Multivariate Discrimination of Emotion-Specific Autonomic Nervous System Activity

by

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ABSTRACT

The present study investigated autonomic nervous system (ANS) patterning during experimentally manipulated emotion. Film clips previously shown to induce amusement, anger, contentment, disgust, fear, and sadness, in addition to a neutral control, were presented to 34 college-aged subjects while electrodermal activity, blood pressure and electrocardiogram (ECG) were recorded as was self-reported affect. Mean and mean successive difference of inter-beat interval were derived from the ECG. Pattern classification analysis revealed emotion-specific patterning for all emotion conditions except disgust. Discriminant function analysis was used to describe the location of discrete emotions within a dimensional affective state space, for both self-report and ANS activity. Findings suggest traditional dimensional emotion models accurately describe the state space for self-reported emotion, but may require modification in order to accurately describe the state space for ANS activity during discrete emotions. Proposed modifications are consistent with the adoption of a discrete-dimensional hybrid model as well as current trends in emotion theory.

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Chapter 1. Introduction

Debate surrounding the patterning of autonomic nervous system (ANS) activity during emotion remains as intriguing to researchers today as when the issue was originally raised by William James (1884) over a century ago. The crux of the argument can be characterized by the contrasting views of James, who indirectly argued for specificity of visceral patterns by describing the phenomenology of emotion as dependent upon visceral feedback, and Cannon (1927, 1931), who proposed that emotions were accompanied by undifferentiated diffuse sympathetic arousal. This historical topic served as a key item on the agenda of the burgeoning discipline of psychophysiology in the 1950's and 60's (Ax, 1964) and a good deal of early evidence favored the specificity position (e.g. Ax, 1953; Funkenstein, King, & Drollette, 1954; Schachter, 1957).

Despite this early empirical support, Schacter and Singer's cognition-arousal theory of emotion (1962) largely defined the zeitgeist regarding emotion and ANS activity during the 1960's and remained extremely influential for at least two decades. During this time, research involving autonomic specificity was essentially nonexistent. Briefly, Schacter and Singer's theory described the experience of emotion as dependent upon the cognitive appraisal of the environment in response to nonspecific ANS activity. The popularity of their theory was likely due in large part to the persistent belief in a unitary concept of physiological activation or arousal, despite clear evidence that such a concept is untenable. Not only do various measures of sympathetic activity fail to exhibit sizeable intercorrelations, but individuals may also exhibit idiosyncratic patterns of somatic activity (Lacey, 1967). Moreover, although the historical view in psychophysiology has been that the relationship between the sympathetic and parasympathetic branches of the ANS is entirely antagonistic, modern theories describe the two branches of the ANS as being, under certain conditions, equally active and sometimes working independently of one another (e.g. autonomic space; Berntson, Cacioppo, & Quigley, 1991). Taken together, these characteristics serve as convincing evidence of the potential for multiple patterns of activation within the ANS, a requisite to justify further inquiry into ANS activity during emotion.

The topic of ANS specificity in emotion has enjoyed a modest revival in the last two decades, and much recent experimentation has provided additional evidence of specific ANS patterns for at least some emotions (e.g. Ekman, Levenson, & Friesen, 1983; Levenson, Ekman, & Friesen, 1990; Levenson, Ekman, Heider, & Friesen, 1992; Sinha, Lovallo, & Parsons, 1992; Stemmler, 1989; Witvliet & Vrana, 1995). However, some researchers have contested the consistency of results in this literature and claim that the assertion of invariant patterns of ANS activity during emotion is unwarranted (Cacioppo, Klein, Berntson, & Hatfield, 1993).

A number of issues that may have contributed to the inconsistency in findings have been highlighted, including an exclusive focus upon the sympathetic branch of the ANS and a predominantly univariate analysis of multiple response variables. In considering that the goal is to uncover patterns of emotion-specific ANS activity, it follows that the ANS should be sampled in its entirety (i.e. from both the sympathetic and parasympathetic branches) and it is necessary to utilize analytic methods that are able to discern the coordination of multiple response systems during emotion (Stemmler, 1992; Fridlund, Schwartz, & Fowler, 1984).

An additional issue that has been less prevalent in recent research but still merits attention is the need to compare different emotions within the same context or experimental setting. Because different stimulus situations are likely to produce different patterns of somatic responses, a phenomenon Lacey (1967) referred to as situational stereotypy, results from experiments that compare emotions from differing contexts are threatened with ambiguity. In such cases it is impossible to distinguish the physiological effects due to emotion from those due to situational context. Concerns regarding the potential threat of emotion-context confounds has motivated Stemmler and colleagues to describe a component model of somatovisceral response organization (Stemmler, Heldman, Pauls, & Scherer, 2001). In this model, a hierarchy of response components is presented which essentially describes the physiological signature of emotion as being additive to the ongoing physiological activity determined by many aspects of the experimental context. Through the inclusion of a "context without emotion" condition,

researchers can begin to tease apart the physiological effects due to emotion from those due to context (Stemmler, 1992).

In an effort to remedy these issues, Nyklicek, Thayer, & Van Doornen (1997) examined a range of cardiorespiratory variables, including an index of parasympathetic cardiac control, during affect manipulation. The first part the study involved selection of music pieces that varied along the dimensions of valence and activation as illustrated by factor analysis with varimax rotation of self-report of the degree to which music pieces were described by a range of affective terms (e.g., cheerful, content, sad relaxing). Music excerpts with the highest loadings on the factors of valence and activation and having small standard deviation in self-report, thus showing high consistency, were selected for use in the main experiment. From 25 original music excerpts, 3 were selected in this manner to represent each of the following affect conditions: happiness (positive valence, high activation), sadness (negative valence, low activation), serenity (positive valence, low activation), and agitation (negative valence, high activation). A neutral "white noise" condition was also included resulting in a total of 13 music clips. Subjects, consisting of both male and female college students between the ages of 18 and 26, listened to each music clip a single time on one of two laboratory visits and analysis was carried out using change from baseline scores. Using multivariate techniques, Nyklicek et al. (1997) were able to reliably distinguish patterns of ANS activity during each of the four affect conditions. Furthermore, two emotion dimensions or activation components in the ANS data, accounting for over 70% of the variance, were identified: valence and activation.

The Structure of Affective Space

A greater understanding of the activation components underlying ANS activity during emotion may prove to be helpful in understanding the structure of affective space, a topic that has also generated much interest. Traditionally, affect models could be assigned to one of two broadly defined categories: discrete or dimensional. In discrete models, the focus is upon well-defined 'primary' emotions such as fear, anger, or disgust and less interest is paid to the relationships between individual emotions. These primary emotions are viewed as locations on an emotional landscape and are often discussed in terms of their adaptive value as a means for

selection across time and species (e.g., Ekman et al., 1983; Ekman, Sorenson, & Friesen, 1969; Levenson, Ekman, & Friesen, 1990).

By contrast, dimensional models essentially view emotions as areas or locals in a multidimensional space defined by a limited number of underlying dimensions. Emotions are related to each other by means of their relative locations in affective space. The most prevalent of the dimensional models is the circumplex, which arranges emotional judgments or description of current (i.e. experienced) affect in a two-dimensional circular arrangement. The nature of the dimensions describing the circumplex has received a good deal of attention. Research has consistently shown that the dimensions that describe the circumplex are 1) valence or hedonic tone, which is the positive or negative nature of the affective experience; and 2) arousal or activation, which is the degree of energy associated with the affective state. There has been a tendency to relate the activation dimension to some form of general physiological arousal or the intensity of the experienced affect. For reasons discussed earlier, the notion of physiological arousal is considered implausible and therefore not suitable to serve as the conceptual basis of the activation dimension. In fact, the term activation is preferable to arousal as it lacks the implication of physiological activity. Recent evidence also suggests the association of activation dimension with intensity of experience is also faulty because felt activation and intensity of valenced affect exhibit relatively small latent correlations (Feldman Barrett & Russell, 1998).

The manner in which the dimensions of the circumplex combine to create emotional experience has been a source of some controversy. On the one hand there is the valence - activation model that asserts the dimensions of valence and activation are both bipolar and orthogonal (i.e., independent). Perhaps the most widely cited example of such a circumplex is that proposed by Russell (1980), although others (e.g., Larsen & Diener, 1992) have described comparable models that differ only in their labeling of the endpoints of the bipolar dimensions (e.g., pleasant-unpleasant vs. pleasure-misery for the valence dimension and high activation-low activation vs. arousal-sleep for the activation dimension). Most recently, Russell and colleagues (e.g., Feldman Barrett & Russell, 1998) have adopted the terms pleasant-unpleasant and activated-deactivated as anchors for the valence and activation dimensions.

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Other emotion theorists have preferred to describe the same affective space using a pair of orthogonal axes identified as positive affect (PA) and negative affect (NA) and rotated 45° relative to the valence and activation axes (Watson & Tellegan, 1985). The most marked theoretical distinctions between the valence-activation and PA/NA circumplex models are 1) the former includes an independent dimension of activation, whereas the latter considers activation to be inseparable from valence and 2) the former describes valence as a single bipolar dimension (i.e., pleasant and unpleasant are located at the opposite ends of a single valence dimension) whereas the latter holds that PA and NA are independent unipolar dimensions (i.e., affective experience is the result of combinations of PA and NA).

