Distribution Agreement

Signature:

______________________________ ________________

Jennifer S. Wilson Date

Cardiorespiratory Patterns Characterize Emotions
Across Elicitation Contexts

By

Jennifer S. Wilson
Master of Arts

Cognitive and Developmental Psychology

____
Stephan Hamann, Ph.D.
Advisor

____
Scott Lilienfeld, Ph.D.
Committee Member

____
Lawrence Barsalou, Ph.D.
Committee Member

Accepted:

____
Lisa A. Tedesco, Ph.D.
Dean of the Graduate School

____
Date

Cardiorespiratory Patterns Characterize Emotions
Across Elicitation Contexts

By

Jennifer S. Wilson
B.S., University of Georgia, 2006

Advisor: Stephan Hamann, Ph.D.

An abstract of
a thesis submitted to the Faculty of the Graduate School of Emory University
in partial fulfillment of the requirements for the degree of
Master of Arts
in Cognitive and Developmental Psychology
2009

Abstract

Cardiorespiratory Patterns Characterize Emotions Across Elicitation Contexts
By Jennifer S. Wilson

Emotion-specific physiological activity is a central element of theories of *discrete* or *basic* emotions. Previous studies provide partial support for this proposal, suggesting that participants' autonomic physiological responses during emotion induction differ based on the induced emotion. Patterns of physiological activity that differentiate emotions consistently across multiple contexts have not yet been identified. This study investigated the extent to which anger, fear, disgust, happiness, and sadness could be discriminated on the basis of cardiorespiratory activity within two experimental contexts. Electrocardiogram, impedance cardiogram, and respiratory activity was recorded while participants recalled emotional and neutral experiences from the past, and watched film clips designed to elicit the target emotions and a neutral state. Dependent cardiovascular measures included heart rate, heart rate variability, respiration rate and amplitude, and respiration-linked heart rate variability. Participants' subjective ratings of their emotional responses indicated that both recollection and film clips elicited strong emotional responses consistent with the targeted emotion category. Univariate and multivariate ANOVAs evaluating the effect of emotion on cardiorespiratory responses indicated strong effects of emotion on respiration frequency, and unexpectedly smaller effects on heart rate and heart rate variability, in both film and recall conditions. Principal components analysis reduced the dependent variables to components reflecting, respectively, respiratory frequency, heart rate, heart rate variability, and respiratory amplitude. The effect of emotion on the pattern of components observed for each emotion type was tested using MANOVA, which revealed significant increases along the respiration component in Happiness and Fear relative to Disgust in the emotional recall condition. No significant effects of emotion were observed in the film condition. Stepwise discriminant analyses then tested the possibility of discriminating emotions in the emotional recall condition, based on the pattern of cardiorespiratory components observed for each emotion type. A discriminant function based on the respiration component allowed emotion classification at an overall correct rate of 30.7% (compared to a 20% rate at chance performance). These findings point to core cardiorespiratory responses for each emotion type that remain constant across several contexts of elicitation; however, findings also highlight the influence of non-emotional contextual effects on responses to emotion-inducting stimuli.

Cardiorespiratory Patterns Characterize Emotions
Across Elicitation Contexts

By

Jennifer S. Wilson
B.S., University of Georgia, 2006

Advisor: Stephan Hamann, Ph.D.

A thesis submitted to the Faculty of the Graduate School of Emory University
in partial fulfillment of the requirements for the degree of
Master of Arts
in Cognitive and Developmental Psychology
2009

Table of Contents

Abstract………………………………………………………………………………………………… 1

Introduction……………………………………………………………………..………………………. 3

Methods……………………………………………………………………………………………….… 12

Participants………………………………………………………………………. 12

Stimuli used for emotion induction…………………………………… 13

Ratings of emotional experience..……………………………………...... 14

Procedures…..…………………………………………………………………… 15

Physiological recording…..…………………………………………………. 20

Behavioral data analysis……………………………………………………. 21

Psychophysiological data analysis……………………………………… 21

Results…………………….……………………………………………………………………………….. 25

Subjective ratings of emotion experience………………………….. 25

Physiological responses:

Univariate tests of Emotion effects……………………….… 26

Principal components and

multivariate tests of Emotion effects………….. 28

Pattern classification……………………………………………… 29

Discussion…………………………………………………………………………………………………. 30

Interpretation of findings…………………….…………………………. 30

Limitations…………………………………………..………………………….. 33

Contributions and future directions……….………………………….. 35

Conclusion……………………………………………..…………………………. 37

References.……………………………………………………………………………………………… 38

Abstract

Emotion-specific physiological activity is a central element of theories of *discrete* or *basic* emotions. Previous studies provide partial support for this proposal, suggesting that participants' autonomic physiological responses during emotion induction differ based on the induced emotion. Patterns of physiological activity that differentiate emotions consistently across multiple contexts have not yet been identified. This study investigated the extent to which anger, fear, disgust, happiness, and sadness could be discriminated on the basis of cardiorespiratory activity within two experimental contexts. Electrocardiogram, impedance cardiogram, and respiratory activity was recorded while participants recalled emotional and neutral experiences from the past, and watched film clips designed to elicit the target emotions and a neutral state. Dependent cardiovascular measures included heart rate, heart rate variability, respiration rate and amplitude, and respiration-linked heart rate variability. Participants' subjective ratings of their emotional responses indicated that both recollection and film clips elicited strong emotional responses consistent with the targeted emotion category. Univariate and multivariate ANOVAs evaluating the effect of emotion on cardiorespiratory responses indicated strong effects of emotion on respiration frequency, and unexpectedly smaller effects on heart rate and heart rate variability, in both film and recall conditions. Principal components analysis reduced the dependent variables to components reflecting, respectively, respiratory frequency, heart rate, heart rate variability, and respiratory amplitude. The effect of emotion on the pattern of components observed for each emotion type was tested using MANOVA, which revealed significant increases along the respiration component in Happiness and Fear relative to Disgust in the emotional recall condition. No significant effects of emotion were observed in the film condition. Stepwise discriminant analyses then tested the possibility of discriminating emotions in the emotional recall condition, based on the pattern of cardiorespiratory components observed for each emotion type. A discriminant function based on the respiration component allowed emotion classification at an overall correct rate of 30.7% (compared to a 20% rate at chance performance). These findings point to core cardiorespiratory responses for each emotion type that remain constant across several contexts of elicitation; however, findings also highlight the influence of non-emotional contextual effects on responses to emotion-inducting stimuli.

Cardiorespiratory Patterns Characterize Emotions Across Elicitation Contexts

An emotion involves a complex interaction between the brain, the body, and the external world. Psychological research focusing on the role of the body and visceral responses in this interaction has its foundations in the concepts and writings of William. His theory of standard emotions describes the emotion experience as the direct perception of differing physiological states originating in the viscera, a model which strongly influences research paradigms focused on emotion states like fear, happiness, anger, sadness, and disgust (James, 1894). This type of scientific definition also parallels the naïve conceptualization of emotions. Intuitively, we conceive of separate emotions as differentiable, state-like entities which we perceive through *feeling* --sensing reactions in our bodies. Affective research has subsequently placed great emphasis upon developing models of emotion which explain the role of visceral responses in ways that fit our subjective concepts of emotion states. A body of evidence has grown to support the theory of basic or discrete emotions, which suggests that emotions evolved as innately defined neural reactions to what we encounter in our external and internal worlds, and that the neural reaction for each emotion is accompanied by programmatic responses in peripheral autonomic systems as well (Ekman, 1999). However, the specific patterns of physiological activity that accompany each emotion, as well as the way in which we perceive and interpret these patterns remains unclear (Caccioppo, Berntson, Larsen, Poehlmann, & Ito, 2000; Sequeira, Hot, Silvert, Delplanque, 2009).

The purpose of the current study is to test the proposition that emotional experiences can be separated into discrete categories based on patterns of physiological responses.

