correlation and profile of similarity were used to discern the test-retest reliability of the four stressor procedures.

Physiological Reactivity to Stressors

Hypothesis #1 stated that all four stressors should result in higher levels of arousal than preceding baseline values across both sessions. This hypothesis was supported in that a significant MANOVA main effect was found across all baseline/test conditions, $F (7, 699) = 84.72, p < .0001$. As shown in Table 2, ANOVA analyses demonstrated that across baseline/test procedures there were significant increases in systolic and diastolic blood pressure and heart rate, along with significant
decreases in vasomotor response, skin temperature and skin resistance. Forearm EMG was the only dependent measure that did not change across baseline/test conditions.

A direct comparison of the baseline/test conditions across the four stressors was conducted and a significant 2 (BL/test) x 4 (stressors) MANOVA interaction was obtained $F(21, 2007) = 11.70, p < .0001$. Similarly, significant 2 (BL/test) x 4 (stressors) ANOVA interactions were found for heart rate, $F(3, 705) = 31.25, p < .0001$; vasomotor response, $F(3, 705) = 7.43, p < .0001$; systolic blood pressure, $F(3, 705) = 14.91, p < .0001$; and diastolic blood pressure, $F(3, 705) = 22.51, p < .0001$. The means for the physiological variables related to these analyses are summarized in Table 3 along with results from Scheffe's post-hoc comparison.

The 2 (BL/test) x 4 (stressors) ANOVA interaction for heart rate is illustrated in Figure 2. Heart rate increased over baseline levels during all four stressors, however, it was differentially affected during mental arithmetic. Specifically, according to Scheffe's technique, the mean heart rate of 88.89 BPM during the mental arithmetic test period was higher than cold pressor ($M = 79.68$ BPM), Quiz EKG ($M = 77.55$ BPM) and isometric challenge ($M = 75.21$ BPM). In addition, heart rate responding during the cold pressor was significantly higher than that of isometric challenge.
Figure 3 shows the 2 (BL/test) x 4 (stressors) ANOVA interaction for vasomotor response (VMR). Scheffe's comparison found that only mental arithmetic and cold pressor resulted in lower VMR during test conditions. Accordingly, isometric challenge and Quiz EKG did not reliably alter VMR activity.

As demonstrated by Figure 4, the 2 (BL/test) x 4 (stressors) interaction for systolic blood pressure identified significant increases for all stressors over baseline, with the exception of Quiz EKG. According to Scheffe's procedure, systolic blood pressure levels during isometric challenge (M = 128.26 mmHg) and mental arithmetic (M = 123.91 mmHg) were higher than during cold pressor (M = 117.63 mmHg) and Quiz EKG (M = 117.06 mmHg). The 2 (BL/test) x 4 (stressors) interaction for diastolic blood pressure is presented in Figure 5. Scheffe's technique found isometric challenge and cold pressor as the only two stressors which increased diastolic blood pressure over baseline levels. Hence, Quiz EKG did not change systolic blood pressure while the tasks of mental arithmetic and Quiz EKG did not reliably influence diastolic blood pressure.

In sum, these data generally support hypothesis #1. That is, overall physiological arousal was increased across baseline/test conditions as a function of the four stressor procedures.
Level Changes Across Sessions

Hypothesis #2 predicted that all four stressors would result in equivalent levels of arousal during the first session while the physical stressors (i.e. cold pressor and isometric challenge) would be significantly higher at the second session relative to mental stressors (i.e. mental arithmetic and Quiz EKG). This hypothesis was not confirmed since the 2 (sessions) x 2 (BL/test) x 4 (stressors) MANOVA across all physiological variables was not significant, \( F (21, 2007) = 0.95, p = .53. \) Likewise, 2 (sessions) x 2 (BL/test) x 4 (stressors) ANOVA's on each physiological response were not significant, with the exception of heart rate, \( F (3, 705) = 3.36, p < .05. \) The mean heart rate values corresponding to this three-way interaction are shown in Table 4 and this effect is illustrated by Figure 6. According to Scheffe's comparison in Table 4, heart rate reactivity during session 1/mental arithmetic (\( M = 93.88 \) BPM) was higher than session 1 values for the Quiz EKG (\( M = 80.40 \) BPM), cold pressor (\( M = 80.69 \) BPM) and isometric challenge (\( M = 76.99 \) BPM). Interestingly, heart rate activity during mental arithmetic was differentially affected from session 1 to session 2. More specifically, heart rate during session 2 (\( M = 83.87 \) BPM) was significantly lower than the respective session 1 level (\( M = 93.88 \) BPM). Thus, although mental arithmetic created heart rate increases over baseline in both sessions, the level in session 2 was significantly
lower than that of the initial session. Since this effect was the only data showing lowered physiological arousal to mental stressors during the second session, it was concluded that hypothesis #2 was not supported by these findings.

A MANOVA comparing overall physiological levels of session 1 with session 2 identified a significant session main effect, $F(7, 699) = 100.09, p < .0001$. As summarized in Table 5, univariate ANOVA analyses found significant decreases in session 2 for heart rate and systolic blood pressure along with increases in skin temperature, skin resistance and EMG. With the exception of EMG, these physiological changes are characteristic of reduced arousal across sessions. In a more direct test of this effect, a significant 2 (sessions) x 2 (BL/test) MANOVA interaction was found, $F(7, 699) = 3.95, p < .0005$. Further investigation of this interaction using ANOVA's yielded the following results. All three of the cardiovascular measures were found to have the significant two-way interaction, i.e. heart rate, $F(1, 705) = 9.90, p < .005$, systolic blood pressure, $F(1, 705) = 13.40, p < .0005$ and diastolic blood pressure, $F(1, 705) = 14.29, p < .0005$. The corresponding means from these ANOVA results are displayed in Table 6 along with findings from Scheffe's statistic. Test levels across all stressors were higher than baseline for these three variables at both sessions. Yet, baseline/test conditions interacted
Table 2