Although both the valence-activation and PA/NA models have generated considerable empirical support, research involving topics as disparate as affective reactions to laboratory stressors (Friedman, Takayama, Long, & Thayer, 1997), self reports of emotional states (Thayer & Sinclair, 1987; Feldman Barrett & Russell, 1998), daily mood reports (Thayer, & Miller, 1988), and judgments of facial expressions of emotion (Johnsen, Thayer, & Hugdahl, 1995) present a considerable convergence of evidence indicating the dimensions of valence and activation are the best descriptors of affective space. There is also a growing body of literature that convincingly illustrates that the dimensions of the PA/NA model are largely the result of a failure to account for random and systematic measurement error (e.g., Feldman Barrett & Russell; Green, Goldman, & Salovey, 1993; Russell & Carroll, 1999). Furthermore, factor analysis of self report following divergent laboratory-based affect manipulations on multiple occasions exhibited the familiar bipolar dimensions of valence and activation, not only at the nomothetic level (i.e., across groups of individuals) but also at the idiographic level (i.e., within individuals; Faith & Thayer, 2001). Finally, additional support has been provided by studies using analytic techniques designed to assess not the bipolarity and independence of the underlying dimensions, but the circumplex structure resulting from the combination of the two dimensions (Remington, Fabrigar, & Visser, 2000).

Research based upon dimensional models of emotion has typically dealt with more general classes of affect rather than individual emotions themselves, and has tended to focus on issues that are social or cognitive in nature (e.g., Sinclair & Mark, 1995). There are exceptions,

however, and some of the more recent investigations of ANS activity during emotion have adopted this dimensional perspective. For example, Nyklicek et al. (1997) and Witvliet and Vrana (1995), both theoretically based upon dimensional models, evidenced differential autonomic and/or somatic response patterns for different emotion categories (e.g., high activation-negative valence).

Although the discrete and dimensional models are often presented as mutually exclusive, the most fruitful approach for describing ANS activity during emotion may be a hybrid of the two (Levenson, 1988). One approach to this hybrid model is to describe a hierarchical relationship between the lower-order discrete emotions and the higher-order emotion dimensions (Nyklicek et al., 1997). That is, the individual emotions of the discrete model represent unique points within the affective state-space described by the dimensional model.

Function and Distinguishing Characteristics of Emotion

Regardless of the type of affect model adopted, it is also helpful to describe emotion in a larger functional framework and to outline the characteristics that are believed to distinguish emotions from other affective constructs such as mood. In a general sense, emotion is described as an organizer of behavior (Levenson, 1988). To this end, emotions serve to coordinate a multitude of behavioral and physiological response systems, ranging from the muscles of the face to the organs of the body, ultimately producing an appropriate organismic response to environmental events or situations. By means of this organizing force provided by emotions, adaptive behaviors that normally reside near the bottom of behavioral hierarchies may be rapidly shifted to the top.

With respect to distinguishing emotion from other affective constructs, Ekman (1984) proposed a series of ten characteristics, each of which fall into one of three general categories involving: (a) the duration or intensity of experience, with emotions being both relatively intense and of short duration; (b) the eliciting stimuli, where the antecedents of emotions appear to be comparatively prototypical situations or events; and (c) patterned changes in expression or physiology, with particular emotions being represented by seemingly universal facial expressions

and unique patterns of physiological activity. It should be noted that it is with great optimism that unique patterns of physiological activity were cited as a defining characteristic of emotion.

<u>Affect Manipulation and Emotion Specificity</u>

A final point that must be addressed is the manner by which affect will be experimentally manipulated. Diverse methodologies are available, including: (a) scripted interaction with trained confederates (e.g. Ax, 1953; Stemmler, 1989); (b) reading affectively valenced statements (e.g. Velten, 1968) or scenarios (e.g., Witvliet & Vrana, 1995); (c) directed facial expressions (e.g. Ekman et al., 1983); (d) emotional imagery (e.g. Lang, 1979); (e) music (e.g. Nyklicek et al., 1997); (f) slides (Lang, Öhman, & Vaitl, 1988); and (g) films (McHugo, Smith, & Lanzetta, 1982). Of these options, films are particularly advantageous because they are readily standardized, require little or no deception, and allow for a "context without emotion" condition, the necessity of which was described above. Films also possess a high degree of ecological validity in so far as emotions are often evoked by dynamic auditory and visual situations external to the individual (Gross & Levenson, 1995).

Not only must the feasibility and effectiveness of these procedures be considered when selecting an affect manipulation, it is also necessary to carefully consider the type of affect model (i.e., discrete or dimensional) upon which the manipulation is based. For example, the facial action task used by Ekman et al. (1983) is meant to assess the impact of discrete emotions such as anger or fear, or at least their respective facial expressions, on ANS functioning. By comparison, the musical affect manipulation generated and used by Nyklicek et al. (1997) is very much based upon the dimensional circumplex model. As such, the nature of the affect induced is representative of the quadrants defined by the dimensions of activation and valence. So, although Nyklicek et al. were successful in describing affective space in general and have shown ANS discrimination between areas or quadrants of that space, it is questionable as to whether they have described or identified individual (i.e., discrete) emotions in particular.

Creating the representative montage of autonomic variables requires sampling from a range of physiological measures with differing autonomic regulatory mechanisms. Electrodermal activity (EDA) and blood pressure (BP) are two measures traditionally utilized in emotion research. EDA is a natural choice as it has been consistently been related to emotional arousal (e.g., Codispoti, Bradley, & Lang, 2001; Lang, Greenwald, Bradley, & Hamm, 1993). With respect to its autonomic basis, EDA is particularly relevant for two reasons: first, the ecrine glands of the fingers are not innervated by parasympathetic fibers so EDA serves as a solely sympathetic measure; and two, the postganglionic sympathetic fibers are cholinergic rather than noradrenergic, as is the case for other organs innervated by the sympathetic system (Boucsein, W., 1992).

The use of BP in emotion specificity research can be traced back to Ax's pioneering work in which systolic and diastolic BP were instrumental in describing the physiological signatures of anger and fear. The autonomic regulation of arterial BP is rather complex as it is the end result of a number of hemodynamic processes (Smith & Kampine, 1984), primarily cardiac output and total peripheral resistance. Cardiac output, the amount of blood ejected by the heart per unit time, is the result of heart rate, regulated by both parasympathetic (i.e. vagal) and beta-adrenergic sympathetic outflow, and stroke volume, which is under predominantly sympathetic beta-adrenergic control. Peripheral resistance, the resistance to the flow of blood provided by the arterial vasculature, is the sum effect of sympathetic alpha- and beta-adrenergic effects on vasodilation and vasoconstriction of the arterial walls. The differential distribution of receptor subtypes and their specific effects on vascular tone gives rise to a complex regulatory process. Activation of alpha-adrenergic receptors, located predominantly in arteries supplying the skin, skeletal muscle, and abdominal viscera, results in vasoconstriction of the arterial walls, and thus an increase in peripheral resistance. By contrast, activation of beta-adrenergic receptors, found almost exclusively in the arteries supplying large skeletal muscles, results in vasodilation and a decrease in peripheral resistance. Considering the number of autonomic inputs affecting its regulation, it is clear that measures of blood pressure cannot be considered to index a single

physiological process (Papillo & Shapiro, 1990), nor should it be considered a measure of general "sympathetic arousal". To do so belies the complexity of its autonomic underpinnings.

Finally, truly complete sampling of the entire ANS requires measures reflective of parasympathetic activity. This can be met through application of various time- and frequency-domain statistics to the inter-beat interval time series. These statistics capture the intrinsic patterns of heart period variability modulated by the parasympathetic branch of the ANS (Saul, 1990).

Multivariate Techniques and the Specificity Question

As stated earlier, if the topic of ANS patterning during emotion is to be adequately addressed, analytic techniques sensitive to configurations of multiple variables (i.e., patterns) must be applied. Pattern classification analysis, the technique utilized by Nyklicek et al., is ideally suited for the research question because it allows for the simultaneous consideration of multiple ANS response variables. In pattern classification analysis, a specific application of discriminant analysis, classification functions are generated for each of several output classes (e.g., emotions). Cases or observations are then assigned to classes based upon a vector of input elements (e.g., a vector of autonomic responses). The effectiveness of the classification functions, and thus the discriminability of the classes based upon respective input elements, is then evaluated by testing the percentage of correct classifications against chance level using a standardized normal test statistic (Huberty, 1994). Because the primary topic of investigation was ANS activity during emotion, the following main hypothesis was examined: the ANS response patterns elicited during the experimentally manipulated emotions of amusement, anger, contentment, disgust, fear, and sadness will be discriminated both from the neutral stimulus condition and from each other.

A secondary goal of the study was to describe the location of discrete emotions, with respect to both ANS and self-report variables, within a dimensional affective space. A descriptive application of discriminate analysis, as opposed to the predictive application utilized by pattern classification analysis, as well as other multivariate techniques such as factor analysis,

can also be useful in describing variable structure. Insight into variable structure allows for the identification of "activation components" underlying the multiple responses of diverse physiological variables during emotion (Stemmler, 1993; Stemmler, Grossman, Schmid, & Foerster, 1992). Discriminant analysis, involving a smaller number of discriminant rather than classification functions, is ideally suited to address this aspect of the data because it identifies the dimensions (i.e., discriminant functions) that maximize group separation in the multivariate space defined by the data. Once discriminant functions are identified, group centroids, essentially multivariate means, can be used to describe each emotion condition within the affective space delineated by the discriminant functions.

An additional issue that emerges in the context of the James (1884) model is the degree of variance in self-reported emotion that can be accounted for by variance in ANS measures. Redundancy analysis is particularly useful for this purpose because it allows for the generation of asymmetric indices of shared variance between two sets of data. As opposed to multivariate techniques that generate symmetrical estimates of covariance (e.g., canonical correlation), redundancy analysis allows one set of variables to be viewed as predictive of another. In this manner, redundancy indices yield the maximum proportion of variance that can be explained in the criterion variables by the predictor variables. The assignment of predictor and criterion may also be reversed such that variance explained is maximized in the "opposite direction". In this sense, the redundancy indices are directional and hence asymmetric (Lambert, Wildt, & Durand, 1989).