The manner in which visceral states contribute to our emotional experiences has been a hugely active area of research. Early findings were often negative. Using epinephrine injection to induce states of physiological arousal, Schacter and Singer (1962) found that participants who had no explanation for feelings of arousal could be induced to behave as though they were angry, happy, or amused, depending on the experimental context. Their influential interpretation proposed that physiological activity varies merely in intensity, and that cues from the situational context are most important type of information that we use to recognize and separate different types of emotions. However, subsequent studies found that participants who received a placebo injection did not differ in behavior from those receiving epinephrine (Marshall & Zimbardo, 1979), instigating a new line of research which tested the possibility that participants may identify emotion states even in the absence of any physiological arousal. For example, Chwalisz, Diener, and Gallagher (1988) found that persons with spinal-injuries, whose perception of visceral states was impaired, did not differ from control participants in their ratings of their subjective experience of emotion, and some reported increases in the levels of joy, love, and sadness since the time of their injury. At first glance, such findings would seem to nullify claims that perceptions of visceral states are essential to the emotion experience—if persons who cannot feel anything in their bodies can still experience emotion, it would seem unlikely that emotions are essentially visceral states.

These findings with spinal-impaired participants, though compelling, do not preclude the possibility that, in healthy persons, visceral changes contribute important cues to the emotion perception and recognition process. The emotions of the spinal-impaired participants were measured through self-report of probable emotional reactions to hypothetical situations and reports of changes in emotionality before and after the injury. Such ratings do not require perception of autonomic activation at the time of the experiment, and are likely to rely more heavily on cognitive appraisal of trait emotionality. To provide more direct measurement of the role of autonomic activity in the emotion experience, recent studies have focused on eliciting emotion during the experiment, and measuring a wide range of physiological and subjective responses to capture the multidimensional nature of emotional experience. Positive evidence for physiological activity that differentiated several emotion states appeared in Paul Ekman's study of emotion elicited through directed facial action and recollections of emotional experiences, in which anger was characterized by high heart rate and high skin temperature, fear and sadness were characterized by high heart rate and low skin temperature, and happiness, surprise, and disgust were characterized by low heart rate (1983).

Studies following in this vein uncovered a variety of physiological responses that differed between emotional and neutral states, as well as responses that differed across each type of emotion. The specific physiological indices which differentiate emotions in each study vary widely across studies, however, and the type of physiological activity that characterize an emotion in one study do not often overlap activity associated with that emotion in any other study (Caccioppo, Berntson, & Klein, 1992; Turner & Ortony, 1992; Cacioppo et al., 2000), suggesting that no single dependent measure of physiological responding captures the core features of an emotion which remain constant across different elicitation contexts. Evidence for some essential elements of peripheral activation which differentiate emotions across multiple contexts is essential, however, to the survival of theories of discrete emotion because their definition of a discrete emotion relies heavily on the idea that visceral afference differentiates the "unique feeling state" associated with each emotion (Izard, 1992).

Multivariate and pattern classification techniques provide a more externally valid method of measuring emotional physiological responses, as emotions involve simultaneous changes in many bodily systems. Furthermore, pattern classification analyses are optimal for measuring response specificity, because they can test consistency in responses across individuals or instances of emotion, as well as discriminability between classes of emotion (Stemmler, 2004). Emotion-specific patterns of activity have been observed in participants' autonomic profiles across many types of emotion elicitation paradigms: emotional photographs (Collet et al., 1997), olfactory stimuli (Vernet-Maury et al., 1999), musical excerpts (Etzel, Johnsen, Dickerson, Tranel, & Adolphs, 2006), and film clips (Christie & Friedman, 2004; Kreibig, Wilhelm, Roth, & Gross, 2007). Although some multivariate studies identify patterns of emotion that characterize and differentiate two emotions, (i.e. sadness and fear in Kreibig et al., 2007), unique physiological patterns have been demonstrated within-study for up to four discrete emotion states, such as fear, anger, happiness, and sadness (Christie & Friedman, 2004; Rainville, Bechara, Naqvi, & Damasio, 2006).

However, the proposal that each emotion state would be consistently (across trials, participants, or experimental contexts) and differentially correlated with characteristic patterns of autonomic nervous system activity has not been conclusively supported. Firstly, characteristic patterns of autonomic activity which differentiate disgust from other emotion states have not yet been observed for the emotion of disgust. Disgust—along with anger, fear, sadness, happiness, and surprise--forms one of the group of “basic” emotions which have been demonstrated to evoke discrete responses (such as facial expressions) that are consistent across many individuals, situational contexts, and cultures (Ekman, 1999). Because “basic” emotions have been shown to elicit discrete responses in overt, communicative responding, discrete theory points to this set of emotions as a group of likely candidates for discrete and characteristic physiological patterning as well.

A second concern arises from the fact that the pattern classification approaches used in several multivariate studies produced results which cannot be generalized to responses outside of the precise set used to define the classification functions. Pattern classification analyses train a set of classification functions to place boundaries upon a multi-dimensional space. Once training has been completed, the ability of the trained functions to blindly classify individual instances of each class is tested. The results of such tests can be very inflated if the same data points are used for both training and testing. Christie and Friedman (2004) reported very high classification success for physiological responses to the target emotions of amusement, anger, contentment, fear, and sadness. This was the greatest reported number of emotions shown to be differentiable on the basis of physiological data to date. However, these results have not been shown to be externally valid because the same data points were used to train and test the classification functions. Similarly high classification rates have been reported in other studies which did not use an externally valid testing method (i.e. Nyclicek, Thayer, & VanDoornen, 1997). Studies using more externally valid classification tests, such as the leave-one-out method or the reservation of data points to be used only in the testing (but not training) phase, have shown successful classification for fewer emotions (Sinha & Parsons, 1996; Kreibig et al., 2004) or lower rates of classification (Rainville et al., 2006).

A third contributor to the lack of firm support for specific patterns associated with discrete emotion states has been the lack of convergence between the results of studies which take a multivariate or pattern classification approach. Although the specific physiological variables have differed across studies, most multivariate studies included cardiorespiratory measures such as heart rate. Multivariate ANOVAs, with univariate paired comparisons, testing the effect of emotion type on multiple physiological indices have shown that the effect of emotion on cardiovascular measures varies across studies. Some studies show multivariate omnibus differences in measures of heart rate or variation in heart rate for different emotions (Nyclicek, Thayer, & VanDoornen, 1997; Rainville et al., 2006; Christie & Friedman, 2004), while others do not show these differences (Sinha & Parsons, 1996; Etzel et al., 2006). Between emotion conditions, heart rate has been shown to increase similarly in fear and anger relative to neutral (Sinha & Parsons, 1996), to accelerate in fear and decelerate in sadness (Etzel et al., 2006), and to increase in sadness, serenity, and agitation but not in happiness (Nyclicek, Thayer, & VanDoornen, 1997). Thus far, multivariate studies have not produced a high degree of overlap in their reports of emotion-specific physiological patterns.

The objective of the current study was to provide a comprehensive picture of how bodily feelings contribute to the emotion experience. We elicited the discrete emotion states of anger, happiness, sadness, fear, and disgust, and we measured cardiorespiratory variables which can be interpreted as specifically reflecting sympathetic or parasympathetic contributions to the autonomic emotional response. This study addresses several remaining questions about the role of autonomic activity in emotion. We tested the predictions that:

1. Univariate and multivariate analyses of variance will reveal patterns of cardiorespiratory activity associated with each target emotion state.
    a. Similarity in the cardiovascular profiles for each target emotion will be observed across different contexts of emotion elicitation.
2. Patterns of cardiorespiratory activity that are observed for happiness, sadness, anger, fear, and disgust will differentiate each target emotion from all others.

We tested these predictions by eliciting anger, happiness, sadness, fear, and disgust within two experimental contexts. Participants watched short emotional film clips, and recalled autobiographical memories of emotional events from the past. No previous study has succeeded in finding core patterns of autonomic activity that characterize an emotion across more than one type of emotion induction paradigm; in the study by Rainville (2006), for example, anger, happiness, sadness, and fear were induced using only an emotional recall paradigm. The use of only one type of emotional stimulus severely limits the extent to which conclusions may be drawn about the underlying emotion structure, because the experimental context and the individual stimuli exert strong influences over physiological responses (Stemmler, 2004). Reactions to emotional stimuli have been shown to be modulated by contextual factors such as orientation of attention in a given task (i.e. Lacey, Bateman & VanLehn, 1953; Lang, Bradley, & Cuthbert, 1998). For example, when participants must attend to external stimuli such as pictures or music, heart rate decreases (even when stimuli are highly negatively arousing), and when participants must attend to internal stimuli such as recollection of negative emotional experiences, heart rate tends to increase (Lang, 1994). The current study directly measures stimulus-specific and stimulus-independent responses by observing within-subjects differences and commonalities in autonomic responses to two elicitation paradigms—one which demands external attention to emotional films, and one which demands internal attention to emotional personal memories. We expected to observe that physiological responses to each target emotion would differ when the target emotion was elicited in the film context versus the autobiographical recollection context, but also expected to observe similarities in the effects of target emotion type on the physiological responses in both contexts. These similarities would be interpreted to reflect constancy in some physiological responses that characterize emotions across many situations.