ANOVA Results for Baseline (BL)/Test Main Effects

<table>
<thead>
<tr>
<th>Physiological Variable</th>
<th>Means</th>
<th>F Value</th>
<th>Significance Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTOLIC BLOOD PRESSURE:</td>
<td>BL 112.6 mmHg, 170.58</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 121.7 mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIASTOLE BLOOD PRESSURE:</td>
<td>BL 72.2 mmHg, 148.29</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 79.9 mmHg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEART RATE:</td>
<td>BL 70.7 BPM, 352.50</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 80.3 BPM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VASOMOTOR RESPONSE:</td>
<td>BL 6.9 mm, 83.66</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 5.3 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKIN TEMPERATURE:</td>
<td>BL 32.6° C, 12.20</td>
<td>p &lt; .0005</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 32.1° C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SKIN RESISTANCE:</td>
<td>BL 61.7 KOhm, 28.42</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 52.4 KOhm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FOREARM EMG:</td>
<td>BL 24.9 µV, 0.11</td>
<td>p = .744</td>
<td></td>
</tr>
<tr>
<td></td>
<td>TEST 24.7 µV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3

Means and Scheffe's Post-Hoc Comparisons for the 2 (BL/Test) x 4 (Stressors) ANOVA Interactions for Vasomotor Response (VMR), Heart Rate (HR), Systolic Blood Pressure (SBP) and Diastolic Blood Pressure (DBP)

PHYSIOLOGICAL VARIABLES

<table>
<thead>
<tr>
<th>VMR (mm)</th>
<th>HR (BPM)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRESSOR CONDITIONS</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

COLD PRESSOR:

<table>
<thead>
<tr>
<th></th>
<th>VMR</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>6.9 a,b</td>
<td>70.7 d</td>
<td>111.9 c</td>
<td>72.1 b</td>
</tr>
<tr>
<td>TEST</td>
<td>3.9 c</td>
<td>79.7 b</td>
<td>117.6 b</td>
<td>83.8 a</td>
</tr>
</tbody>
</table>

MENTAL ARITHMETIC:

<table>
<thead>
<tr>
<th></th>
<th>VMR</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>6.7 a,b</td>
<td>71.1 d</td>
<td>112.5 b,c</td>
<td>72.5 b</td>
</tr>
<tr>
<td>TEST</td>
<td>4.7 c</td>
<td>88.9 a</td>
<td>123.9 a</td>
<td>75.6 b</td>
</tr>
</tbody>
</table>

ISOMETRIC CHALLENGE:

<table>
<thead>
<tr>
<th></th>
<th>VMR</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>7.5 a</td>
<td>70.6 d</td>
<td>112.7 b,c</td>
<td>72.0 b</td>
</tr>
<tr>
<td>TEST</td>
<td>6.4 a,b</td>
<td>75.2 c</td>
<td>128.3 a</td>
<td>86.3 a</td>
</tr>
</tbody>
</table>

QUIZ EKG:

<table>
<thead>
<tr>
<th></th>
<th>VMR</th>
<th>HR</th>
<th>SBP</th>
<th>DBP</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL</td>
<td>6.8 a,b</td>
<td>70.5 d</td>
<td>113.3 b,c</td>
<td>72.0 b</td>
</tr>
<tr>
<td>TEST</td>
<td>6.1 b</td>
<td>77.6 b,c</td>
<td>117.1 b,c</td>
<td>74.2 b</td>
</tr>
</tbody>
</table>

Note: Means with no letters in common reliably differ (p < .05).
Figure 2. The 2 (Baseline/Test) x 4 (Stressors) interaction for heart rate. CP=cold pressor, MA=mental arithmetic, IC=isometric challenge, QE=quiz EKG.
Figure 3. The 2 (Baseline/Test) x 4 (Stressors) interaction for vasomotor response (VMR). CP=cold pressor, MA=mental arithmetic, IC=isometric challenge, QE=quiz EKG.
Figure 4. The 2 (Baseline/Test) x 4 (Stressors) interaction for systolic blood pressure. CP=cold pressor, MA=mental arithmetic, IC=isometric challenge, QE=quiz EKG.
Figure 5. The 2 (Baseline/Test) x 4 (Stressors) interaction for diastolic blood pressure. CP=cold pressor, MA=mental arithmetic, IC=isometric challenge, QE=quiz EKG.
Table 4

Means and Scheffe's Post-Hoc Comparisons for the 2 (Sessions) X 2 (BL/Test) X 4 (Stressors) ANOVA Interaction for Heart Rate (BPM)

<table>
<thead>
<tr>
<th>STRESSOR CONDITIONS</th>
<th>SESSION 1</th>
<th>SESSION 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLD PRESSOR:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>72.0 d,e,f</td>
<td>69.3 f</td>
</tr>
<tr>
<td>TEST</td>
<td>80.7 b,c</td>
<td>78.7 b,c,d</td>
</tr>
<tr>
<td>MENTAL ARITHMETIC:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>72.0 d,e,f</td>
<td>70.2 e,f</td>
</tr>
<tr>
<td>TEST</td>
<td>93.9 a</td>
<td>83.9 b</td>
</tr>
<tr>
<td>ISOMETRIC CHALLENGE:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>71.4 d,e,f</td>
<td>69.8 e,f</td>
</tr>
<tr>
<td>TEST</td>
<td>77.0 b,c,d,e</td>
<td>73.4 c,d,e,f</td>
</tr>
<tr>
<td>QUIZ EKG:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>71.5 d,e,f</td>
<td>69.5 f</td>
</tr>
<tr>
<td>TEST</td>
<td>80.4 b,c</td>
<td>74.7 c,d,e,f</td>
</tr>
</tbody>
</table>

**Note:** Means with no letters in common reliably differ (p < .05).
Figure 6. The 2(Sessions) x 2 (BL/TEST) x 4(Stressors) interaction for heart rate. BL=baseline, CP=cold pressor, MA=mental arithmetic, IC=isometric challenge, QE=quiz EKG.
Table 5

ANOVA Results for Main Effects Across Sessions One and Two (S1, S2)