Summary & Overview of the Experiment

The goal of the present study was to replicate and extend the findings of Nyklicek, et al (1997) working from the same hybrid discrete-dimensional model of emotion. The major departure, however, is the use of an affect manipulation generated from the discrete emotion perspective. This allows not only the opportunity to corroborate the dimensional structure of affective space described by Nyklicek et al., but also the ability to describe the nature and location of discrete emotions within the dimensional affective state-space.

To achieve these goals, the current study: 1) employed a standardized set of affective films (Gross & Levenson, 1995), including a relatively neutral "context without emotion" condition necessary to avoid potential emotion-context confounds (Stemmler, 1992); 2) applied multivariate techniques sensitive to the coordination of multiple response variables to assess the degree of emotion-specific patterning present (Stemmler, 1992); and 3) included parasympathetic measures that have been lacking in much of the previous ANS and emotion literature. Specifically, it is predicted that the ANS response patterns elicited during the experimentally manipulated emotions of amusement, anger, contentment, disgust, fear, and sadness will be discriminated both from the neutral stimulus condition and from each other.

Chapter 2. Method

<u>Subjects</u>

Thirty-four subjects (16 males and 18 females) were recruited via fliers and received their choice of either extra credit or $10 for their participation in an experimental session lasting approximately one and a half hours. Subjects were screened on the basis of age (18-26 years old; sample mean: 18.7 years; standard deviation: .88) and health status as determined by questionnaire (see Appendix A). Those indicating a history of neurological deficits, cardiovascular problems, or those currently taking medication for hypertension, depression, or anxiety were excluded. In addition, because the characteristic blunted affect accompanying depression or an inability to accurately identify or describe affective states, a characteristic of alexithymia, could interfere with the goals of the study, subjects were screened based upon scores on the Beck Depression Inventory-II (BDI-II; Beck, Steer, & Brown, 1996; see Appendix B) and the Toronto Alexithymia Scale (TAS-20; see Appendix C; Bagby, Taylor, & Parker, 1992; Bagby, Parker, & Taylor, 1992).

For the BDI-II a cutoff of 19, the upper limit for mildly depressive symptomatology (Beck et al., 1996), was used (sample mean: 5.06; standard deviation: 3.8; range: 0-14). For the TAS a cutoff of 51, the lower limit for diagnosis of alexithymia (Bagby, Taylor et al., 1992; Bagby, Parker et al., 1992), was used (sample mean: 38.8; standard deviation: 7.7; range: 25-51). All screening data was collected via online questionnaire and qualified subjects were contacted by means of email in order to schedule an appointment for the second stage of the study.

<u>Materials</u>

<u>Film clips.</u>

The proposed study made use of standardized films shown to elicit the discrete emotions amusement, anger, contentment, disgust, fear, sadness, and a relatively neutral state (Gross & Levenson, 1995). The clips varied in length ranging from 81 to 203 seconds, with an average length of 145 seconds and were presented on a 42 inch flat-panel television approximately 2 meters from the subject. Descriptions of film clips can be found in Appendix D.

<u>Questionnaires.</u>

At designated times throughout the experimental protocol, subjects completed an 18-item affect self-report scale (ASR; see appendix E). Consistent with the adoption of a hybrid model of affective space the ASR contains items traditional to both the discrete (amused, fearful, angry, sad, disgusted, and content) and dimensional (good, calm, unpleasant, passive, excited, negative, relaxed, active, positive, agitated, bad, and pleasant) models. The discrete portion of the scale is comparable to that used to generate and validate the standardized film set (Gross & Levenson, 1995) and the dimensional portion is based upon an English translation of the scale used by Nyklicek et al. (1997).

<u>Physiological recording equipment.</u>

Electrocardiogram (ECG) and electrodermal activity were recorded by means of the Ambulatory Monitoring System (AMS; Vrije Universiteit, Department of Psychophysiology, Amsterdam, The Netherlands), a small battery-driven device the size of a "Sony Walkman" specifically designed for psychophysiological research. EDA was recorded from the index and middle fingers of the right hand by two reusable electrodes attached with Velcro strips. EDA was recorded using a .5 V constant voltage procedure and was sampled at 2 Hz. EDA output from the AMS was in standard micro Siemen (μS) conductance units. The ECG was analog filtered (high

pass 17 Hz) at the time of recording and subjected to an online auto trigger level R-wave detection resulting in an interbeat interval (IBI) resolution of 1 ms.

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were recorded by means of the Vasotrac, a non-invasive semi-continuous blood pressure monitor (Medwave, Arden Hills, MN). The Vasotrac obtains blood pressure readings every 12-15 beats via a small circular sensor placed over the radial artery and has been validated against readings obtained from a radial artery catheter (Belani, Buckley, & Poliac, 1999). The sensor and housing are held in place by a Velcro wrist strap.

Physiological measures

Mean arterial pressure (MAP), essentially a time-weighted indicator of arterial pressure throughout the cardiac cycle, was derived from SBP and DBP readings (MAP = 2/3 DBP + 1/3 SBP). From the IBI time series both mean IBI and the mean successive difference (MSD) statistic were derived. MSD is calculated as the mean of the absolute differences between successive IBIs, effectively filtering low frequency sources of heart period variability such as linear trends and low frequency oscillations. Due to differing response frequency characteristics (Saul, 1990) the remaining high frequency variations in heart period captured by the MSD statistic are reflective of parasympathetic (i.e., vagal) contributions to heart period variability. Accordingly, MSD has been validated against pharmacologically determined cardiac vagal control (Hayano et al., 1991). IBI reflects the additive effects of both sympathetic and parasympathetic control (Saul; Smith & Kampine, 1984).

<u>Procedure</u>

All experimental sessions were held at the Laboratory for the Study of Human Thought and Action (LSHTA). All subjects read and signed an informed consent approved by the university Institutional Review Board (See Appendix F for Informed Consent). Film clips were presented in one of five counterbalanced orders; order was counterbalanced with the constraint that negatively valenced film clips alternated with positively or neutrally valenced film clips. Subjects were randomly assigned to one of the five film orders.

A gender-matched researcher attached transducers and electrodes used to record physiological data. A modified lead II electrode configuration using three disposable pre-gelled electrodes (Surtrace; ConMed Co., Utica, NY) was used to acquire the ECG signal. ECG electrode attachment sites were prepared with a mild skin prep (omni prep; D.O. Weaver & Co., Aurora, CO) designed for the purpose of reducing electrode impedance followed by a 70% isopropyl alcohol wash. EDA electrodes were applied to the volar surface of the medial phalanges of the index and middle fingers of the right hand. Since a decrease in conductance is noted following the use of soap and water, and the amount of time passed since a subject last washed their hands is variable, all subjects washed their hands using a nonabrasive liquid soap immediately following completion of the informed consent, as recommended by Venables and Christie (1973). The blood pressure sensor was placed over the radial artery on the subject's left wrist.

Subjects were told they would be watching a number of short film clips with different emotional content and that they were to pay close attention to how they feel as they watch the film clips. Subjects were also told that following each film they would be asked to describe how they felt during the preceding film clip (see Appendix G for complete subject instructions). After a short period of recording to insure proper equipment functioning, subjects completed a baseline ASR followed by a rest period and the first film.

After presentation of the film clip, subjects completed the ASR scale to assess their affective response during the film. Following completion of the scale, subjects viewed a 1-

minute "washout" film clip (the second neutral clip from Gross & Levenson, 1995) followed by a two-minute rest during which they were instructed to "sit quietly with your eyes closed and clear your minds of all thoughts, feelings, and memories". The next stimulus presentation then commenced. This procedure was repeated for the remaining six stimulus conditions. This procedure is comparable to that used during the generation and validation of the standardized film set (Gross & Levenson).

Data Quantification & Analysis

Due to differences in film length, physiological measures recorded during the final minute of each film were used for analysis. Likewise, the final minute of the baseline preceding each film clip was used to create change scores for each emotion condition (film clip minus baseline). All subsequent analysis involving physiological measures makes use of these change scores. Two subjects were dropped due to equipment failure resulting in missing data.

Two pattern classification procedures were conducted, the first using physiology variables to classify observations into affective categories, and the second using the dimensional items from the ASR scale to classify observations. The latter pattern classification was conducted as a means to verify patterning in the ASR variables (i.e. experienced emotion) accompanies any observed physiological patterning. Because the discrete portion of the ASR scale consisted of single items used to assess experienced emotion, multivariate analyses were deemed inappropriate and univariate analyses were used. Specifically, repeated measures ANOVAs, using the discrete ASR items as the repeated variable, were conducted for each emotion condition with significant effects further examined using post hoc paired t-tests.

An issue that is perhaps more salient when using multivariate statistics such as pattern classification are involved is the sample size necessary to legitimately carry out statistical procedures. Although there is no definitive rule regarding sample size in pattern classification and discriminant analysis, recommendations range from three to five times the number of predictors used for classification (Huberty, 1994). Considering that the analysis made use of six

predictors and each subject will generate seven observations, the total number of observations (238) clearly exceeded even the more conservative recommendation.

Finally, the relationship between self-reported affect and physiological responding was examined by means of canonical redundancy analysis, a multivariate non-symmetric measure of the relationship between two sets of variables (Lambert, Wildt, & Durand). The redundancy analysis was carried out using the dimensional variables of the ASR in conjunction with the physiology variables.