Because of the lack of overlap in patterns of physiological activity identified as emotion-specific in previous studies, we did not make specific predictions about the direction or pattern of physiological differences between emotion conditions. We did select dependent physiological measures such that the dependent physiological variables can be interpreted in terms of autonomic activity. We collected cardiovascular and respiratory measures that would reflect relatively independent contributions from sympathetic and parasympathetic autonomic systems. The parasympathetic and sympathetic systems exert influence on heart function via two different mechanisms which can each be associated with a different temporal profile of responses in heart rate and heart rate variability. The sympathetic system innervates the sinoatrial node of the heart, through release of norepinephrine. Sympathetic innervation is associated with speeding of the rhythm of the sinoatrial node, but changes in speed of heart rate are slow because norepinephrine reuptake in the synapse is slow. The sympathetic system can also influence heart rate in an indirect manner, via release into the circulating bloodstream of adrenaline from the adrenal medulla; this influence also results in slow changes in heart rate. In contrast, the parasympathetic system modulates heart rate through release of acetycholine at the sinoatrial node. Acetycholine is quickly degraded in the synapse, and so parasympathetic changes in heart rate are quicker than those caused by the sympathetic system. These changes in the rate and variability of heart beats are not as easily interpretable as might seem at first glance, however. Respiration strongly influences the rate of cardiovascular activity, producing fast increases in heart rate during the inspiration period that are associated with parasympathetic activity (Grossman, Van Beek, & Wientjes, 1990). Thus, increases in heart rate, and slow changes in heart rate variability (across an emotion elicitation event) may be interpreted as primarily reflecting sympathetic activity. Fast changes in heart rate variability may be interpreted as reflecting primarily parasympathetic activity. Additionally, fast changes in heart rate variability within respiratory cycle reflect respiratory-linked parasympathetic influences on the heart. However, changes in heart rate do not often reflect pure sympathetic or parasympathetic innervation. Both autonomic systems may influence the heart simultaneously, or may work in opposition to one another. Sympathetic influences on the heart have been especially difficult to tease apart from parasympathetic and non-autonomic influences (Bernton et al., 1997; Task Force, 1996), so many studies include additional indices of sympathetic activity.

Methods

Participants

20 undergraduate volunteers participated in this study, 13 female and 7 male 20.6 $\pm$ 2.68 (mean $\pm$ SD). Of this group, 10 were White/Caucasian, 3 were African-American, 3 were Asian (nationality unspecified), 1 was Korean, 1 was Hispanic, 1 was Native-American, and 1 was Indian. Participants received either class credit or $10 per hour for their time. The Institutional Review Board of Emory University approved the

procedures for use with human participants. Participants gave informed consent before taking part in the study.

Stimuli Used for Emotion Induction

Autobiographical Memories

To elicit self-generated emotion states, we asked participants to recall and mentally re-experience strongly emotional experiences from the past. Each participant generated one recent and one remote memory for each of the target emotions of anger, happiness, sadness, fear, and disgust, and for a neutral control condition. *Recent* memories were defined as memories for events occurring between the experimental session and three years before, and *Remote* memories were defined as memories for events occurring any time previously to three years before. One memory from each time window was included to minimize possible confounding effects of event recency on the quality or strength of emotional responses. We were concerned that participants might tend to select very recent memories for the neutral condition in order to meet the vividness criterion, but select older memories for the emotional conditions when selecting a memory of a particularly emotional instance. We chose a large Recent window of three years to allow participants some freedom to target those episodes which they recalled as having been the most emotionally evocative times in their lives. Previous studies using autobiographical memories to elicit emotional states have not restricted the time window for memory selection (i.e. Damasio, Grabowski, Bechara, Damasio, Ponto, et al., 2000; Pelletier et al., 2003; Rainville, Bechara, Naqvi & Damasio,

2006) in order to allow participants freedom to select very emotional past events. During the Interview session, the experimenter discussed each memory with the participant to determine that it met additional inclusion criteria for arousal, discreteness of emotion, and vividness/detail (‘Session 1, described below in Procedures). Participants assigned a cue word to each memory which would later be used to prompt them during the emotion induction task in the second experimental session.

Film Clips

To elicit emotional reactions to external stimuli, we used short film clips designed to elicit happiness, sadness, anger, fear, disgust, and a neutral state. Clips were also selected using several additional controls—each clip included human beings throughout its length, and was edited to a duration of approximately 90 seconds (plus or minus 20 seconds). Investigators selected film content from popular movies, and from documentaries, and edited a set of 75 clips to target the length of 90 seconds. A final set of 36 clips were selected using an adapted version of the methods described by Gross and Levenson (1995), through behavioral norming. The final set of clips targeted elicitation of emotions which were discrete (eliciting primarily the target emotion) and strong (received high arousal ratings). Participants’ mean ratings of arousal, valence, and typicality can be found in Appendix 1.

Ratings of emotional experience

After every emotion induction event, the participant was prompted by the computer to rate their subjective emotional experience. Responses were entered on the keyboard, along a six-point Likert-type scale (0 = low, 5 = high); rating scales and anchors were displayed on the screen below each item. The computer waited for the participants to enter a response before moving on to the next item. The questionnaire contained three items measuring dimensional aspects of affective experience—arousal, positive valence, and negative valence. For emotional arousal, participants were instructed to assess the degree of emotional response evoked during the film clip or autobiographical recall experience, and to rate the strength of that response (0 = *no response*, 5 = *very strong response*). For positive and negative valence, participants rated their response in terms of pleasantness/unpleasantness (0 = *not at all positive / negative*, 5 = *very positive / negative*). Participants also compared their experience to a prototype of each discrete emotion, by making separate ratings of how *typical* the experience was of happiness, sadness, anger, disgust, and fear. Participants were instructed to assess the typicality of their experience in terms of whether it was typical of how they usually feel when they feel happiness, sadness, anger, disgust, and fear (0 = *not an example*, 5 = *very typical*).

Procedures

During recruitment, participants indicated that they would be able to generate memories of specific instances during which they experienced strong feelings anger, fear, sadness, disgust, and happiness (a recent and a remote memory for each emotion type), and a recent and a remote neutral memory. Participants took home a short worksheet to note each experience, and brought the sheet with them when attending the first experimental session. The worksheet asked the participant to write a sentence describing a specific event during which he or she strongly felt the target emotion, and did not feel any other emotions. The participant was also asked to select only memories which elicited the target emotion at the time of the event, and currently elicit the emotion when the event is recalled. For both the emotional and neutral memories, the participant was encouraged to select events which he or she could recall very vividly. A copy of this worksheet can be found in Appendix 2.

Participants came in to the lab for two separate experimental sessions. During the first session, the experimenter assessed whether memories generated by each participant fit experimental criteria for the strength and discreteness of emotion felt during the recalled event. Upon arrival at the lab, the participant was greeted and given consent forms to read and sign. After consenting, the participant was asked to recall and describe in turn each of the 12 memories he or she had selected and noted on the worksheet. He or she was directed to focus on the emotionally evocative aspects of the experience, and to formulate narrative descriptions in terms of how he or she felt when experiencing the event. While the participant described each memory, the experimenter noted whether the participant was able to provide much detail about the experience, and whether the participant recalled a specific place and time during which the event had occurred. If a participant did not provide a detailed account of the event, or did not include information about place/time, the experimenter prompted him or her by asking, “Tell me more about that.” If the participant did not then volunteer further details, or information about place/time, he or she was asked to select a memory which could be recalled in detail. The experimenter then asked the participant some follow-up questions to verify that the memory fit a set of qualitative criteria for age of memory, event specificity, emotional discreteness, vividness, and arousal.