<table>
<thead>
<tr>
<th>Physiological Variable</th>
<th>S1</th>
<th>S2</th>
<th>Means</th>
<th>F Value</th>
<th>Significance Level (df = 1,705)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SKIN TEMPERATURE:</td>
<td>31.7° C.</td>
<td>32.9° C.</td>
<td>60.70</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td>SKIN RESISTANCE:</td>
<td>43.9 KOhm</td>
<td>70.3 KOhm</td>
<td>230.70</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td>FOREARM EMG:</td>
<td>18.8 μV</td>
<td>30.8 μV</td>
<td>319.83</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td>HEART RATE:</td>
<td>77.4 BPM</td>
<td>73.7 BPM</td>
<td>52.12</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td>SYSTOLIC BLOOD PRESSURE:</td>
<td>119.6 mmHg</td>
<td>114.8 mmHg</td>
<td>47.25</td>
<td>p &lt; .0001</td>
<td></td>
</tr>
<tr>
<td>DIASTOLIC BLOOD PRESSURE</td>
<td>76.3 mmHg</td>
<td>75.8 mmHg</td>
<td>0.41</td>
<td>p = .406</td>
<td></td>
</tr>
<tr>
<td>VASOMOTOR RESPONSE:</td>
<td>6.2 mm</td>
<td>6.0 mm</td>
<td>1.27</td>
<td>p = .260</td>
<td></td>
</tr>
</tbody>
</table>
Table 6
Means and Scheffe's Post-Hoc Comparisons for the 2 (Sessions) X 2 (BL/Test) ANOVA Interactions for Heart Rate (HR), Systolic Blood Pressure (SBP), and Diastolic Blood Pressure (DBP)

<table>
<thead>
<tr>
<th>PHYSIOLOGICAL VARIABLES</th>
<th>HR (BPM)</th>
<th>SBP (mmHg)</th>
<th>DBP (mmHg)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SESSION CONDITIONS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SESSION 1:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>71.8 c</td>
<td>113.7 c</td>
<td>71.2 c</td>
</tr>
<tr>
<td>TEST</td>
<td>82.9 a</td>
<td>125.4 a</td>
<td>81.5 a</td>
</tr>
<tr>
<td><strong>SESSION 2:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BL</td>
<td>69.7 c</td>
<td>115.5 c</td>
<td>73.1 c</td>
</tr>
<tr>
<td>TEST</td>
<td>77.7 b</td>
<td>118.0 b</td>
<td>78.5 b</td>
</tr>
</tbody>
</table>

**Note:** Means with no letter in common reliably differ (p < .05).
with the two sessions in that the second stressor presenta-
tion resulted in significantly lower heart rate, systolic
and diastolic blood pressure responding. Thus, relative
to session 1, cardiovascular reactivity at session 2 was
lower during the implementati
on of stressor procedures, regardless of the type of stressor.

In summary, these findings do not support hypothesis
#2 since the session 2/mental stressors did not result
in lower levels of physiological arousal compared to
session 2/physical stressors. Nevertheless, overall
physiological responding was lower at session 2, as were
heart rate, systolic and diastolic blood pressure session
2 test values compared to respective session 1 levels.

Univariate Test-Retest Reliability Analyses

Hypothesis #3 predicted that physiological variables
would have stronger test-retest correlations across
sessions for physical rather than mental stressors. This
hypothesis was not supported since test-retest correlations
were remarkably consistent across all four stressors.
Table 7 presents the Pearson correlations between sessions
for baseline, test and difference scores of each stressor.

Regarding reliability of baseline values, significant
correlations were obtained for all variables, with the
exception of EMG preceding mental arithmetic, isometric
challenge and Quiz EKG. Also, VMR was not significant
prior to isometric challenge. The Pearson coefficients
of significant baseline correlations ranged from $r = .36$
to $r = .77$. Heart rate, skin temperature, systolic and diastolic blood pressure were the more reliable baseline measures, accounting for 13 to 59 percent of the variance across sessions. Hence, univariate test-retest reliability of baseline physiological responding across sessions was generally adequate.

Significant correlations were found for all physiological measures during presentations of both physical and mental stressors. Only EMG during mental arithmetic and cold pressor failed to demonstrate significant test-retest correlations. The Pearson coefficients of significant correlations ranged from $r = .32$ to $r = .74$. Similar to the baseline reliabilities, heart rate, skin temperature, systolic and diastolic blood pressure were generally the more reliable dependent variables. EMG was consistently the least reliable variable during all four stressor presentations. Overall, univariate test-retest reliability of the absolute physiological values was adequate for reactivity to the stressor procedures.

In contrast to the positive findings of the absolute test values, test-retest reliabilities for the difference scores were low and few significant correlations were observed. Difference scores were calculated by subtracting each preceding baseline from the following stressors test value, except for VMR which had a percent change calculation as described in the Method section. Only four physiological measures were significant during isometric challenge,
while three variables during cold pressor and mental
arithmetic had significant correlations. Furthermore,
difference scores related to Quiz EKG resulted in no
significant test-retest correlations. Therefore,
physiological responding as represented by difference
scores was found to have inadequate univariate test-retest
reliability.

In sum, hypothesis #3 was not supported by the results
of the Pearson correlations. Test and baseline univariate
reliabilities across the four stressors were adequate
for all physiological responses except EMG. Test-retest
reliability of difference scores was not found to be
adequate.

**Multivariate Test-Retest Reliability Analyses**

A random group of twenty four subjects was withheld
from profile of similarity (PSI) assessments in order
to form a covariance matrix which allowed the remaining
twenty four subjects to have group and individual PSI
analyses conducted. Both of these groups contained each
of the twenty four possible sequences of stressor
presentation. According to PSI data shown in Table 8,
all physiological response patterns from baseline, test
and difference scores were not significantly different
from session 1 to session 2. As such, these group PSI
analyses demonstrate that when considering overall
physiological patterns and levels of responding, all
baseline, test and difference scores were similar from
sessions 1 and 2.

Direct comparisons of the relative PSI values across stressors for baseline, test and difference scores were performed. Specifically, nonparametric analyses of PSI rankings of subjects across all four stressors were calculated via the Friedmann test (Conover, 1980). It was found that PSI rankings did not differ across sessions for baseline, $F_C (3) = 4.85, p = .18$; test, $F_C (3) = 0.75, p = .86$; and difference scores, $F_C (3) = 3.05, p = .38$. Thus, it can be concluded that multivariate test-retest reliability, as measured by the PSI, did not vary among the stressor conditions. This finding suggests that levels of reliability for baseline, test and difference scores were relatively equivalent for the group physiological profiles.

Individual PSI analyses were also conducted for each of the twenty four subjects. The rationale of these comparisons was to identify, on an individual basis, the occurrence of dissimilar response patterns across sessions. The percentage of cases found to have reliably similar physiological profiles are reported in Table 8. These percentages ranged from 83% to 100% and provide further evidence for the multivariate test-retest reliability of the experimental conditions. The PSI values and related probability levels for all twenty four subjects are listed in Appendices D - G.