Chapter 3. Results

Pattern classification using ANS variables

        Results from pattern classification using physiology variables and the corresponding tests for significance are summarized in Tables 1 and 2. As a whole, 37.39 % of observations were correctly classified into emotion conditions. Classification hit rates for individual emotion conditions, shown in the diagonal of Table 1, ranged from 17.65 % to 61.76 %. The overall classification hit rate, essentially an omnibus test of classification success, was statistically greater than chance ($z = 10.19$, $p < .0001$). With respect to individual emotion conditions, amusement ($z = 3.01$, $p = .0013$), anger ($z = 3.99$, $p < .0001$), contentment ($z = 7.91$, $p < .0001$), fear ($z = 6.44$, $p < .0001$), and sadness ($z = 3.99$, $p < .0001$) were successfully classified at statistically greater than chance levels. The classification hit rates for the disgust ($z = 1.05$, $p = .1468$) and neutral ($z = .56$, $p = .2877$) conditions did not reach statistically greater than chance levels. Means and standard deviations for all ANS variables can be found in Table 3.

Pattern classification using ASR variables

        The results from the second pattern classification, using dimensional ASR items, are summarized in tables 4 and 5. The overall classification hit rate was 68.07 % with individual emotion condition hit rates ranging from 32.35 % to 88.24 %. Hit rates for both overall classification ($z = 23.71$, $p < .0001$) and each of the emotion conditions were statistically greater than chance (amusement: $z = 11.83$, $p < .0001$; anger: $z = 10.36$, $p < .0001$; contentment: $z = 12.23$, $p < .0001$; disgust: $z = 6.93$, $p < .0001$; fear: $z = 7.42$, $p < .0001$; neutral : $z = 3.01$, $p = .0013$; and sadness: $z = 10.85$, $p < .0001$). Means and standard errors for all dimensional ASR variables can be found in Table 6.

Univariate analysis of discrete ASR variables

Repeated measures analysis of variance revealed significant within subject differences in discrete ASR variables for each emotion condition (all ps < .0001; Greenhouse-Geisser correction applied for violations of sphericity). Paired t-tests were used to explore the effectiveness of the affect manipulations with respect to the discrete ASR items. For the amusement, contentment, disgust, fear, and sadness emotion conditions, ratings on discrete item for the respective conditions were significantly greater than all other discrete items (all ps < .05). For example, in the amusement condition, the amusement item was greater than the anger, contentment, disgust, fear, and sadness items. In the anger emotion condition, the discrete anger item did not differ from the sadness and disgust items; however, each were greater than the ratings for amusement, contentment, and fear (all ps < .0001). Means and standard errors for all discrete ASR variables can be found in Table 7.

Discriminant analysis using ANS & ASR variables

The ANS variables for each emotion condition (amusement, anger, contentment, disgust, fear, sadness) were entered into a discriminant analysis resulting in 5 (the number of conditions minus 1) discriminant functions accounting for 51.52 %, 30.85 %, 14.47 %, 3.09 %, and .06 % of the total variance in the ANS variables. A similar discriminant analysis was conducted using the dimensional ASR variables and 5 discriminant functions resulted accounting for 66.11 %, 14.31 %, 10.32 %, 6.32 %, and 2.95 % of the total variance in self-reported affect.

Redundancy analysis

Canonical redundancy analysis revealed that 7.26 % of the variance in physiology was explained by variability in self-reported affect. In contrast, 3.58 % of the variance in self-reported affect was explained by variability in physiology.

Chapter 4. Discussion

The presence of unique patterns of ANS activity during emotional states, the primary hypothesis of the study, was convincingly illustrated by statistically significant classification using physiology variables. The fact that disgust did not exhibit significant patterning is likely due to one of two reasons. First, though a fairly diverse montage of physiology variables were used, none of the dependent measures specifically capture gastric activity. Thus, changes in gastric function that accompany nausea, a physiological process reasonably believed to be related to disgust, would not be captured by the recorded variables. Second, preliminary data suggests physiological responding to the stimuli such as the disgust film clip used in this study (arm amputation) may be particularly sensitive to individual differences (e.g., medical versus non-medical students; Kallenberg, Pennings, & Vingerhoets, 2001).

In addition, it was predicted that the emotion conditions would be distinguished not only from one another, but also from the neutral control condition. Although classification of the neutral condition did not reach greater than chance levels (i.e., there was no discernable pattern of variables identifying the neutral condition), examination of the classification matrix (table 1) reveals very few observations were misclassified into the neutral condition. In all, only 11 observations (4.6 %) were misclassified as neutral, suggesting that the emotion conditions are discernable from the neutral control despite the fact that the reverse may not hold true. Patterning within the self-report variables appeared to be more robust, with both higher overall classification hit rates and greater than chance classification for all conditions.

Interpretation of the discriminant analysis results is less straightforward. Ideally, examination of the group centroids for a particular discriminant function reveals the dimension of the data captured by that function. Figure 1 depicts the first and third discriminant functions and their respective group centroids generated from the ANS variables. The remaining discriminant functions did not provide meaningful interpretation. Discriminant function 1 (horizontal axis), explaining 51.52 % of the variance, is consistent with the activation dimension of the circumplex model with the with anger, disgust, amusement, and fear conditions located higher on this dimension relative to contentment and sadness. The third discriminant function

(vertical axis), explaining 14.47 % of the variance, initially seems to track the valence dimension of the valence-activation circumplex model; however, upon further examination the dimension is more accurately described by the approach/withdrawal characteristics of the respective emotions conditions with anger, contentment, amusement, and disgust located higher on the dimension relative to sadness and fear. In particular, it is the disparate locations of anger and fear along this dimension that provide support for the interpretation that anger is related to approach behavior whereas fear is associated with withdrawal behavior. This conceptualization is actually supported by a good deal of prior research involving hemispheric asymmetries that appear to accompany affective states. This vein of research relates frontal EEG activity with a fundamental biobehavioral dimension of approach-withdrawal and the accompanying motivations and emotions (for a review, see Davidson, 1992). Such an interpretation is wholly consistent with the view that the primary functional role of emotion is the organization of behavior and the coordination of physiological response systems.

Discriminant analysis using the dimensional ASR variables yielded two interpretable functions, the first explaining 66.11 % and the second 14.31 % of the variance. Again, the remaining discriminant functions did not result in conceptually meaningful dimension of the emotion conditions. As can be seen in Figure 2, the first discriminant function (vertical axis) is consistent with the valence dimension of the circumplex with amusement and contentment located higher on the dimension relative to anger, sadness, disgust, and fear. The second discriminant function (horizontal axis) is consistent with the activation dimension of the circumplex model with amusement, fear, disgust, and anger falling higher on the dimension than contentment and sadness.

Based on these findings, it appears that, despite its success in describing the structure of self-reported affect, the valence-activation circumplex model in its pure form may not fully capture the dimensions underlying ANS activity during emotion. Rather, a slightly modified version of the valence-activation model, where the traditional valence dimension is replaced with one that differentiates the approach-withdrawal characteristics of individual emotions, may be more appropriate in describing the activation components that characterize emotional states. This finding is not necessarily inconsistent with the single extant study addressing these issues from a

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dimensional multivariate perspective. The Nyklicek et al. study included a single high activation-negative affect condition and therefore did not allow for differentiation along this dimension. In contrast, the present study included two such emotions, anger and fear, and thus was able to capture this dimension of separation interpreted as approach/withdrawal. An additional explanation is the possibility that the dimensions discriminating discrete emotions are fundamentally different from those discriminating the general affective classes described by the circumplex. It is a distinct possibility that the dimensions underlying more general affective states (e.g., moods) may mirror the dimensions of self-report whereas the dimensions separating discrete emotions may more accurately describe motivational characteristics. Further research will be necessary to address this question.

An additional issue that may prove useful in future research is an assessment of the unique contribution provided by individual physiological measures to both ANS patterning and dimensions of separation identified by discriminant function analysis. The most obvious manner in which to address this question is through examination of variable loadings on the classification and discriminant functions generated during pattern classification and discriminant function analyses. Interpretation of classification functions is challenging for a number of reasons, not the least of which is the fact that the calculations used to generate the structure correlations (i. e., loadings) for the classification functions are "quite involved" (Huberty, 1994). With respect to interpretation of discriminant functions, there is also controversy regarding the appropriateness of structure correlations versus standardized coefficients in the interpretations of discriminant functions (Rencher, 1992).

Another method to address the question of variable contribution is stepwise discriminant analysis. In a stepwise analysis variables are selected based upon their contribution to group separation with respect to discriminant function analysis. An important point to consider when selecting variables, or ordering variables with respect to importance, is the fact that the output of stepwise procedures do not provide information regarding the nature of separation provided by a given variable. If a researcher's primary interest is the separation of multiple groups along multiple dimensions, as was the case in the present study, the stepwise results are of questionable utility. Along with the fact that the addition of a variable cannot decrease group separation, these

issues raise serious questions regarding the utility of stepwise procedures in selecting the "best" variables. In addition, at present, none of the major statistical packages (e.g., SAS, SPSS, BMDP) offer a stepwise procedure based upon classification accuracy rather than group separation. Thus, along with its questionable use in discriminant function analysis, the application of stepwise analysis to classification procedures seems entirely inappropriate. The most likely solution, then, is the computationally costly task of running multiple analyses for, in the most extreme case, all possible variable subsets. For a detailed treatment of this issue, including the conceptual shortcomings of stepwise procedures, see Huberty (1989). Regardless of the method selected, and the potential shortcomings involved, such inquiry has the potential to inform future research in a number of ways, not the least of which is the selection of variables that, in combination, may be most likely to result in emotion specific patterned responding.