Age of memory. The experimenter asked the participant to give the age of the memory in number of years between the recalled episode, and the experimental session. If the episode had occurred less than one year previously, the participant gave the age of the memory in months. Because we wanted one Recent and one Remote memory for each emotion condition, if the participant failed to describe one memory from greater than three years ago, and one memory from less than three years ago, then he or she was asked to generate a replacement memory at the end of the interview session. The participant described the replacement memory via the same interview process used for the other memories.

Event specificity. The participant had been asked to generate memories of specific instances or events. However, participants in pilot sessions often discussed events which would likely have unfolded over a protracted period of time, such as parental divorce, a death in the family, or a breakup. In cases during which participants described a memory that did not appear to be tied to a single place and time (anything longer than a single day, or taking place in several locations), the experimenter followed up by asking the participant to focus on a specific moment. For example, the experimenter might have prompted the participant by saying, "Can you tell me about a specific moment when you felt especially ________ (angry, sad, etc), during the time when your parents were getting divorced?". The experimenter would then refer to this more specific event as the emotional memory when proceeding with the other follow-up questions.

Emotional discreteness. The experimenter asked the participant, "Does this memory strongly elicit any other emotion, besides ________ (target emotion)?" The experimenter noted the participant's response. If the participant did respond with other emotions elicited by the memory, the experimenter asked whether the target emotion was the primary emotion felt at the time of the event, and the primary emotion felt when currently reflecting upon the event. If the participant responded that the target emotion was not the primary emotion elicited by the memory, then at the end of the interview session, he or she was asked to select another memory which elicited only the target emotion. The participant described the replacement memory via the same interview process used for the other memories.

Vividness. The experimenter then asked the participant to rate the vividness of their recollection on a scale of zero to five, with zero being "not at all vivid" and five being "very vivid."

Arousal. The participant rated the level of emotional arousal he or she felt at the time of the event. The experimenter defined emotional arousal for the participant by asking him or her to "rate the strength of [his or her] emotional response." The participant made this rating on a scale of zero to five, with zero being "not at all strong" and five being "very strong."

The interview session lasted for approximately 45 minutes, and was conducted a few days before Session 2.

In the second session, the participant engaged in the emotion induction tasks. The participant was fitted with the physiological recording devices (ECG and ICG electrodes, and respiration belt), and then seated 30 cm from an eye-level 10” x 17” widescreen computer monitor. Psyscope X software (Build XB53, International School of Advanced Studies- SISSA/ISAS) was used to present the experimental stimuli and the subjective rating of emotion prompts, and to record participants’ ratings. The participant wore headphones through which he or she heard beeps that indicated when to begin and end recollection of autobiographical events, and heard the audio tracks for each film clip.

The order of emotion induction tasks was counterbalanced—half of the participants completed the film clip task first, and the other half completed the autobiographical recall task first. Within each task, the order of events was pseudo-randomized across participants in order to avoid time-dependent confounds such as fatigue, and to account for any residual affective states from one event to the next.

At the onset of the autobiographical trials, one of the cue words generated by the participant in the Interview session was presented for five seconds, followed by a fixation cross. The cue word and fixation cross were presented in white, 40 point, sans-serif font on a black background. The participant was instructed to close his or her eyes, and try to mentally recreate the episode associated with this cue word, focusing on sensory details with the goal of reliving the event as vividly as possible. The participant pressed a button when he or she began to feel any emotion in response to the recollection; this button press time stamped the physiological recording with an Emotion Onset event. After pressing the button, the participant continued to focus on the memory, for a 90-second recall period in total. The participant then heard a beep over the headphones, at which point he or she was instructed to focus again on the computer screen, and completed the subjective rating questions. The next trial began after the participant had completed the last rating, with a minimum interstimulus interval of 155 seconds. The participant attended to a fixation cross during the interval between the ratings and the presentation of the cue word for the next trial.

At the onset of the film trials, one of the film clips was presented. The onset and offset of each clip was timelocked to the physiological recording. The participant was instructed to attend closely to the clip, and to press a button as soon as he or she felt any emotional reaction to the clip; this button press marked an Emotion Onset event in the psychophysiological recording. He or she then completed subjective ratings of emotional experience. The next trial began after the participant had completed the last rating, with a minimum interstimulus interval of 155 seconds. During this time the participant was instructed to relax, clear his or her mind, and look at a fixation cross until the onset of the next clip.

Physiological Recording

Electrocardiogram (ECG), respiration, and impedance cardiogram (ICG) were recorded continuously during the emotion induction session, and data was digitally sampled at 1000Hz using the MP100 system and AcqKnowledge software (Biopac

Systems Inc., Santa Barbara, CA). ECG was recorded using disposable Ag-AgCl electrodes in a 3 leads montage (Einthoven lead 2 configuration), with shielded electrode leads. Respiration was indexed as abdominal expansion and contraction measured through a tension transducer belt tightened around the lower ribcage. Hardware filters on the respiration amplifier band-passed the data at 0.05 - 1Hz. ICG was collected using disposable Ag-AgCl strip electrodes—two voltage electrodes located at the base of the neck and just below the sternum, and two current electrodes placed three cm distal to each voltage electrode. Hardware filters on the ICG amplifier low-pass the data at 10Hz.

Behavioral Data Analysis

Descriptive statistics for the subjective ratings of emotion experience were calculated for each item, across participants. Each item received a target emotion designation, defined as the discrete emotion having received the highest mean typicality rating. A dependent-samples t statistic was used to test differences in typicality, valence, and arousal ratings between each emotion condition, and the neutral condition.

Psychophysiological Data Analysis

Trials for analysis began at the point of Emotion Onset (when the participant pressed the button to indicate a perceived emotional response; for instances in which the participant did not make a button-press to a particular stimulus, Emotion Onset was marked at that participant's average latency between stimulus onset and button-press), and lasted for 90 seconds. For any individual trial in which the 90-second period following the button press overlapped the beginning of the next film clip or autobiographical recall event, or for trials in which the participant made no button press, the Emotion Onset was set to the average across subjects for the button press latency.

Heart rate variability (HRV).

Using the procedures outlined by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (TESCNASPE; 1996) and recommendations from Berntson et al. (1997), we calculated time-domain and frequency-domain indices of cardiorespiratory activity.

Post-acquisition, R-R intervals were extracted from the filtered ECG data using a modified Pan-Tompkins QRS detector (Pan & Tompkins; 1985). Respiration data was downsampled to 62.5Hz, and the data was band-passed at 0.05 – 1 Hz using a digital finite impulse response filter with Bartlett windowing.

For each 90 second trial, we extracted time domain measures of cardiovascular and respiratory activity. The mean, median, and standard deviation across the trial were calculated for respiration cycle period, respiration amplitude, R-R interval. We also extracted time-domain measures of respiration-linked changes in cardiovascular activity, calculating the mean and standard deviation across each trial for respiratory sinus arrhythmia (RSA; calculated using the peak-to-valley method of Grossman, Van Beek, & Wientjes, 1990), mean R-R per respiratory cycle, and standard deviation in R-R per respiratory cycle. Finally, spectral measures were extracted from the ECG and respiration data, within each trial. A Welsch periodogram was implemented to calculatethe power spectral density (PSD) of the R-R tachogram and continuous respiration signal within high (0.15 – 0.4Hz) and low (0.04 – 0.15Hz) frequency bands (ranges of each recommended by TESCNASPE; 1996).

Pre-ejection period (PEP).

PEP is a measure of myocardial contractility and is measured as the distance between the q-point in the electrocardiogram waveform, and the in b-point in the waveform of the impedance cardiogram (Sherwood et al., 1990). During online recording, the acquisition software automatically calculated the first derivative of the change in thoracic impedance. The resulting dZ/dt signal was filtered using a scaled Fourier linear combiner (SFLC) with a step size of 0.001, to correct for motion artifact (Barros, Yoshizawa, & Yasuda, 1995). This filter uses the location of the R-wave in the ECG signal to construct a sinusoidal model of dZ/dt containing only components that are correlated to the heart rate. The results of this filtering were visually examined to determine that inflection points of the waveform had not shifted in time, and an automated classifier was then used to mark inflection points in each cycle. B-points were classified following the recommendations of Sherwood and colleagues (1990). The b-point was first classified as the maximum third derivative of impedance within 300ms before the C-point. This classification was then subjected to a visual inspection in which we compared the b-point classification to a visually identified inflection point in both the filtered and unfiltered dZ/dt signal. Bad classifications of the b-point were manually corrected during this inspection.