Hypothesis #4 predicted that according to the PSI
analyses, group and individual overall physiological response patterns would be more reliable across sessions for physical stressors than for mental stressors. This hypothesis was not supported since PSI results indicated an equivalent degree of multivariate test-retest reliability across all four stressors. In addition, hypothesis #5 stated that mental arithmetic would be more reliable, according to PSI, than Quiz EKG due to a shorter stressor duration which might maintain more consistent cognitive involvement. This hypothesis was also not confirmed by the PSI analyses. Thus, PSI assessments did not find significantly different response patterns related to any of the stressor conditions. Therefore, it can be concluded, from a group and individual multivariate perspective, that test-retest reliability of the physiological profiles was adequate.
Table 7

Pearson Correlations Demonstrating Test-Retest Reliabilities of the Four Stressors
(HR = Heart Rate, SR = Skin Resistance, ST = Skin Temperature, VMR = Vasomotor Response
EMG = Electromyogram, SBP = Systolic Blood Pressure
DBP = Diastolic Blood Pressure)

<table>
<thead>
<tr>
<th>Stressor</th>
<th>Baseline</th>
<th>Test</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLD PRESSOR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>.69 *</td>
<td>.66 *</td>
<td>.50 *</td>
</tr>
<tr>
<td>SR</td>
<td>.48 *</td>
<td>.38 *</td>
<td>.51 *</td>
</tr>
<tr>
<td>ST</td>
<td>.55 *</td>
<td>.61 *</td>
<td>.07</td>
</tr>
<tr>
<td>VMR</td>
<td>.49 *</td>
<td>.35 *</td>
<td>.16</td>
</tr>
<tr>
<td>EMG</td>
<td>.36 *</td>
<td>.28</td>
<td>.16</td>
</tr>
<tr>
<td>SBP</td>
<td>.57 *</td>
<td>.55 *</td>
<td>.46 *</td>
</tr>
<tr>
<td>DBP</td>
<td>.64 *</td>
<td>.56 *</td>
<td>.23</td>
</tr>
<tr>
<td>MENTAL ARITHMETIC</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>.73 *</td>
<td>.72 *</td>
<td>.59 *</td>
</tr>
<tr>
<td>SR</td>
<td>.41 *</td>
<td>.36 *</td>
<td>.42 *</td>
</tr>
<tr>
<td>ST</td>
<td>.62 *</td>
<td>.65 *</td>
<td>.20</td>
</tr>
<tr>
<td>VMR</td>
<td>.42 *</td>
<td>.44 *</td>
<td>.33 *</td>
</tr>
<tr>
<td>EMG</td>
<td>.21</td>
<td>.23</td>
<td>.09</td>
</tr>
<tr>
<td>SBP</td>
<td>.62 *</td>
<td>.58 *</td>
<td>.27</td>
</tr>
<tr>
<td>DBP</td>
<td>.70 *</td>
<td>.51 *</td>
<td>.21</td>
</tr>
<tr>
<td>ISOMETRIC CHALLENGE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>.77 *</td>
<td>.73 *</td>
<td>.30 *</td>
</tr>
<tr>
<td>SR</td>
<td>.46 *</td>
<td>.54 *</td>
<td>.18</td>
</tr>
<tr>
<td>ST</td>
<td>.66 *</td>
<td>.64 *</td>
<td>.36 *</td>
</tr>
<tr>
<td>VMR</td>
<td>.23</td>
<td>.53 *</td>
<td>.09</td>
</tr>
<tr>
<td>EMG</td>
<td>.28</td>
<td>.32 *</td>
<td>.17</td>
</tr>
<tr>
<td>SBP</td>
<td>.36 *</td>
<td>.67 *</td>
<td>.44 *</td>
</tr>
<tr>
<td>DBP</td>
<td>.51 *</td>
<td>.74 *</td>
<td>.40 *</td>
</tr>
<tr>
<td>QUIZ EKG</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td>.58 *</td>
<td>.60 *</td>
<td>.22</td>
</tr>
<tr>
<td>SR</td>
<td>.39 *</td>
<td>.38 *</td>
<td>.09</td>
</tr>
<tr>
<td>ST</td>
<td>.58 *</td>
<td>.65 *</td>
<td>.17</td>
</tr>
<tr>
<td>VMR</td>
<td>.51 *</td>
<td>.57 *</td>
<td>.18</td>
</tr>
<tr>
<td>EMG</td>
<td>.28</td>
<td>.32 *</td>
<td>.17</td>
</tr>
<tr>
<td>SBP</td>
<td>.52 *</td>
<td>.46 *</td>
<td>-.01</td>
</tr>
<tr>
<td>DBP</td>
<td>.62 *</td>
<td>.70 *</td>
<td>.06</td>
</tr>
</tbody>
</table>

* p < .05
Table 8  
Profile of Similarity Indices (PSI) Across Baseline, Test and Difference Scores for the Four Stressors

<table>
<thead>
<tr>
<th>Stressor Procedure</th>
<th>Baseline</th>
<th>Test</th>
<th>Difference Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>COLD</td>
<td>PSI = 58.51</td>
<td>45.38</td>
<td>38.71</td>
</tr>
<tr>
<td>PRESSOR</td>
<td>p = .14</td>
<td>.58</td>
<td>.83</td>
</tr>
<tr>
<td></td>
<td>% = 92%</td>
<td>96%</td>
<td>96%</td>
</tr>
<tr>
<td>MENTAL ARITHMETIC</td>
<td>PSI = 33.24</td>
<td>45.06</td>
<td>63.65</td>
</tr>
<tr>
<td></td>
<td>p = .95</td>
<td>.59</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td>% = 96%</td>
<td>92%</td>
<td>83%</td>
</tr>
<tr>
<td>ISOMETRIC CHALLENGE</td>
<td>PSI = 48.89</td>
<td>59.73</td>
<td>63.63</td>
</tr>
<tr>
<td></td>
<td>p = .44</td>
<td>.12</td>
<td>.07</td>
</tr>
<tr>
<td></td>
<td>% = 96%</td>
<td>88%</td>
<td>83%</td>
</tr>
<tr>
<td>QUIZ EKG</td>
<td>PSI = 44.81</td>
<td>53.74</td>
<td>26.17</td>
</tr>
<tr>
<td></td>
<td>p = .61</td>
<td>.26</td>
<td>.99</td>
</tr>
<tr>
<td></td>
<td>% = 92%</td>
<td>92%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Note: % = Percentage of subjects with similar profiles.
DISCUSSION

Physiological Arousal Across Baseline/Test Conditions

Hypothesis #1 predicted that all stressors would create higher levels of arousal than preceding baseline values. In general, this hypothesis was supported by a significant MANOVA main effect for baseline/test conditions. It can be concluded, therefore, that overall physiological responding was reliably altered through the manipulation of the stressor conditions.