A final approach that may prove useful in assessing variable contribution is univariate analysis of the ANS measures. Table 8 summarizes the results of paired t-tests for each ANS measure across the seven conditions. Of the ANS measures, only MSD and EDA showed significant differences between conditions. MSD values were less during anger than during fear, contentment, disgust, neutral, amusement, and sadness conditions. None of the remaining conditions differed with respect to MSD. Slightly greater utility was found in EDA with significantly smaller values during neutral than during sadness, anger, fear, disgust, and amusement. Contentment did not differ from neutral or sadness but was also significantly less than anger, fear, disgust, and amusement. Likewise, sadness did not differ from contentment or anger but was significantly less than fear, disgust, and amusement. Anger was less than amusement but did not differ from fear and disgust. Fear, disgust, and amusement did not differ. At best, EDA appears to provide crude distinction between emotion conditions. This also serves to illustrate the utility of the multivariate approach in detection of patterned ANS activity. Had only univariate analysis been applied in the current study, the results would have been no more successful than the attempt to assess variable contribution.

The use of films to discretely manipulate emotion, though not without difficulty, also appears to warrant further attention. The film clips seemed to be very effective in manipulating experienced emotion, especially when assessed as patterned responding of dimensional variables

but also with respect to discrete items. An encouraging finding in the present study was the emergence of a valence-activation circumplex structure in experienced emotion despite the fact that the films were generated from a discrete emotion perspective (see Gross & Levenson, 1995). This is an encouraging concordance between the discrete and dimensional affect theories, and provides additional support for the use of a hybrid discrete-dimensional model. The most apparent shortcoming in the use of films is the discrepant length required to present a complete scene aimed at manipulating a target emotion. In the present study, change scores (from baseline) were used in an attempt to account for differences in both film length and differences in baseline levels (i.e., the law of initial values), although concerns remain as to whether either of these issues are truly resolved. The use of change scores in research of this nature is not without precedent (e.g., Nyklicek et al., 1997); however, future research may benefit from alternative methods such as percent change scores or more advanced techniques aimed to assess the degree of difference in initial values across groups (e.g., Geenen & Van de Vijver, 1993).

The final issue to be addressed is the degree to which variance in self-reported affect can be accounted for by variance in physiology, and vice versa. Assessed by redundancy analysis, the variance in physiology explained by self-report is roughly two times that of the variance in self-report explained by physiology (7.25 % vs. 3.58). This finding implies that subjective experience of affect plays a greater role in ANS activity than ANS activity plays on the subjective experience of affect. Though the evidence of emotion-specific patterning of ANS activity provides some support for James' visceral feedback theory of emotion, the results of the redundancy analysis suggests the direction of the relationship may be opposite that described by James.

A drawback inherent to this analytic technique is the potential for a discrepant number of canonical variates identified in the two groups of variables, thus explaining differing degrees of total variance within the variable groups. Because the number of canonical variates identified in any multivariate data set is equal to the number of variables, the smaller of two groups of variables will actually have a greater percentage of variance explained relative to the total variance of the variables. Because the number of canonical variates in the two variable groups of a redundancy analysis must be equal, the variance in the larger of the two groups of variables

will be accounted for by less than its maximum number of canonical variates. As a result, the total amount of variance in the larger variable group may not be accounted for in the analysis. Such is the case with the present redundancy analysis where 6 physiology variables are entered into the analysis with 12 self-report variables. Accordingly, 6 canonical variates are derived from the two groups of variables explaining 100 % of the total variance in the physiology variables and 60.58 % of the total variance in the self-report variables. Despite this potential analytic discrepancy, the results of the redundancy analysis are nonetheless intriguing.

In summary, the present study has provided additional evidence of emotion-specific ANS patterning using the necessary multivariate techniques. Findings also illustrate the utility of the hybrid discrete-dimensional model of emotion in two ways: 1) by establishing the location of self-reported discrete emotions within an affective space described by a dimensional structure consistent with the traditional circumplex model; and 2) by describing the location of emotion-specific ANS activity within an affective space described by a modified circumplex with the traditional dimension of valence replaced by an approach-withdrawal dimension, a conceptualization that has become increasingly popular among emotion theorists in recent years. Finally, results suggest the experience of the discrete emotions addressed in the present study may have a greater effect on ANS function than ANS function has on the experience of emotion.

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Table 1

Pattern Classification Matrix Using ANS Variables

| | | Predicted Emotion Condition | | | | | | | Total |
		Amu	Ang	Con	Dis	Fea	Neu	Sad	
Actual Emotion Condition	Amu	**11** **(32.35)**	2 (5.88)	7 (20.59)	3 (8.82)	6 (17.65)	0 (0)	5 (14.71)	34 (100)
	Ang	1 (2.94)	**13** **(38.24)**	7 (20.59)	4 (11.76)	5 (14.71)	1 (2.94)	3 (8.82)	34 (100)
	Con	0 (0)	1 (2.94)	**21** **(61.76)**	0 (0)	3 (8.82)	4 (11.76)	5 (14.71)	34 (100)
	Dis	5 (14.71)	2 (5.88)	8 (23.53)	**7** **(20.59)**	7 (20.59)	1 (2.94)	4 (11.76)	34 (100)
	Fea	0 (0)	0 (0)	7 (20.59)	1 (2.94)	**18** **(52.94)**	2 (5.88)	6 (17.65)	34 (100)
	Neu	1 (2.94)	1 (2.94)	13 (38.24)	0 (0)	6 (17.65)	**6** **(17.65)**	7 (20.59)	34 (100)
	Sad	1 (2.94)	1 (2.94)	11 (32.35)	1 (2.94)	4 (11.76)	3 (8.82)	**13** **(38.24)**	34 (100)
Total		19 (7.98)	20 (8.4)	74 (31.09)	16 (6.72)	49 (20.59)	17 (7.14)	43 (18.07)	238 (100)

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 2

Significance Tests for Classification Using ANS Variables

Film	N	Observed	Expected	z	P
Amu	34	11	4.86	3.01	.0013
Ang	34	13	4.86	3.99	< .0001
Con	34	21	4.86	7.91	< .0001
Dis	34	7	4.86	1.05	.1468
Fea	34	18	4.86	6.44	< .0001
Neu	34	6	4.86	.56	.2877
Sad	34	13	4.86	3.99	< .0001
Overall	238	89	34	10.19	< .0001

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 3

Means and Standard Errors of ANS Variables for Each Emotion Condition

| | | | Condition | | | | | | |
			Amu	Ang	Con	Dis	Fea	Neu	Sad
	IBI (msec)	Mean	14.98	11.55	6.59	8.97	-4.36	-4.83	3.02
		StDev	55.46	36.85	32.64	50.21	46.68	39.79	44.46
	MSD (msec)	Mean	1.24	-8.66	-1.82	-1.29	-3.17	-0.19	1.48
		StDev	12.86	14.19	7.94	15.13	11.59	8.59	9.71
	SCL (μS)	Mean	0.63	0.22	-0.21	0.44	0.26	-0.45	-0.11
Variable		StDev	0.97	0.94	0.59	1.05	0.90	0.55	0.59
	SBP (mmHg)	Mean	1.54	-0.07	-0.46	0.88	0.30	-0.85	-0.32
		StDev	6.63	6.05	7.80	6.81	4.93	4.48	6.12
	DBP (mmHg)	Mean	0.16	-0.64	-0.75	0.42	0.20	-1.25	-0.16
		StDev	5.77	4.93	4.92	4.88	3.98	3.95	4.36
	MAP (mmHg)	Mean	0.91	-0.18	-0.63	0.61	0.73	-1.25	-0.30
		StDev	6.02	5.58	6.13	6.33	4.55	4.53	5.21

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 4

Pattern Classification Matrix Using Dimensional ASR Variables

| | | Predicted Emotion Condition | | | | | | | Total |
		Amu	Ang	Con	Dis	Fea	Neu	Sad	
Actual Emotion Condition	Amu	**29** **(85.29)**	0 (0)	5 (14.71)	0 (0)	0 (0)	0 (0)	0 (0)	34 (100)
	Ang	0 (0)	**26** **(76.47)**	0 (0)	3 (8.82)	1 (2.94)	1 (2.94)	3 (8.82)	34 (100)
	Con	4 (11.76)	0 (0)	**30** **(88.24)**	0 (0)	0 (0)	0 (0)	0 (0)	34 (100)
	Dis	4 (12.12)	3 (9.09)	0 (0)	**19** **(57.58)**	1 (3.03)	0 (0)	6 (18.18)	33 (100)
	Fea	8 (23.53)	1 (2.94)	3 (8.82)	1 (2.94)	**20** **(58.82)**	0 (0)	1 (2.94)	34 (100)
	Neu	7 (20.59)	1 (2.94)	13 (38.24)	1 (2.94)	1 (2.94)	**11** **(32.35)**	0 (0)	34 (100)
	Sad	1 (2.94)	3 (2.94)	2 (32.35)	1 (2.94)	0 (11.76)	0 (8.82)	**27** **(38.24)**	34 (100)
Total		53 (22.36)	34 (14.35)	53 (22.36)	25 (10.55)	23 (9.7)	12 (5.06)	37 (15.61)	237 (100)

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 5

Significance Tests for Classification Using ASR Variables

Film	N	Observed	Expected	Z	P
Amu	34	29	4.86	11.83	< .0001
Ang	34	26	4.86	10.36	< .0001
Con	34	30	4.86	12.32	< .0001
Dis	34	19	4.86	6.93	< .0001
Fea	34	20	4.86	7.42	< .0001
Neu	34	11	4.86	3.01	.0013
Sad	34	27	4.86	10.85	< .0001
Overall	238	162	34	23.71	< .0001

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 6

Means and Standard Errors of Dimensional ASR Variables for Each Emotion Condition