PEP was defined as the interval between the Q-wave on the ECG waveform, and the b-point on the dZ/dt waveform. PEP was extracted for each dZ/dt cycle, and mean, median, and standard deviation was calculated per trial epoch.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS 13.5, Chicago, IL). A within-subjects univariate analysis of variance (uniANOVA) was performed for each the film task and the autobiographical recall task to examine the main effect of emotion on each of the cardiovascular and respiratory variables. For each dependent measure, t-tests compared the emotion conditions to the neutral condition. In order to control for individual differences using responses to neutral items as a baseline, dependent cardiovascular and respiratory measures were then transformed to reflect the ratio of the emotion condition over the neutral condition -- [(Emotion – Neutral) / Neutral]. The resulting ratios across all cardiorespiratory measures were then transformed uniformly using a $\log_{10}$ transformation which reduced skew in the distributions. Outliers among the dependent measures (greater than 3 SD beyond the mean) were discarded; 1.13% of all observations were discarded—1.11% of observations from the Autobiographical session, and 1.15% of observations from the Film session. Post-hoc pairwise comparisons tested for differences between the emotion conditions on each dependent variable.

Because of the large number of dependent measures, and to account for the underlying structure of autonomic contributions to cardiorespiratory activity measured by our variables, we performed a principal components (PCA) data reduction. First, the correlation matrix among all dependent measures was examined to search for redundancies among them, and measures were excluded whose variance overlapped another measure by more than 90%. Measures upon which there was no significant effect of emotion in the paired comparisons between the emotional and neutral conditions were also excluded (list or summarize). The included dependent measures were entered into the PCA. Minimum eigenvalue was set to 1. The resulting component loadings were rotated using Varimax rotation with Kaiser normalization. The effect of emotion on the components extracted from the PCA was then tested using a repeated-measures multivariate analysis of variance (MANOVA), and post-hoc contrasts testing for differences between pairs of emotions.

Lastly, stepwise discriminant analyses tested the possibility of categorizing emotions based on the factors extracted from the PCA. The discriminant analysis was cross-validated using the leave-one-out method.

Results

Subjective ratings of emotion experience

Participants' likert-scale ratings (0 – 5) of the typicality of their emotional experience indicated that the target emotion was elicited more strongly than any other emotion. The mean typicality rating for the target emotion was at least 2 points higher than for any other emotion in both the Autobiographical and Film elicitation conditions, with the exception of films targeting Anger and films targeting Fear. Anger films elicited some disgust and sadness [typicality ratings of 2.38(1.67) for anger, versus 1.85(1.47) for disgust and 1.2(1.35) for sadness; *M*(*SD*)]. Fear films elicited some disgust [typicality ratings of 3.62(1.53) for fear, versus 1.95(1.77) for disgust]. Mean ratings of Neutral target stimuli were less than 1 in both the Autobiographical and Film elicitation conditions. See Table 1 for an extended summary of ratings.

Paired t-tests were conducted to compare arousal ratings for events in each of the Emotion conditions versus events in the Neutral condition. Ratings of arousal were significantly higher for emotional target events than for Neutral target events (see Table 2).

Physiological responses: Univariate tests of Emotion effects

Before data was transformed to account for the Neutral baseline, within-subjects contrasts (paired t-tests) on each dependent physiological measure assessed differences between each Emotion and Neutral. The results of these tests are listed in Table 3. Decreases in the respiratory cycle period (Resp Period Mean and Resp Period Median) differentiated Anger, Disgust, and Fear in both the Autobiographical and Film sessions. These decreases in respiratory period were accompanied by decreases in high-frequency PSD in the respiratory signal in Anger, Disgust and Fear (this difference was not significant for Disgust in the Film session). Decreases in variability of the respiratory cycle period (Resp Period *SD*) differentiated Anger in both sessions. In the Film session, respiratory cycle period also decreased in Happiness relative to Neutral.

Decreases in linear measures of R-R interval [increases in heart rate, as indexed by (Mean R-R / Resp Cycle) – Mean] were observed in the Autobiographical session only for the Anger condition. In the Film session, increases in R-R interval [decreases in heart rate, as indexed by R-R Mean, R-R Median, and (Mean R-R / Resp Cycle) –Mean] were observed for Anger and Happiness, and to a lesser extent for Disgust.

Significant effects of emotion on HRV were apparent only in the Autobiographical task. Decreases in R-R SD were observed in Anger, Disgust, and Sadness. In Sadness, this effect was accompanied by decreases in variability across the epoch in R-R interval within each respiratory cycle [(Mean R-R / Resp Cycle) –*SD*].

Significant effects of emotion were not observable on measures of fast variability in R-R interval [(SD R-R / Resp Cycle) -Mean, and (SDRR/RespCycle) -SD], or on high frequency PSD in the R-R signal.

After the psychophysiological dependent variables were transformed to the log of the ratio of the Emotion condition relative to the Neutral baseline, differences between the emotions were examined using univariate ANOVA followed by paired comparisons between each emotion and each other emotion. Results are summarized in Table 4. Paralleling the results found in first analysis of each Emotion vs Neutral, measures of respiratory period and variability demonstrated significant omnibus effects of emotion in both the Autobiographical and Film sessions. Respiratory amplitude also demonstrated a significant effect of emotion in the Film session. Paired comparisons between Emotion conditions showed significant differences on several dependent variables, which provide preliminary indications of patterns of cardiorespiratory function for some emotions. Anger, Fear, and Disgust were not significantly differentiated on any dependent measure in the Film session. Anger and Disgust were not differentiated on any dependent measure in the Autobiographical session, nor were Disgust and Sadness.

Physiological Responses: Principal Components and multivariate tests of Emotion effects

For Autobiographical dependent measures, PCA converged after 5 iterations onto a 4-factor structure that accounted for 78.34% of the variance in the dependent measures. The rotated component matrix is displayed in Table 5, part 1. Component 1 accounted for almost all of the variance in respiratory frequency—high frequency PSD, low frequency PSD, and mean respiratory period—as well as respiratory variability—*SD* of the respiratory period. Component 2 accounted for the variance in linear measures of R-R interval – (Mean R-R / Resp Cycle) -Mean, and median R-R. It also captured a portion of the variance in mean RSA. Component 3 accounted for the variance in mean and *SD* for respiratory amplitude. And Component 4 accounted for the variance in measures of HRV— SD in R-R interval, (Mean R-R / Resp Cycle) –SD, and mean RSA.

Reducing the physiological dependent measures from the Film session, PCA converged after 4 iterations onto a 3-factor structure that accounted for 78.14% of the variance. The rotated component matrix is displayed in Table 5, part 2. The rotation converged on a solution very similar to the one observed for the Autobiographical task. Component 1 is comparable to a collapsed version of Components 1 and 3 from the Autobiographical PCA, capturing the variance of all of the respiratory measures. Component 2 is analogous to Component 4 from the Autobiographical PCA, accounting for the variance from the three measures of HRV. Component 3 appears similar to component 2 from the Autobiographical PCA, capturing variance in the measures of linear R-R interval. In general, the physiological variability space appears to be very similar for both emotion elicitation sessions.

We predicted that there would be a significant effect of emotion on these principal components. MANOVA (Pillai's trace) indicated a trend in this direction ($F(16, 380) = 1.17$, $p = 0.29$) for the Autobiographical session. No effect was observed for the Film session. Subsequent univariate tests of the Autobiographical condition indicated a significant effect of emotion on Component 1 ($F(4, 95) = 2.53$, $p = 0.045$), but no effects on Components 2 -4. Post-hoc comparisons (Tukey's LSD) demonstrated that Component 1 differentiated Disgust and Fear, and Happiness and Fear (see Table 6.). Both Disgust and Happiness exhibited significantly higher Component 1 values than Fear; we can infer from the loadings on Component 1 that this difference results from longer respiratory periods and more variability in the length of the respiratory cycle in Happiness and Disgust than in Fear.