Results of the 2 (BL/Test) x 4 (Stressors) ANOVA interactions in Table 3 provide an evaluation of the degree of reactivity elicited by the stressors. As such, these data allow an assessment of the relative potency of each stressor procedure. The findings related to heart rate responding show that all stressors generated significant heart rate increases over baseline levels. Furthermore, mental arithmetic resulted in greater heart rate reactivity relative to the other three stressors. Similarly, mental arithmetic and cold pressor created significantly greater vasconstriction than isometric challenge and Quiz EKG. Regarding systolic blood pressure, mental arithmetic and isometric challenge led to reliably higher responding while cold pressor and
isometric challenge resulted in significantly greater diastolic blood pressure. Thus, three major results were observed relative to the other stressors: (1) mental arithmetic yielded greater changes in heart rate, VMR and systolic blood pressure; (2) cold pressor resulted in the greatest vasoconstriction and diastolic blood pressure reactivity; and (3) isometric challenge generated higher systolic and diastolic blood pressure responding. The mental arithmetic data will be discussed in this section along with the BL/test main effects. The last two findings related to cold pressor and isometric challenge will be discussed in later sections.

The baseline/test main effect can be largely explained through consideration of the general organization of nervous system mechanisms. The central nervous system (CNS) is comprised of the brain and spinal cord, and is generally considered responsible for sensorimotor integration as well as higher order physiological and cognitive activities. On the other hand, the peripheral nervous system (PNS) is composed of all the area outside the brain and spinal cord and can be further divided into somatic and autonomic divisions. The somatic division has been associated with "voluntary" responses of the striate muscles while the autonomic division has been related to so-called "involuntary" physiological reactions. However, during the past two decades a rather large body of research has led to a reconsideration of these
"involuntary" responses. Nonetheless, conceptualizations of the PNS as comprised of somatic and autonomic branches is quite useful.

The autonomic division of the PNS can be further divided into sympathetic and parasympathetic systems. The neural pathways associated with sympathetic activity originate at the thoracic and lumbar segments of the spinal cord then project to ganglia located just outside the spinal cord. Efferent fibers leaving the ganglia extend to innervate the smooth muscles and glands in the viscera and skin. The post-ganglionic neurotransmitter of the sympathetic system is norepinephrine with the exception of acetylcholine for sweat gland activity. The catabolic action of sympathetic stimulation is generally responsible for diffuse activation of bodily functions as in response to emergency situations. Conversely, the parasympathetic branch of the autonomic nervous system has neurons originating at the cranial and sacral segments of the spinal cord which then project to ganglia located near the target organs. The post-ganglionic neurotransmitter for parasympathetic activity is acetylcholine. The anabolic effect of the parasympathetic division is generally characterized as a discrete physiological pattern which counteracts sympathetic activity and thus conserves bodily resources.

This distinction between sympathetic and parasympathetic responding provides a theoretical basis for
the physiological reactivity observed in this study. ANOVA main effects across baseline/test conditions were observed for significant increases in systolic and diastolic blood pressure and heart rate, along with significant decreases in VMR, skin temperature and skin resistance. Taken together, these changes can be characteristic of a sympathetic-like response pattern. Cardiovascular activity (i.e. heart rate and blood pressure), peripheral vascular responding (i.e. VMR and skin temperature) and electrodermal activity (i.e. skin resistance) are mediated by the sympathetic branch of the autonomic nervous system (Janig, 1975). Hence, it appears the underlying mechanism for the physiological reactivity to the stressors was generated by sympathetic stimulation.

Physiological Reactivity to Mental Arithmetic

Explanations for findings from the 2 (BL/test) x 4 (stressors) ANOVA's, illustrated in Figures 2 - 5, require more analysis of theoretical accounts of CNS and PNS functioning. As previously stated, mental arithmetic resulted in greater heart rate, systolic blood pressure and VMR reactivity compared to the other stressors. One theoretical approach which can be employed to explain this result, as well as the baseline/test main effect, has been termed "energy mobilization" (Duffy, 1962). The historical antecedents of this notion came from the work of Cannon (1915, 1939). This interpretation of the arousal hypothesis posits the existence of a generalized
physiological response which serves to enhance, through physiological stimulation, an increased behavioral drive. It follows then that the higher sympathetic arousal found for mental arithmetic can be considered a result of greater "energy mobilization." However, a major problem with this notion in general and the current data in particular, is that not all of the physiological variables comprise this physiological response. That is, of all the dependent variables assessed in this project, only heart rate, systolic blood pressure and VMR were significantly altered by mental arithmetic.

A more recent and potentially more viable interpretation of the present data is related to the principle of situational stereotypy. This psychophysiological principle underscores the tendency of individuals to respond in sterotypically different physiological patterns across tasks with different psychological demands (Lacey, 1967). In this regard, a hypothesis has been forwarded concerning differential physiological responding dependent upon whether stressful stimuli elicit active or passive coping responses. Examples of active tasks would involve shock-avoidance or monetary bonus contingencies related to quality of performance on an experimental procedure. Passive tasks differ by having subjects inactively tolerate the stressor exposure, such as cold pressor or viewing a stressful film. There is evidence that experimental tasks which require active
participation of the subject bring about a pattern of cardiovascular responding indicative of strong beta-adrenergic influences on the heart (Light & Obrist, 1980). This beta-adrenergic cardiovascular profile includes increased heart rate and systolic blood pressure but not necessarily increased diastolic blood pressure (Obrist, 1981). This response pattern was found in the present data for mental arithmetic which can be considered an active task since subjects had to perform numerical subtractions aloud. Therefore, it can be concluded that the active coping model may be a useful framework for conceptualizing the mental arithmetic data. The findings from the Quiz EKG and the physical stressors do not follow this precise physiological pattern and will be discussed in later sections.