Variable			Condition						
			Amusement	Anger	Contentment	Disgust	Fear	Neutral	Sadness
	good	Mean	5.00	1.41	5.38	2.24	2.26	3.85	1.50
		StDev	1.28	0.96	1.58	1.46	1.54	1.91	1.19
	calm	Mean	4.88	2.62	6.21	2.94	3.00	4.94	3.53
		StDev	1.65	1.58	0.88	1.58	1.81	1.91	1.80
	unpleasant	Mean	1.12	5.12	1.06	4.73	2.91	1.32	3.88
		StDev	0.41	1.75	0.24	2.15	1.82	0.81	1.57
	passive	Mean	2.18	2.38	3.71	2.64	2.41	3.41	3.12
		StDev	1.38	1.46	2.21	1.67	1.48	2.41	1.59
	excited	Mean	3.65	1.91	2.56	1.79	3.71	1.74	1.18
		StDev	1.74	1.31	1.85	1.27	1.95	1.33	0.52
	negative	Mean	1.09	4.88	1.06	2.70	2.24	1.29	3.00
		StDev	0.29	1.92	0.24	1.70	1.52	0.72	1.87
	relaxed	Mean	4.47	2.68	6.09	2.64	2.85	4.76	3.24
		StDev	1.73	1.65	1.03	1.58	1.84	1.83	1.84
	active	Mean	2.97	2.29	1.88	1.73	2.88	2.41	1.41
		StDev	1.98	1.64	1.51	0.91	1.87	1.86	0.70
	positive	Mean	5.03	1.47	5.09	2.18	2.24	3.38	1.56
		StDev	1.87	1.11	1.71	1.51	1.42	2.12	1.24
	agitated	Mean	1.12	4.44	1.12	2.85	2.32	2.50	2.00
		StDev	0.33	1.69	0.48	1.82	1.63	1.90	1.33
	bad	Mean	1.00	5.18	1.00	3.21	2.09	1.18	4.06
		StDev	0.00	1.91	0.00	1.87	1.46	0.63	1.91
	pleasant	Mean	5.12	1.41	5.79	1.64	2.24	3.59	1.44
		StDev	1.55	0.96	1.30	1.17	1.50	2.02	0.93

Table 7

Means and Standard Errors of Discrete ASR Variables for Each Emotion Condition

			Condition						
			Amu	Ang	Con	Dis	Fea	Neu	Sad
	amusement	Mean	6.12	1.76	2.82	1.82	3.21	2.53	1.68
		StdDev	1.27	1.42	1.82	1.42	2.11	1.56	1.30
	fear	Mean	1.00	3.53	1.12	1.88	3.65	1.06	1.91
		StdDev	0.00	2.08	0.48	1.47	1.89	0.34	1.42
	anger	Mean	1.00	5.44	1.00	1.15	1.38	1.35	1.91
Variable		StdDev	0.00	1.65	0.00	0.56	0.85	0.95	1.40
	sadness	Mean	1.00	5.35	1.26	1.29	1.21	1.03	5.38
		StdDev	0.00	1.69	0.79	1.06	0.73	0.17	1.76
	disgust	Mean	1.24	5.41	1.00	5.00	2.74	1.03	1.53
		StdDev	0.70	1.79	0.00	2.15	1.81	0.17	0.96
	contentment	Mean	4.62	1.68	5.41	1.94	2.56	3.59	1.79
		StdDev	1.48	1.17	1.31	1.32	1.62	1.76	1.23

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Table 8

Summary of T-tests of ANS Variables

IBI

-4.83	-4.36	3.02	6.59	8.97	11.55	14.98
neu	fea	Sad	con	dis	ang	amu

MSD

-8.66	-3.17	-1.82	-1.29	-0.19	1.24	1.48
ang	fea	Con	dis	neu	amu	sad

EDA

-0.45	-0.21	-0.11	0.22	0.26	0.44	0.63
neu	con	Sad	ang	fea	dis	amu

SBP

-0.85	-0.46	-0.32	-0.07	0.30	0.88	1.54
neu	con	Sad	ang	fea	dis	amu

DBP

-1.25	-0.75	-0.64	-0.16	0.16	0.20	0.42
neu	con	Ang	sad	amu	fea	dis

MAP

-1.25	-0.63	-0.30	-0.18	0.61	0.73	0.91
neu	con	Sad	ang	dis	fea	amu

Key: Amu=Amusement, Ang=Anger, Con=Contentment, Dis=Disgust, Fea=Fear, Neu=Neutral, Sad=Sadness

Note. Emotion conditions sharing the same horizontal line to differ; p's < .05 for all significant differences.

Figure 1. Group centroids of emotion condition using ANS variables. Discriminant function 1 (horizontal axis) is interpreted as activation and discriminant function 2 (vertical axis) as approach/withdrawal.
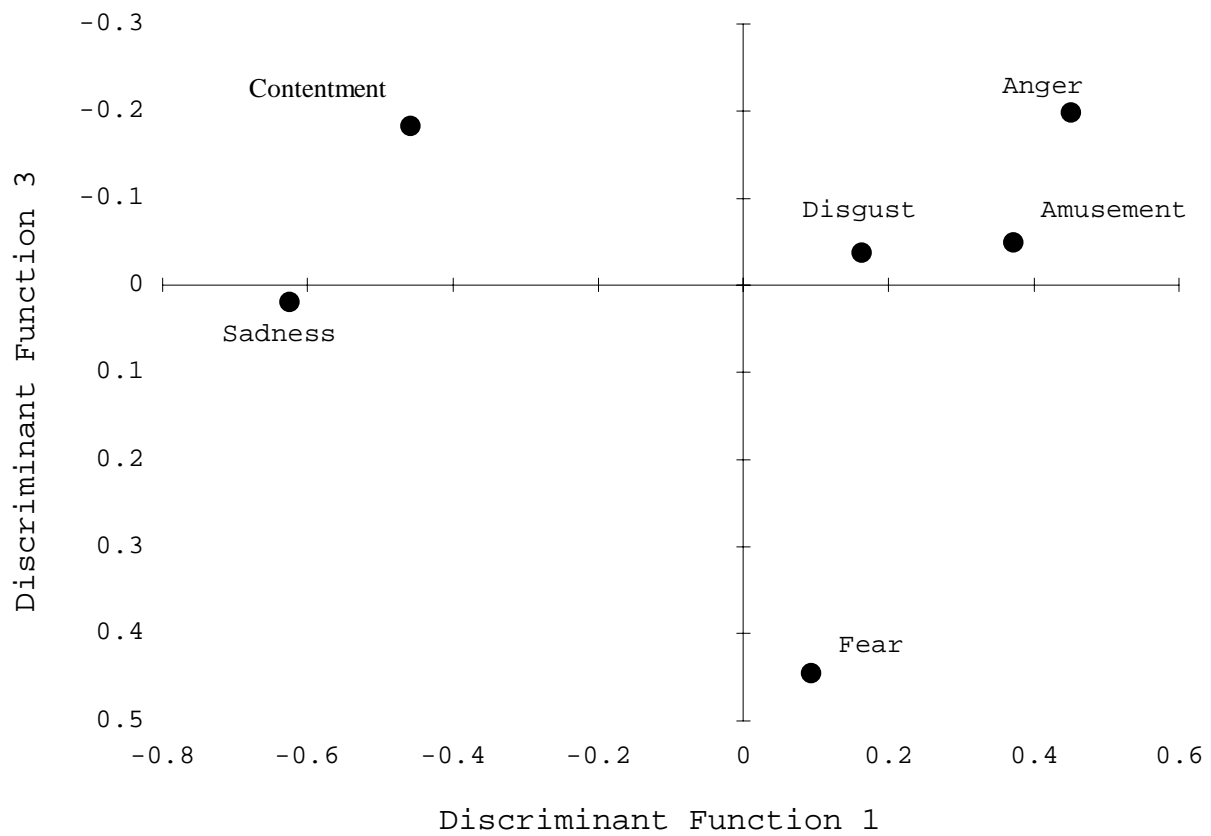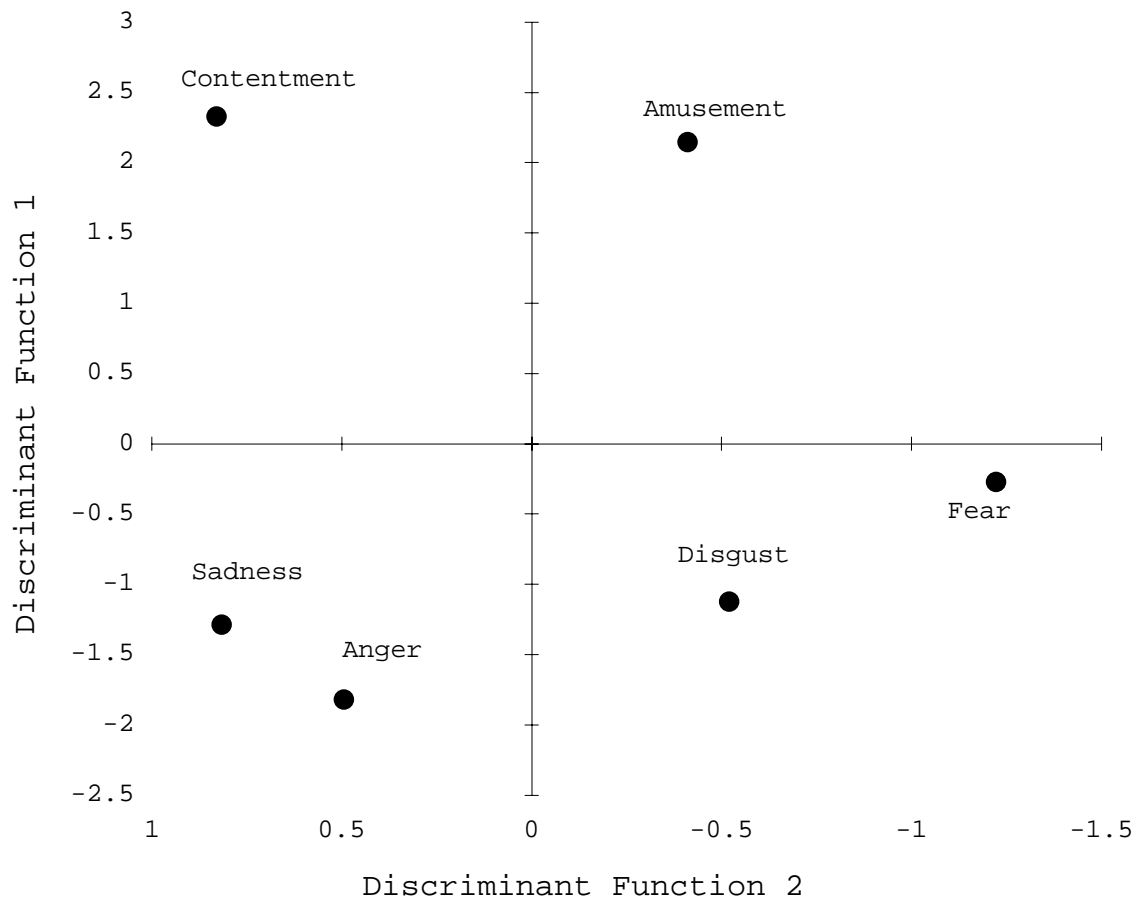
Figure 2. Group centroids of emotion condition using dimensional ASR variables. Discriminant function 2 (horizontal axis) is interpreted activation and discriminant function 1 (vertical axis) as valence.