Physiological Responses: Pattern Classification

Discriminant analyses of the PCA components summarizing cardiorespiratory activity during the Autobiographical session tested the possibility that emotions can be classified based on physiological patterns. The stepwise entry of components into the discriminant analysis at an entry criterion of $p < 0.05$ for Pillai's Trace allowed only Component 1—the respiratory component--to enter the discriminant solution. Component 1 differentiated emotions at an overall rate of 28%, for both the original and cross-validated (leave-one-out) classifications. This overall rate was marginally higher than the chance rate of classification at 20% among the five emotion categories. Classification rates for individual emotions are displayed in Table 7.

Discussion

Interpretation of findings

The results of this study only partially supported the hypothesis that patterns of cardiorespiratory activity characterize each discrete emotion state. Univariate comparisons of each emotion with the neutral baseline revealed that emotional stimuli elicited shorter respiratory cycles across all emotions, and smaller deviations in respiratory period. Decreases in heart rate variability, both within respiratory cycles and over the length of the trial, were also observed across all emotion conditions relative to neutral. These results differed from results of Rainville and colleagues (2006) in which these effects were secondary to a robust increase in heart rate for emotional relative to neutral responses, indexed by decreases in R-R interval. Emotional differences in heart rate have also been noted as an effect which is consistently observed in affective psychophysiological research (Cacioppo, Berntson, Larsen, Poehlmann & Ito, 2000). In conflict with results observed by Rainville and colleagues (2006), we did not observe increases in heart rate and, conversely, found small decreases in heart rate (increases in R-R interval) for Anger, Disgust, and Happiness in the Film condition. Our observation of small effects of emotion on heart rate may be consistent with more complex models of emotional responding. For example, the defense cascade model proposes that heart rate *decelerates* in response to slightly- to moderately-arousing events, and then only accelerates in response to highly arousing events which might necessitate the mobilization of resources for fight-or-flight behavior (Lang, Bradley, & Cuthbert, 1997). Deceleration in heart rate has been associated with increased attentional responses to externally-presented emotional stimuli, such as emotionally arousing pictures (Bradley, Codispoti, Cuthbert, & Lang, 2001), and has been interpreted as a defensive resource-conservation response. Our results were consistent with such findings, as heart rate deceleration relative to the Neutral baseline was observed only in the Film condition, when attention is directed toward external stimuli. The small size of this effect and effects in the Autobiographical condition may be explained by a wash-out due to the large number of elicitation events experienced by our participants. Each participant completed many more trials in each the Autobiographical and Film sessions than participants in most previous studies eliciting emotions using emotional recollection or film clips (our study = 12 and 18 trials, respectively; other studies = 2-3 trials with only one elicitation condition). Several other studies using pattern classification of ANS responses to emotional film clips failed to observe significant univariate differences in heart rate (Christie & Friedman, 2000; Etzel et al., 2006).

The fact that we did not find robust effects of emotion on heart rate in the univariate analysis provided a preview for the small omnibus effects of emotion that we later observed in the MANOVA testing emotion effects on the components extracted from PCA. Several previous multivariate studies of emotion-specific physiological responses reported significant differences between emotion types when conducting multivariate tests on patterns of dependent physiological variables (Nyclicek, Thayer, &

VanDoornen, 1997; Rainville, Bechara, Naqvi, & Damasio, 2006). In the results of Rainville and colleagues (2006), R-R mean demonstrated strong sensitivity to emotion in the univariate tests , and was moderated by emotion type in a MANOVA test of the effect of emotion on patterns of physiological activity—mean R-R interval was shorter in Fear than in Happiness or Sadness. The authors interpreted R-R interval as contributing the main index of sympathetic activity within their study. Similarly, in the results of Nyclicek and colleagues (2000), a significant effect of emotion on the interval between heart beats was observed in univariate and multivariate ANOVAs, and this was a measure that the investigators had selected to reflect sympathetic activity. Our failure to observe significant differences between emotion conditions comparable to those observed in previous studies may have occurred because we did not have an emotion-sensitive measure of sympathetic responses. None of our measures related to sympathetic responding, such as R-R interval or PEP, were more than slightly sensitive to emotion in univariate tests of the emotions versus the neutral condition, nor in the univariate ANOVA tests contrasting each emotion condition against the others.

Our results did not provide complete support for the hypothesis that these patterns are sufficiently unique to differentiate each target emotion from all others. This hypothesis was tested directly in the discriminant analysis. In the Film condition, no discriminant functions were created because the PCA components were not sensitive to Emotion. In the Autobiographical condition, the discriminant functions based on the PCA component reflecting respiratory frequency could only be used to correctly classify emotions at a rate of 28%. This component differentiated Fear from Happiness and

Disgust. The result that a respiration component accounted for much of the variance in dependent measures in the PCA, and that the respiration component differentiated target emotions in the discriminant analysis, are markedly consistent with results of other studies which incorporated respiration in multivariate pattern classification analysis. Components reflecting respiratory frequency were observed by Nyclicek and colleagues (1997) as well as by Rainville and colleagues (2006) as first principal component in PCA analyses. Moreover, the largest omnibus emotion effects were observed in MANOVAs of the components in both studies, and in other studies (Nyclicek, Thayer, & VanDoornen, 1997; Rainville et al., 2006; Etzel et al., 2006).

Limitations

The small sample size and narrow distribution of ages among participants limit the generalizability of our results. Also, the use of averages across a 90 second period of responding to the emotional stimuli restricted the power of our study to detect changes in emotional responding that vary temporally. One way to address this in future studies might be to collect continuous subjective ratings from participants throughout each elicitation event, and to use the continuous ratings as regressors in a general linear model predicting emotion effects on a more continuous record of dependent physiological measures during the elicitation event.

We also found, based on participants' subjective ratings, that although most of the target emotions were elicited discretely (i.e. the participants' subjective ratings indicated responses more typical of the target emotion than any other emotion), the negative emotions were particularly difficult to tease apart. In the Film condition, notably, participants' reactions were mixed. Participants ratings of film clips targeting Disgust, Fear, Anger, and Sadness indicated that, on average, the clips elicited the target emotion to a high degree, but also elicited low to moderate amounts of the other negative emotions. This may explain, in some part, the smaller cardiovascular differences between emotion types observed in the Film condition relative to the Autobiographical condition. Mixed reactions are difficult to avoid in any implementation of non-personalized stimuli such as film clips, because individual responses to such stimuli vary between participants. One way to account for this type of individual variability in future studies might be to include an index of discreteness of participants' ratings, to use as a covariate in ANOVA analyses, or as an additional regressor in regression analyses.

The current study was also somewhat limited in terms of construct validity. The results provide only indirect evidence that these discrete patterns are perceived and integrated into the on-line recognition and categorization of emotion. Questions that more specifically address the link between emotion production and emotion perception can be asked about the role of interoception—the ability to perceive visceral responses—in the process of categorizing emotions. Results with more direct bearing on this issue are beginning to emerge from studies of both visceral contributions to experience (Wiens, Mezzacappa, & Katkin, 2000; Vianna, Weinstock, Elliott, Summers, & Tranel, 2006), as well as neural responses to visceral signals (Critchley et al., 2004). Generally, these studies provide converging evidence that with increasing perceptual sensitivity to visceral signals, participants report greater feelings of emotional intensity or arousal and exhibit greater activity in certain brain areas such as the anterior cingulate cortex. To more directly address the processes involved in emotion categorization, future studies might investigate whether interoceptive sensitivity influences participants' ability to classify emotional experiences into discrete categories, and which brain regions or networks contribute to the categorization process.

Contributions and future directions

The results of this study also help to resolve outstanding questions about the role of autonomic activity in discrete emotions theory. We identified characteristic patterns of autonomic nervous system activity which, in our study, accompanied each target emotion state. The nature of these patterns can inform scientific perspectives on first-person, qualitative aspects of emotion experience. Because basic emotion theories propose that visceral afferent signals form the bases for the *feelings* that accompany emotion, the patterns of physiological activity identified here may provide objective information about the experiential component of emotions. Interestingly, we observed constancy in participants' profiles of physiological responses across the two elicitation conditions—in both the Film and Autobiographical conditions, principal components analysis reduced the data to very similar component structures, reflecting dimensions of respiratory frequency, heart rate frequency, and heart rate variability. The variables loading strongly onto each dimension also differentiated emotion conditions in both Film and Autobiographical conditions in the univariate analyses. Such similarities indicate similar underlying profiles of variance between conditions in both elicitation conditions, indicating responses which may characterize the constant aspects of *feeling* which accompany an emotion elicited in a variety of contexts.