Another task dimension thought to elicit specific physiological responding involves sensory and informational processing. It has been asserted that physiological profiles of cardiac functioning can vary according to the sensory demands of the experimental task (Lacey, 1967, 1972). The nature of these stimulus conditions are divided into sensory intake and sensory rejection. Sensory intake relates to tasks which demand attentive observation of the environment such as reaction time tasks. On the other hand, sensory rejection is involved in tasks that necessitate only internal cognitive functioning, thus filtering external stimulation, as in mental arithmetic. Some
research has demonstrated that cardiac activity decelerates during experimental conditions which require sensory intake, while cardiac acceleration has been related to sensory rejection tasks (Lacey & Lacey, 1970, 1973). A neuro-physiological model has been proposed which describes cardiac and pressor responses as facilitating sensory processing during deceleration and during acceleration being inhibitory to sensory processing (Lacey, 1967, 1972). This model assumes a functional relationship between cardiac activity, cortical activity and behavior. Specifically, heart rate and blood pressure are thought to indirectly alter cortical activity through a visceral afferent feedback loop mediated by the baroreceptors (Lacey, 1967, 1972; Lacey & Lacey, 1978). Thus, simply stated, decreases in heart rate and blood pressure are considered to facilitate attention to external environmental events, i.e. sensory intake. Increases in heart rate and blood pressure, conversely, are thought to disrupt such behaviors in turn leading to sensory rejection. In general, the proposed mechanism of the effects of sensory rejection is the inhibition of specific cortical and subcortical activities which occur due to baroreceptor stimulation at the carotid sinus and aortic arch. Heart rate and blood pressure decreases, associated with sensory intake, result from decreasing baroreceptor discharge and thus a relative reduction of inhibition or effectively an "excitation" (Siddle & Turpin, 1980).
Although research has not provided unequivocal support for this model nor specification of precise causal relationships, it nevertheless provides a useful theoretical framework (Elliot, 1972; Lacey & Lacey, 1974). Accordingly, this model could have direct application to the mental arithmetic data. The task demand for this stressor is characteristic of sensory rejection since mental arithmetic only required internal cognitive activity in the absence of any environmental stimulation. Therefore, the elevated heart rate and systolic blood pressure levels related to mental arithmetic could have resulted from the nature of the task which demanded sensory rejection. In contrast, Quiz EKG required attention be focused on the external provision of taped questions while the two physical stressors have a different proposed route of action to be discussed in the next two sections.

In sum, three theoretical perspectives are available as explanations of the mental arithmetic results. First, VMR responding as well as heart rate and systolic blood pressure increases, could be variables which manifest an "energy mobilization." This physiological response pattern may be a result of the generalized arousal created in reaction to a stimulus perceived to have an intense quality or a significant degree of challenge. Secondly, in a related account, responding to mental arithmetic could have resulted from the subjects' active coping to
the task, thus leading to strong beta-adrenergic cardiovascular influences. Finally, the third model can account for heart rate and systolic blood pressure increases by noting the sensory rejection demands of the mental arithmetic task. These three theoretical perspectives are not necessarily mutually exclusive and may each account for some aspects of these findings. In conclusion, further psychophysiological research is needed to identify the proper stimulus domains of these theoretical positions.

**Physiological Reactivity to Cold Pressor**

As previously mentioned, the cold pressor task resulted in significantly greater increases in diastolic blood pressure and decreases in VMR, relative to the other stressors. Along with these changes, heart rate and systolic blood pressure were also reliably elevated by cold pressor over baseline levels. These physiological changes can be primarily explained by the neurogenic reflex which is characteristic of hand immersion in ice cold water. This neurogenic reflex is generally typified by a sympathetically mediated peripheral vasoconstrictive response, increased heart rate activity and increased blood pressure responding. These physiological changes were observed for cold pressor in this present project.

This cold pressor reaction is dependent upon intact innervation from the immersed extremity since the response is initiated by peripheral neural impulses (Appenzeller, 1970). The cold stimulation excites temperature and pain
fibers that enter the dorsal roots of the spinal cord and project to the lateral spinothalamic, anterior spinothalamic and spinotectal tracts. The lateral and anterior spinothalamic tracts proceed through the thalamus to the somatic sensory cortex, while at the medulla collaterals are sent to the reticular formation. The spinotectal fibers enter the tectum, which is partly responsible for the mechanisms of the neurogenic reflex. Overall, cold pressor stimulation influences subcortical, cortical and perhaps limbic areas through the reticular formation and tectum (Appenzeller, 1970; Lovallo, 1975).

In view of these neurophysiological processes, it appears two primary mechanisms of action trigger the cold pressor response. One mode of action is the actual physiological response to the cold stimulus per se. This direct physiological reaction to the cold temperature is largely controlled by subcortical structures, particularly the hypothalamus and medulla. This mechanism is likely to account for the neurogenic reflex related to cold pressor. The second mode of action is associated to the negative affective responding elicited from the pain of the cold stimulus. Thus, cortical structures may account for some of the sympathetic arousal associated with cold pressor. Similarly, cortically mediated memory effects related to affective associations to painfully cold temperatures could also account for some physiological changes (Appenzeller, 1970; Lovallo, 1975).
In summary, the physiological pattern discerned for cold pressor in this project replicates previous research. This characteristic profile of responding is primarily due to a neurogenic reflex as well as affective reactions to the cold stimulus.

**Physiological Reactivity to Isometric Challenge**

Isometric challenge generated higher systolic and diastolic blood pressure, in comparison to the other stressors. Moreover, heart rate activity was significantly elevated over baseline levels during isometric challenge. This physiological response pattern can be largely attributed to a neurogenic reflex elicited by an isometric contraction (Mitchel & Wildenthal, 1974). This type of muscle contraction results from activities like gripping a hand dynamometer and is characterized by sustained static tension with little change in length of a muscle group. In contrast, isotonic muscular contractions, which result from rhythmic exercise like running, cause a change in muscle length with little alteration in muscular tension. Isotonic exercise causes large increases in heart rate with little change in blood pressure. Conversely, isometric contraction leads to marked increases in blood pressure with moderate heart rate change. As expected, this latter physiological profile was observed in this study during the isometric challenge.
The rapid cardiovascular changes related to isometric challenge strongly suggest a neurogenic reflex (Freyschuss, 1970). Although the actual neural pathways are unknown, two general neurogenic mechanisms have been hypothesized to account for these classic cardiovascular changes (Mitchell & Wildenthal, 1974). One proposed mechanism is the direct action of the motor cortex on the cardiovascular center. Hence, the increased blood pressure and heart rate associated with isometric muscular contraction may be directly influenced by central mechanisms. The second account considers the neurogenic reflex to originate at the site of the contracting muscle. This peripheral explanation views the cardiovascular changes as being mediated by reflex arcs triggered at the involved skeletal muscle. Strong empirical evidence has been reported in support of these positions as contributory yet separate mechanisms (Mitchel & Wildenthal, 1974). As such, it appears that central and peripheral factors independently affect the cardiovascular reactivity observed during isometric challenge.