APPENDIX A

HEALTH STATUS QUESTIONNAIRE

It is necessary for us to obtain a very brief medical history in order to determine if you are eligible for participation in the second part of the study. It is very important that you be completely honest. This screening information will be kept strictly confidential.

1. What is your age, height, weight, and gender?
Age: _____ years
Height: _____ feet, _____ inches
Weight: _____ pounds
Gender: ___M ___F

2. Since birth, have you ever been hospitalized or had any major medical problems?
___ Yes ___ No
If Yes, briefly explain:

3. Have you ever experienced a concussion or lost consciousness due to a blow to the head?
___ Yes ___ No
If Yes, briefly explain:

4. Have you ever had problems that required your seeing a counselor, psychologist, or psychiatrist?
___ Yes ___ No
If Yes, briefly explain:

5. Do you use tobacco products of any kind?
___ Yes ___ No
If Yes, describe what kind how often/much:

6. Do you currently have or have you ever had a hearing problem?
___ Yes ___ No
If Yes, briefly explain:

7. Do you currently have or have you ever had any of the following?
___ Yes ___ No Strong reaction to cold weather
___ Yes ___ No Circulatory problems
___ Yes ___ No Tissue disease
___ Yes ___ No Skin disorders (other than facial acne)
___ Yes ___ No Arthritis
___ Yes ___ No Asthma
___ Yes ___ No Lung problems
___ Yes ___ No Cardiovascular disorder/disease
___ Yes ___ No Diabetes
___ Yes ___ No Hypoglycemia
___ Yes ___ No Hypertension (high blood pressure)
___ Yes ___ No Hypotension (low blood pressure)
___ Yes ___ No Hepatitis
___ Yes ___ No Neurological problems
___ Yes ___ No Epilepsy or seizures
___ Yes ___ No Brain disorder
___ Yes ___ No Stroke

If you responded Yes to any of the above conditions, briefly explain:

8. Have you ever been diagnosed as having:

___ Yes ___ No Learning deficiency or disorder
___ Yes ___ No Reading deficiency or disorder
___ Yes ___ No Attention deficit disorder
___ Yes ___ No Attention deficit hyperactivity disorder;

9. Do you have:

___ Yes ___ No Claustrophobia (extreme fear of small closed spaces)
___ Yes ___ No Blood phobia (extreme fear of needles or blood)

10. List any over-the-counter or prescription medications you are currently taking:

11. List any other medical conditions that you have or have had in the past:

12. (Females Only) When was first day of your last menstrual period?

_____ days ago

APPENDIX B
BECK DEPRESSION INVENTORY

This questionnaire consists of 21 groups of statements. Please read each group of statements carefully, and then pick out the one statement in each group that best describes the way you have been feeling during the past two weeks, including today. Select the number beside the statement you have picked. If several statements in the group seem to apply equally well, select the highest number in the group. Be sure that you do not choose more than one statement for any grou p, including Item 16 (Changes in Sleep Pattern) or Item 18 (Changes in Appetite).

1. Sadness

0. I do not feel sad.
1. I feel sad much of the time.
2. I am sad all the time.
3. I am so sad or unhappy that I can't stand it.

2. Pessimism

0. I am not discouraged about my future.
1. I feel more discouraged about my future than I used to be.
2. I do not expect things to work out for me.
3. I feel my future is hopeless and will only get worse.

3. Past Failure

0. I do not feel like a failure.
1. I have failed more than I should have.
2. As I look back, I see a lot of failures.
3. feel I am a total failure as a person.

4. Loss of Pleasure

0. I get as much pleasure as I ever did from the things I enjoy.
1. I don't enjoy things as much as I used to.
2. I get very little pleasure from the things I used to enjoy.
3. I can't get any pleasure from the things I used to enjoy.

5. Guilty Feelings

0. I don't feel particularly guilty.
1. I feel guilty over many things I have done or should have done.
2. I feel quite guilty most of the time.
3. I feel guilty all of the time.

6. Punishment Feelings

0. I don't feel I am being punished.
1. I feel I may be punished.
2. I expect to be punished.
3. I feel I am being punished.

7. Self-Dislike

0. I feel the same about myself as ever.
1. I have lost confidence in myself.
2. I am disappointed in myself.
3. I dislike myself.

8. Self-Criticalness

0. I don't criticize or blame myself more than usual.
1. I am more critical of myself than I used to be.
2. I criticize myself for all of my faults.
3. I blame myself for everything bad that happens.

9. Suicidal Thoughts or Wishes

0. I don't have any thoughts of killing myself.
1. I have thoughts of killing myself but would not carry them out.
2. I would like to kill myself.
3. I would kill myself if I had the chance.

10. Crying

0. I don't cry anymore than I used to.
1. I cry more than I used to.
2. I cry over every little thing.
3. I feel like crying, but I can't.

11. Agitation

0. I am no more restless or wound up than usual.
1. I feel more restless or wound up than usual.
2. I am so restless or agitated that it's hard to stay still.
3. I am so restless or agitated that I have to keep moving or doing something.

12. Loss of Interest

0. I have not lost interest in other people or activities.
1. I am less interested in other people or things than before.
2. I have lost most of my interest in other people or things.
3. It's hard to get interested in anything.

13. Indecisiveness

0. I make decisions about as well as ever.
1. I find it more difficult to make decisions than usual.
2. I have much greater difficulty in making decisions than I used to.
3. I have trouble making any decisions.

14. Worthlessness

0. I do not feel I am worthless.
1. I don't consider myself as worthwhile and useful as I used to.
2. I feel more worthless as compared to other people.
3. I feel utterly worthless.

15. Loss of Energy

0. I have as much energy as ever.
1. I have less energy than I used to have.
2. I don't have enough energy to do very much.
3. I don't have enough energy to do anything.

16. Changes in Sleep Pattern

0. I have not experienced any change in my sleeping pattern.
1a. I sleep somewhat more than usual.
1b. I sleep somewhat less than usual.
2a. I sleep a lot more than usual.
2b. I sleep a lot less than usual.
3a. I sleep most of the day.
3b. I wake up 1-2 hours early and can't get back to sleep.

17. Irritability

0. I am no more irritable than usual.
1. I am more irritable than usual.
2. I am much more irritable than usual.
3. I am irritable all the time.

16. Changes in Appetite

0. I have not noticed any change in my appetite.
1a. My appetite is somewhat less than usual.
1b. My appetite is somewhat more than usual.
2a. My appetite is much less than before.
2b. My appetite is much greater than usual.
3a. I have no appetite at all.
3b. I crave food all the time.

19. Concentration Difficulty

0. I can concentrate as well as ever.
1. I can't concentrate as well as usual.
2. It's hard to keep my mind on anything for very long.
3. I find I can't concentrate on anything.

20.Tiredness or Fatigue

0. I am not more tired or fatigued than usual.
1. I get more tired or fatigued more easily than usual.
2. I am too tired or fatigued to do a lot of things I used to do.
3. I am too tired or fatigued to do most of the things I used to do.

21. Loss of Interest in Sex

0. I have not noticed any recent change in my interest in sex.
1. I am less interested in sex than I used to be.
2. I am much less interested in sex now.
3. I have lost interest in sex completely.

APPENDIX C
TWENTY-ITEM ALEXITHYMIA SCALE

Using the scale provided as a guide, indicate how much you agree or disagree with each of the following statements by checking the corresponding number. Give only one answer for each statement.