Further replication of such findings may also allow us to identify physiological measures to serve as non-verbal indicators of various emotions. Cardiovascular measures are inexpensive and non-invasive, so these patterns of autonomic activity may be optimal for use in developmental studies to examine emotional functioning in preverbal children. Studies of emotionality in n on-human primates would also shed light on the idea of discrete emotions as “basic” states that have evolved over time to allow us to adaptively react in situations fundamental to promoting life—our closest genetic relatives might reasonably be expected to have evolved similar emotional needs.

Our results may have interesting implications not only for affective, but also cognitive scientific endeavors. Research on the interaction of emotion and cognition focuses primarily on the effects of emotional intensity on cognitive performance. Models which heavily emphasize the dimension of intensity, however, are not sensitive to the qualitative differences in emotion states that we can observe in the subjective experience of emotion, and in cross-cultural expression of emotion. Because efferent and afferent pathways between the autonomic and central nervous system are relatively well-mapped (Berntson et al., 1997), autonomic information can allow us to make predictions about related activity in the central nervous system. The results of this study will begin to build a foundation upon which we may base hypotheses that address qualitative differences between emotions, allowing new predictions about emotion's influence on cognition in the brain.

Conclusion

Although we did not find complete support for the hypothesis that patterns of physiological activity would differentiate the target emotions, we did find evidence that changes in respiration frequency and heart rate variability differentiate emotional from neutral states, and target emotions from other emotion states. These findings allow us to reject the null hypothesis of non-specificity in emotional autonomically-controlled bodily activity.

References

Sources of film clips marked with *

Barros, A.K., Yoshizawa, M., & Yasuda, Y. (1995). Filtering noncorrelated noise in impedance cardiography. *IEEE Transactions on Biomedical Engineering, 42*(3), 324-327.

* Belzberg, L., Sadowski, P. (Producers), & Shapiro, P. (Director). (2005). *Spring Break Shark Attack* [Motion picture]. New York, NY: CBS Television Network.

Berntson, G.G., Bigger, J.T.Jr., Eckberg, D.L., Grossman, P., Kaufmann, P.G., et al. (1997). Heart rate variability: Origins, methods, and interpretive caveats. *Psychophysiology, 34*, 623-648.

* Bevan, T., Fellner, E., Kenworthy, D. (Producers), & Curtis, R. (Director). (2003). *Love Actually* [Motion picture}. Paris, France: StudioCanal.

* Bruckheimer, J., Oman, C. (Producers), & Yakin, B. (Director). (2000). *Remember the Titans* [Motion picture]. Burbank, CA: Walt Disney Pictures.

Cacioppo, J.T., Berntson, G.G., Kein, D.J. (1992). What is an emotion? The role of somatovisceral afference, with special emphasis on somatovisceral "illusions." *Review of Personality and Social Psychology, 14,* 63-98.

Cacioppo, J.T., Berntson, G.G., Larsen, J.T., Poehlmann, K.M., & Ito, T.A. (2000). The psychophysiology of emotion. In Lewis, M., & Haviland, J.M. (Eds). *Handbook of emotions*, pp. 119-142. New York, NY: Guilford Press.

* Chaffin, S., Feig, E., Moritz, N. H. (Producer), &Gillespie, J. (Director). (1997). *I know what you did last summer* [Motion picture]. Culver City, CA: Columbia Tristar Home Video.

Christie, I.C., Friedman, B.H. (2004). Autonomic specificity of discrete emotion and dimensions of affective space: A multivariate approach. *Int. J. Psychophysiol., 51*, 143-153.

Chwalisz, K., Diener, E., & Gallagher, D. (1988). Autonomic arousal feedback and emotional experience: Evidence from the spinal cord injured. *Personality Processes and Individual Differences, 54*(5), 820-828.

Cohen J.D., MacWhinney B., Flatt M., and Provost J. (1993). PsyScope: A new graphic interactive environment for designing psychology experiments. *Behavioral Research Methods, Instruments, and Computers, 25*(2), 257-271.

Collet, C., Vernet-Maury, E., Delhomme, G., Dittmar, A. (1997). Autonomic nervous system response patterns specificity to basic emotions. *J. Auton. Nerv. Syst., 62*, 45-57.

Critchley, H.D., Wiens, S., Rotschtien, P., Ohman, A. & Dolan, R.J. (2004). Neural systems supporting interoceptive awareness. *Nature Neuroscience, 7*(2), 189-195.

Damasio, A., Grabowski, T.J., Bechara, A., Damasio, H., Ponto, L.L.B., Parvizi, J., & Hichwa, R.D. (2000). Subcortical and cortical brain activity during the feeling of self-generated emotions. *Nature Neuroscience, 3*(10), 1049-1056.

* Darabont, F. (Producer & Director), & Valdes (Producer). (1999). *The Green Mile* [Motion picture]. Burbank, CA: Castle Rock Entertainment.

Darwin, C. (1899). *The Expression of Emotion in Man and Animals*. 3rd ed. New York: Appleton and Company.

* Disney, W. (Producer), & Hand, D. (Director). (1942). *Bambi* [Motion picture]. New York, NY: RKO Radio Pictures Inc.

Ekman, P., Levenson, R.W., Friesen, W.V. (1983). Autonomic nervous system activity distinguishes among emotions. *Science, 221*, 1208-1210.

Ekman, P. (1999). Basic emotions. In T. Dalgleish & M. Power (Eds.). *Handbook of Emotion and Cognition*. Sussex, U.K.: John Wiley & Sons, Ltd., 1999.

* Emmerich, T., Johnson, M. (Producers), & Cassavetes, N. (Director). (2004). *The Notebook* [Motion picture]. Burbank, CA: New Line Cinema.

Etzel, J.A., Johnsen, E.L., Dickerson, J., Tranel, D., & Adolphs, R. (2006). Cardiovascular and respiratory responses during musical mood induction. *International Journal of Psychophysiology, 61*, 57-69.

* George, T. (Producer & Director). (2004). *Hotel Rwanda* [Motion picture]. Santa Monica, CA: Lions Gate Entertainment.

* Gladstein, R.N., Bellflower, N. (Producers), & Forster, M. (Director). (2004). *Finding Neverland* [Motion picture]. New York, NY: Miramax Films.

Gross, J.J., Levenson, R.W. (1995). Emotion elicitation using films. *Cognition & Emotion, 9*(1), 87-108.

Grossman, P., Van Beek, J., & Wientjes, C. (1990). A comparison of three quantification methods for respiratory sinus arrhythmia. *Psychophysiology, 27*(6), 702-714.

* Haggis, P., Cheadle, D., Yari, B., Schulman, C. (Producers), & Haggis, P. (Director). (2004). *Crash* [Motion picture]. Los Angeles, CA: Bob Yari Productions.

* Hardman, K., Streiner, R. (Producers), & Romero, G.A. (Director). (1968). *Night of the Living Dead* [Motion picture]. Public domain.

Izard, C.E. (1992). Basic emotions, relations among emotions, and emotion-cognition relations. *Psychological Review, 99*(3), 561-565.

James, W. (1894). The physical basis of emotion. *Psychological Review, 1*, 516-529.

* Konrad, C., Woods, C. (Producers), & Craven, W. (Director). (1996). *Scream* [Motion picture). Burbank, CA: Dimension Films.

* Kraemer, C. (Producer & Director). Date unpublished. Short documentary on letterpress. Downloaded 01 June, 2008 from http://elsa.photo.net/firefly.html.

Kreibig, S.D., Wilhelm, F.H., Roth, W.T., Gross, J.J. (2007). Cardiovascular, electrodermal, and respiratory response patterns to fear- and sadness-inducing film clips. *Psychophysiology, 44*, 787-806.

* Kubrick, S. (Producer & Director), Harlan, J., & Richards, M. (Producers). (1980). *The Shining* [Motion picture]. Burbank, CA: Warner Bros., Entertainment.

Lacey, J.I., Bateman, D.E., & VanLehn, R. (1953). Autonomic response specificity: An experimental study. *Psychosomatic Medicine, 15*(1), 8-21.