Physiological Responding Across Sessions

Hypothesis #2 stated that all stressors would be equivalent at session 1 and physical stressors would create significantly higher levels of arousal at session 2 relative to mental stressors. This hypothesis was not confirmed. However, a significant 2 (sessions) x 2 (BL/test) x 4 (stressors) interaction for heart rate was
found and these data were in the direction of the experimental hypothesis (see Table 4 and Figure 6). Mental arithmetic, which caused the highest level of heart rate at session 1, was significantly lower at session 2. Likewise, heart rate for Quiz EKG at session 1 was significant over baseline whereas this difference did not occur at session 2. Cold pressor had heart rate increases over respective baselines at each session while isometric challenge was not different over baseline at either session.

These findings suggest that the mental stressors of Quiz EKG and mental arithmetic had lost some of their stressful properties at retest. Yet, mental arithmetic still elicited significant heart rate over baseline at session 2 whereas Quiz EKG did not. These results partially replicate the Williamson et al. (1985) data which found Quiz EKG to have lower physiological reactivity at session 2.

In this present study, the Quiz EKG was conducted in strict accordance to the protocol established by Schiffer et al. (1976) where a subject was allowed seven seconds to answer each question before the correct response was provided. Williamson et al. (1985) used the items from the Quiz EKG but did not provide the correct response after each item. However, even though Williamson et al. (1985) did not adhere to Schiffer et al.'s (1976) protocol, they found similar levels of responding at session 2.
(M = 75.34 BPM) as was found in the present investigation (M = 74.73 BPM). In any event, it appears that the mental stressors in this project lost some potency at session 2, when heart rate was the dependent variable. This reduced potency was especially apparent for Quiz EKG, perhaps due to the provision of correct responses at the initial presentation, which may have been recalled by subjects at session 2. This factor could partially account for the reduced stressfulness of Quiz EKG at session 2. Nonetheless, both mental stressors generated less heart rate reactivity at the second session, warranting caution in using heart rate as the sole physiological measure with either stressor. It should be noted, however, that heart rate was the only variable to demonstrate this effect. The other six dependent measures did not have the significant 2 (sessions) x 2 (BL/test) x 4 (stressors) ANOVA, and the corresponding MANOVA was also not significant. Therefore, an overall session effect as a function of stressor type was not found.

Univariate and Multivariate Test-Retest Reliability

Hypotheses #3 and #4 predicted that Pearson correlations and PSI analyses would identify physical stressors as more reliable than mental stressors. These hypotheses were not supported since test-retest reliability was high for all stressors. Hypothesis #5 stated that the brief mental arithmetic stressor would be more reliable than the relatively longer Quiz EKG. This hypothesis
was also not supported.

Regarding univariate reliability analyses, most baseline and absolute test-retest Pearson correlations were adequate across all stressors, with the exception of EMG. This finding replicates Williamson et al. (1985), which reported consistently significant test-retest correlations across most physiological variables except EMG. In contrast, Arena et al. (1983) and earlier researchers (e.g. Martin, 1956, 1958) have found high test-retest reliability for EMG. No apparent explanation for this discrepancy is readily available, but perhaps the employment of different stressors across studies can account for some of this variance. Also, it is possible that poor EMG reliability was related to ineffective experimental manipulation since EMG was the only dependent variable not to change across baseline/test conditions. This explanation, however, may not be sufficient because baseline levels would still be expected to be reliable but were not.

Two stressors, cold pressor and mental arithmetic, were used in both the current study and Arena et al. (1983). Inspection of the respective Pearson correlations demonstrate generally comparable results for absolute test values. The only exception to this general trend were higher correlations for skin resistance in the present study while Arena et al. (1983) cited greater EMG reliability.
Univariate test-retest reliability of difference scores was not found to be adequate. This finding replicates Williamson et al. (1985) and Arena et al. (1983). Therefore, difference scores have been consistently found to be unreliable using univariate correlations. These findings could be due to the restricted variability of difference scores which may preclude significant correlational results.

Multivariate test-retest reliability as measured by PSI group analyses indicated that all baseline, test and difference scores had adequate reliability. These results demonstrate that overall physiological profiles for session 1 were similar to the second session. This finding corresponds with PSI analyses reported by Williamson et al. (1985) with the exception of difference scores for Quiz EKG. Specifically, the present PSI data found Quiz EKG difference scores to be stable, whereas Williamson et al. (1985) did not. The reason for these differential results is not clear. One major difference between these two projects is the stricter accordance of the current study to the Schiffer et al. (1976) protocol. This difference, however, does not logically account for the differential multivariate reliability. Another potential source for this difference is the current study employed a larger sample of twenty four subjects, excluding the holdout group, while Williamson et al. (1985) used only fifteen subjects. This larger sample could have allowed
a more stable analysis of response patterns related to difference scores. Nevertheless, the general conclusions from both studies are in agreement. Thus, from a multivariate perspective, group psychophysiological responding can be reliably indexed according to PSI analyses.

PSI assessments also provided an evaluation of the reliability of data from individual subjects. These data indicated that a very high percentage of the subjects had significantly similar physiological response patterns across sessions. The results from the individual PSI analyses correspond with findings from the group analysis. That is, overall physiological profiles were reliable from session 1 to session 2 across baseline, test and difference scores. Again, this finding replicates the Williamson et al. (1985) study.

In sum, the univariate test-retest reliability was adequate for absolute test values and baseline levels across all physiological measures except EMG, whereas difference scores did not have adequate univariate reliability. Multivariate test-retest reliability was also adequate, replicating and extending previous research. This comparative study found that the two physical stressors and two mental stressors created significant and equivalent levels of reliability. Thus, regarding the intimate relationship between reliability and validity, the remarkably consistent reliability across stressors
provides an empirical basis for the validity of conclusions from psychophysiological reactivity research. In conclusion, with test-retest reliability established under the specific aforementioned conditions, research can now be focused upon the validity of theoretical constructs ascribed to psychophysiological responding.