1. I am often confused about what emotion I am feeling.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

2. It is difficult for me to find the right words for my feelings.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

3. I have physical sensations that even doctors don't understand.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

4. I am able to describe my feelings easily.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

5. I prefer to analyze problems rather than just describe them.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

6. When I am upset, I don't know if I am sad, frightened, or angry.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

7. I am often puzzled by sensations in my body.

| Strongly Disagree | Moderately Disagree | Neither Disagree Nor Agree | Moderately Agree | Strongly Agree |

8. I prefer to just let things happen rather than to understand why they turned out that way.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

9. I have feelings that I can't quite identify.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

10. Being in touch with emotions is essential.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

11. I find it hard to describe how I feel about people.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

12. People tell me to describe my feelings more.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

13. I don't know what's going on inside me.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

14. I often don't know why I am angry.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

15. I prefer talking to people about their daily activities rather than their feelings.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

16. I prefer to watch "light' entertainment shows rather than psychological dramas.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

17. It is difficult for me to reveal my innermost feelings, even to close friends.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

18. I can feel close to someone, even in moments of silence.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

19. I find examination of my feelings useful in solving personal problems.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

20. Looking for hidden meanings in movies or plays distracts from their enjoyment.

Strongly   Moderately   Neither Disagree   Moderately   Strongly
Disagree   Disagree   Nor Agree   Agree   Agree

APPENDIX D
FILM CLIP DESCRIPTIONS

Amusement (2:35)
From <u>When Harry Met Sally</u> (rated R).
Discussion of orgasm in café.

Anger (2:36)
From <u>Cry Freedom</u> (rated PG).
Protesters are abused by police.

Contentment (0:58)
Waves crashing on shore (noncommercial).

Disgust (1:03)
Surgical amputation of arm (noncomgical) (noncommercial).

Fear (3:29)
From <u>Silence of the Lambs</u> (rated R).
Chase scene in dark basement.

Sadness (2:51)
From <u>The Champ</u> (rated PG).
Boy cries at father's death.

Neutral (1:30)
Lines of random color, length, and orientation (noncommercial).

"Washout" Clip (1:00)
Repeating colored vertical "screen test" bars (noncommercial).

APPENDIX E
AFFECT SELF-REPORT SCALE

Circle the number on the scale that best describes <u>how you felt during the film clip</u> that you <u>just watched</u>. If the word does not at all describe how you felt during the film, circle 1. If the word very accurately describes how you felt, circle 7, or an intermediate amount, circle 4, etc.

Amused	1	2	3	4	5	6	7
Fearful	1	2	3	4	5	6	7
Angry	1	2	3	4	5	6	7
Sad	1	2	3	4	5	6	7
Disgusted	1	2	3	4	5	6	7
Content	1	2	3	4	5	6	7
Good	1	2	3	4	5	6	7
Calm	1	2	3	4	5	6	7
Unpleasant	1	2	3	4	5	6	7
Passive	1	2	3	4	5	6	7
Excited	1	2	3	4	5	6	7
Negative	1	2	3	4	5	6	7
Relaxed	1	2	3	4	5	6	7
Active	1	2	3	4	5	6	7
Positive	1	2	3	4	5	6	7
Agitated	1	2	3	4	5	6	7
Bad	1	2	3	4	5	6	7
Pleasant	1	2	3	4	5	6	7

APPENDIX F

INFORMED CONSENT

VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY
Informed Consent for Participants in Research Projects Involving Human Subjects

Title of Project: Autonomic Nervous System Patterning in Response to Affective Stimuli (IRB #01-395).
Investigator: Israel C. Christie, Dr. Bruce H. Friedman

I. Purpose of this Research: The purpose of this research is to examine autonomic nervous system (ANS) activity in response to affective stimuli. Approximately 30 male and female non-smoking subjects without major medical problems will be recruited.

II. Procedures: The study will take place in two stages. Individuals participating in the first stage may or may not be invited to participate in the second stage. The first stage is an online screening involving only questionnaires and should take less than one hour to complete.

      If invited to participate in the second stage of the study, subject's physiological activity will be recorded via 1) three single-use, adhesive electrodes positioned on the chest by a gender matched researcher; 2) two electrodes secured with Velcro strips to my middle and index fingers; 3) a small sensor secured with a Band-Aid to the middle finger; and 4) a small sensor housing secured to the wrist by means of a Velcro strap. The second stage of the study will take between one and one and a half hours to complete and will be carried out at the Laboratory for the Study of Human Thought and Action (LSHTA) located behind Macado's on University Boulevard.

      During both stages of the study subjects will be asked to fill out a number of questionnaires describing a variety of personal characteristics (e.g., general health and degree of physical activity, the nature of typical affective experience, the nature of social interaction and personal relationships, etc). During the second stage of the study subjects will be required to view a number of film clips with both positive and negative affective content including a fairly graphic surgical procedure. During the second stage, subjects may also be asked to perform a number of routine laboratory tasks (e.g., paced breathing, mental arithmetic, reaction time tasks, extended hand-grip, or submersion of my hand in cold water).

III. Risks: The risks of this study are minimal. However, the film segments viewed during the second stage of the study may evoke varying degrees of uncomfortable images or feelings. Subjects are free to withdraw from the study at any time without penalty. On rare occasion some individuals have reported mild reactions (e.g., temporary itching or irritation) to the electrode gel.

IV. Benefits of this Project: Participation in this study will contribute to the general scientific knowledge regarding ANS functioning during a range of affective situations. Subjects may request to receive a synopsis of the results of the study when completed. To receive such a summary, subjects must provide the investigator with a self-addressed stamped envelope.

V. Extent of Anonymity and Confidentiality: Any information provided through questionnaire or acquired through physiological recording will be kept strictly confidential and will be accessed only by designated research personnel. Subjects will be identified only by means of an assigned subject number during subsequent analysis and written reports.

  A subject's indication of intent to harm others or themselves obligates the researcher to break confidentiality and notify the appropriate agency.

VI. Compensation: Subjects will receive one point of extra credit for their participation in the online screening. Those subjects who participate in the second stage of the study will be given the option of receiving either an additional two points of extra credit or a payment of ten dollars. Availability of extra credit for a given course is dependent upon the instructor's permission.

VII. Freedom to Withdraw: As stated earlier, subjects may withdraw from the study at any time without penalty. If a subject chooses to withdraw, they will be compensated for the portion of time participating in the study.

VIII. Approval of Research: This research project has been approved, as required, by the Institutional Review Board for Research Involving Human Subjects at Virginia Tech and by the Department of Psychology's Human Subjects Committee.

IX. Subject's Responsibilities: I voluntarily agree to participate in this study and agree to take part in the procedures described above.

X. Participants Permission: I have read and understand the Informed Consent and conditions of this project. I have had all my questions answered. I hereby acknowledge the above and give my voluntary consent:

_____ _____ _____
Name (please PRINT clearly) Signature   Date

Should I have any questions about this research or its conduct, I may contact:
Israel C. Christie   231-4428 ichristie@vt.edu
Main Investigator
Department of Psychology

Dr. Bruce H. Friedman   231-9611 bhfriedm@vt.edu
Faculty Advisor
Department of Psychology

Dr. David W. Harrison   231-4422 dwh@vt.edu
Chair, Human Subjects Committee
Department of Psychology

Dr. David Moore   231-4991 moored@vt.edu
Chair, Institutional Review Board
Office of Research Compliance

APPENDIX G

SUBJECT INSTRUCTIONS

Subject Instructions

The purpose of this study is to investigate the changes that occur in a number of physiological variables while people watch film clips with different emotional content. When you are watching the film clips, you should try to sit as still as possible; simply sit comfortably with your feet flat on the floor. Following each film clip you will fill out a short questionnaire, similar to the one you completed earlier, describing how you felt as you watched the film. For this reason, you should pay close attention not only to the film clip, but also to any emotions that you might experience as you watch it.

Just before each film clip begins there will be a short rest period. During this time you'll watch a generic film clip and then spend a few minutes sitting qu ietly with your eyes closed. While you do both of these things, try to clear your mind of all thoughts, feelings, and memories and just sit comfortably with your feet flat on the floor. The researcher will let you know when the film clips are about to begin.

Curriculum Vitae
Israel Christie

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Education

University of Tennessee, Knoxville: 5/93-5/98.
        B.A. in psychology.
        B.S. in biology.

Academic Employment

Virginia Tech, Blacksburg, VA
        1/02-Present, Graduate Research Assistant
        8/99-12/01, Graduate Teaching Assistant, Department of Psychology
East Tennessee State University, Johnson City, TN
        5/99-8/99, Research Assistant, Division of Cardiology Research
Yerkes Regional Primate Research Center, Atlanta, GA
        8/98-5/99. Senior Lab Technician, Division of Visual Science.
Emory University, Atlanta, GA
        9/98-12/98. Teaching Assistant, Department of Psychology.

Research Interests

Psychophysiology of affective states.
Psychophysiological indicators of cognitive processes.
Individual differences in physiological variability.
Use of technology and interactive media as teaching aids.
Ethical concerns in research involving both human and non-human subjects.

Publications

Manuscripts Submitted for Publication

Friedman, B.H., Allen, M.T., Christie, I.C., & Santucci, A.K. Quantification issues in time- and frequency-domain measures of heart rate variability. Under review.
Published Abstracts

Christie, I.C., Friedman, B.H., & Santucci, A.K. (2002). Multivariate demonstration of stimulus-response specificity and individual-response stereotypy: implications for reactivity research. Annals of Behavioral Medicine, 24(Suppl), S72.

Christie, I.C., Friedman, B.H., & Weaver, J.B. (2002). Multivariate pattern classification analysis of affect-specific autonomic nervous system activity. Annals of Behavioral Medicine, 24(Suppl), S72.

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Submitted Abstracts

Christie, I.C., Friedman, B.H. (submitted) Multivariate Discrimination of Emotion-Specific Autonomic Nervous System Activity. Psychophysiology.

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Affect-specific ANS patterning following Velten mood induction. Department of Psychology, Virginia Polytechnic Institute and State University, Blacksburg, VA, October, 2001.

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