Summary

In summary, there was no support for hypotheses #2 - #5, which each predicted a particular differential pattern of physiological responding across stressors. Only hypothesis #1 was supported, which predicted that all four stressors would result in greater arousal over baseline levels. Univariate test-retest reliability was generally adequate for absolute test values and baseline levels but not for difference scores. Multivariate test-retest reliability was adequate across all stressor conditions. Equivalent levels of univariate and multivariate reliability were consistently observed for mental and physical stressors. Therefore, in conclusion, degree of reliability was not affected by stressor type.
REFERENCES
REFERENCES


APPENDIX A

Exclusion Criteria Checklist

Potential subjects will be asked if they have any of the following physical problems. Individuals who answer in the affirmative to any item below will be excluded from the study.

- Current symptoms of a cold or a flu
- Any prior surgery to the right hand
- Any personal history of: Raynaud's syndrome
  Coronary heart disease
  High blood pressure
  Allergy to cold
APPENDIX B

Informed Consent

This experiment is a project that will last one hour on two occasions separated by two weeks. This study will measure your physiological responding (e.g. heart rate, muscle tension) while engaging in several experimental tasks on these two different days. If you agree to participate in this study today, you will be asked to return in exactly two weeks for a second session. Please sign under the statement after reading it if you volunteer to participate.

I have volunteered to participate in this experiment and realize that I can discontinue participation at any time without penalty. I also acknowledge that the information obtained from me will be kept confidential and will not be used against me in any way.

______________________________
Signature of Participant

Date: ________________

______________________________
Witness

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APPENDIX C

Quiz Electrocardiogram

You will now be given an oral test. You will be asked a series of questions, each requiring a short answer. You must tell your response aloud, within the allotted time. After the allotted time, the correct answer will be given, and then a new question will be asked. If you should miss a question, simply go on to the next question. A sample question is: Question: Five plus five equals? (Pause) Answer: Ten.

You are asked to make a determined effort to complete the test, but if you wish, you may stop at any time. The test is designed to evaluate your ability to learn and to use information wisely as compared to other individuals your age. A perfect score is indicative of genius, and few are expected to attain that level. If any mental deficiencies are noted, you will be given the opportunity for further evaluation. Your final evaluation will be revealed to you at the end of the last session. Do you have any questions?

We will now begin:

Question number 1: Complete the following sequence: 2, 7, 12, 17, blank. Answer: 22.
Question number 2: If X is greater than Y and Y is greater than Z, then X is blank than Z? Answer: Greater than.
Question number 3: Wheel is to car as blank is to sleigh? Answer: Runner.
Question number 4: Which is more, 10, or 2 times 4.5? Answer: 10.
Question number 5: Music and sculpture are both blank? Answer: Art.
Question number 6: Fill in the blank. Far is to near as tall is to blank. Answer: Short.
Question number 7: Which word does not have the same meaning as the other words: Eminent, vulnerable, distinguished, outstanding? Answer: Vulnerable.
Question number 8: Repeat backwards: 1, 5, 7, 9. Answer: 9, 7, 5, 1.
Question number 9: If Y is greater than X and Z is less than X, then Z is blank than Y. Answer: Less than.
Question number 10: H-2-0 is to water as C-O-2 is to blank? Answer: Carbon dioxide.
### APPENDIX D

#### Individual PSI Results for Cold Pressor

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**Note:** * = Significantly different profile from sessions one and two (p < .05).
## APPENDIX E

### Individual PSI Results for Mental Arithmetic

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**Note:** * = Significantly different profile from sessions one and two (p < .05).
APPENDIX F

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Note: * = Significantly different profiles from sessions one and two (P < .05).
APPENDIX G

Individual PSI Results for Quiz EKG

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CURRICULUM VITAE

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POSITIONS HELD:
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Greenwell Springs, Louisiana

1983 - 1984 Graduate Research Assistant, Psychology
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Baton Rouge, Louisiana

1982 - 1983 Psychology Practicum, Earl K. Long Hospital,
Baton Rouge, Louisiana
1982  Research Consultant, Angola State Penitentiary  Angola, Louisiana


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American Psychological Association
APA Division of Clinical Psychology (Division 12)
Association for Advancement of Behavior Therapy
AABT Behavioral Medicine Special Interest Group
Association for the Advancement of Psychology
Society of Behavioral Medicine
Southeastern Psychological Association

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Multivariate psychometric approaches to assessment of medical and psychiatric populations

Psychophysiological and psychobiological assessments of stress-related medical disorders

Validation of biological markers of psychopathology via psychometric assessment

Assessment and treatment of stress-related disorders including headache and dermatological conditions

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Introduction to Psychology - Hinds Junior College, Jackson, Mississippi

Advanced Behavior Therapy - Mississippi State University, Jackson, MS Branch

Psychology of Aging - Mississippi State University, Jackson, MS Branch

Advanced Statistics for Social Sciences - Jackson State University, Jackson, Mississippi

BIBLIOGRAPHY:


Faulstich, M. E., Brantley, P. J. and Barkemeyer, C. A. Creatine phosphokinase, the Minnesota Multiphasic Personality Inventory and psychosis. American Journal of Psychiatry, 1984, 141, 584-586.


Faulstich, M. E. Behavioral analysis of sexual dysfunction


In Press:


Submitted:

Faulstich, M. E., Moore, J. R., and Roberts, R. W. A cognitive-behavioral perspective of conduct disorders:
A selective review.


Moore, J. R., Faulstich, M. E. and Gresham, F. M. Analysis of DSM III diagnoses in an adolescent inpatient setting.


PAPERS PRESENTED/PROGRAMS CHAIRED:


Faulstich, M. E. and Jarrell, M. P. "The Effects of Feedback Sensitivity During Learned Control of Skin Temperature." Presented at the annual meeting of the Southeastern Psychological Association, Atlanta, 1983.


Faulstich, M. E. "Societal Reactions to employment of the


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Major Field: Psychology

Title of Dissertation: The Reliability of Psychophysiological Assessment: A Comparative Analysis of Two Mental and Two Physical Stressors

Approved:

[Signatures]

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

November 22, 1985