Lang, P.J. (1994). The varieties of emotional experience: A meditation on James-Lange theory. *Psychological Review, 101*, 211-221.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1997). Motivated attention: Affect, activation, and action. In P. J. Lang, R. F. Simons, & M. T. Balaban (Eds.), *Attention and orienting: Sensory and motivational processes* (pp. 97–135). Hillsdale, NJ: Erlbaum.

Lang, P. J., Bradley, M. M., & Cuthbert, B. N. (1998). Emotion, motivation, and anxiety: Brain mechanisms and psychophysiology. *Biological Psychiatry, 44*, 1248-1263.

* Lewis, R.B. (Producer), & Sheridan, K. (Director). (2007). *August Rush* [Motion picture]. Burbank, CA: Warner Bros., Entertainment, Inc.

* Macdonald, A., Reich, A., Lopez-Lavigne, E. (Producers), & Fresnadillo, J.C. (Director). (2007). *28 Weeks Later* [Motion picture]. Los Angeles, CA: 20th Century Fox.

Marshall, G.D., & Zimbardo, P.G. (1979). Affective consequences of inadequately explained physiological arousal. *Journal of Personality and Social Psychology, 37*(6), 970-988.

* McG (Producer & Director), & Iwanyk, B. (Producer). (2006). *We Are Marshall* [Motion picture]. Burbank, CA: Warner Bros., Entertainment.

* Morrissey, J. (Producer), & Kaye, T. (Director). (1998). *American History X* [Motion picture]. New York, NY: New Line Cinema.

* Neufeld, M. (Producer), & Robinson, P.A. (Director). (2002). *The Sum of All Fears* [Motion picture]. Hollywood, CA: Paramount Pictures.

Nyclicek, I., Thayer, J.F., & Van Doornen, L.J.P. (1997). Cardiorespiratory differentiation of musically-induced emotions. *Journal of Psychophysiology, 11*, 304-321.

Pan, J., & Tompkins, W.J. (1985). A real-time QRS detection algorithm. *IEEE Transactions on Biomedical Engineering, 32*(3), 230-236.

* Parkes, W.F., Lee, R., Macdonald, L., Macari, M. (Producers), & Verbinski, G. (Director). (2002). *The Ring* [Motion picture]. Universal City, CA: DreamWorks Studios.

Pelletier, M., Bouthillier, A., Levesque, J., Carrier, S., Breault, C. et al. (2003). Separate neural circuits for primary emotions? Brain activity during self-induced sadness and happiness in professional actors. *NeuroReport, 14*(8), 1111-1116.

Rainville, P., Bechara, A., Naqvi, N., Damasio, A.R. (2006). Basic emotions are associated with specific patterns of cardiorespiratory activity. *International Journal of Psychophysiology, 61*, 5-18.

Sequeira, H., Hot, P., Silvert, L., Deplanque, S. (2009). Electrical autonomic correlates of emotion. *International Journal of Psychophysiology, 71*, 50-56.

Sinha, R., & Parsons, O.A. (1996). Multivariate response patterning to fear and anger. *Cognition and Emotion, 10*(2), 173-198.

Schacter, S., & Singer, J.E. (1962). Cognitive, social, and physiological determinants of emotional state. *Psychological Review, 69*(5), 379-399.

* Scott, R. (Producer & Director), & De Laurentiis, D. (2001). *Hannibal* [Motion picture]. Universal City, CA: Universal Studios.

Sherwood, A., Allen, M.T., Fahrenberg, J. Kelsey, R.M., Lovallo, W.R, et al. (1990). Methodological Guidelines for Impedance Cardiography. *Psychophysiology, 27* (1), 1-23.

* Smith, W., Tisch, S., Lassiter, J., Black, T., Blumenthal, J. (Producers), & Muccino, G. (Director). *Pursuit of Happyness* [Motion picture]. Beverly Hills, CA: Overbrook Entertainment.

SPSS for Windows, Rel. 13.0. 2004. Chicago: SPSS Inc.

Stemmler, G. (2004). Physiological processes during emotion. In P. Philipot, & R.S. Feldman (Eds), *The Regulation Of Emotion* (pp. 35-66). Mawah, NJ: Lawrence Earlbaum Associates, Inc. Publishers.

* Todd, J. Todd, S. (Producers), & Nolan, C. (Director). (2000). *Memento* [Motion picture]. Universal City, CA: Summit Entertainment.

* Turtletaub, M., Saraf, P., Berger, A., Yerxa, R. (Producers), Dayton, J., & Faris, V. (Directors). (2006). *Little Miss Sunshine* [Motion picture]. Los Angeles: Fox Searchlight Pictures.

Vernet-Maury, E., Alaoui-Ismaili, O., Dittmar, A., Delhomme, G., Chanel, J. (1999). Basic emotions induced by odorants: a new approach based on autonomic pattern results. *J. Auton. Nerv. Syst., 75*, 176-183.

Task Force of The European Society of Cardiology and The North American Society of Pacing and Electrophysiology (1996). Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. *European Heart Journal, 17*, 354–381.

Turner, T.J., & Ortony, A. (1992). Basic emotions: Can conflicting criteria converge? *Psychological Review, 99*(3), 566-571.

* Waters, J. (Producer & Director). (1972). *Pink Flamingos* [Motion picture]. New York, NY: New Line Cinema.

* Wise, R. (Director). (1965). *The Sound of Music* [Motion picture]. Los Angeles, CA: 20th Century Fox.

* Ziskin, L. (Producer), & Marshall, G. (Director). (1990). *Pretty Woman* [Motion picture]. Burbank, CA: Touchstone Pictures.

List of Tables

Table 1. Means and standard deviations for subjective ratings of emotional experience

Table 2. Paired samples tests of arousal ratings

Table 3. Differences between each Emotion condition and the Neutral condition

Table 4. Differences between Emotion conditions

Table 5. Principal component analysis of physiological measures: Rotated component matrices

Table 6. Comparisons between Emotion conditions on Component1 for the Autobiographical condition

Table 7. Percent of correct classifications based on stepwise discriminant analyses of Autobiographical session

Table 1. Means and standard deviations for subjective ratings of emotional experience

			Valence		*Typicality*				
Elicitation	*Target Emo.*	*Arousal*	*Positive*	*Negative*	*Anger*	*Happiness*	*Sadness*	*Disgust*	*Fear*
Film	Anger	2.82 (1.44)	0.65 (1.07)	3.10 (1.54)	**2.38 (1.67)**	0.32 (0.91)	1.20 (1.35)	1.85 (1.47)	0.52 (0.98)
	Happiness	2.75 (1.36)	3.88 (1.38)	0.17 (0.69)	0.28 (1.11)	**3.10 (1.60)**	0.38 (1.03)	0.23 (0.87)	0.13 (0.70)
	Sadness	3.45 (2.97)	0.78 (1.17)	3.02 (1.56)	1.03 (1.73)	0.37 (0.90)	**3.32 (1.44)**	0.85 (1.47)	0.97 (1.44)
	Disgust	4.08 (1.23)	0.23 (0.65)	3.70 (1.51)	0.98 (1.58)	0.17 (0.67)	0.93 (1.51)	**4.25 (1.17)**	1.73 (1.95)
	Fear	3.83 (1.36)	0.63 (1.18)	3.42 (1.60)	0.50 (1.03)	0.42 (1.00)	0.75 (1.17)	1.95 (1.77)	**3.62 (1.53)**
	Neutral	0.43 (0.77)	1.08 (1.36)	0.43 (0.93)	0.35 (1.04)	0.33 (0.93)	0.35 (1.02)	0.37 (1.04)	0.23 (0.93)
Autobio	Anger	3.28 (1.18)	0.23 (0.48)	3.63 (1.25)	**3.45 (1.18)**	0.08 (0.27)	0.98 (1.00)	1.08 (1.25)	0.35 (0.80)
	Happiness	3.65 (1.10)	4.23 (1.29)	0.35 (0.86)	0.10 (0.38)	**3.75 (1.39)**	0.30 (0.94)	0.15 (0.66)	0.23 (0.66)
	Sadness	3.25 (1.28)	0.73 (0.99)	3.58 (1.20)	1.05 (1.38)	0.25 (0.63)	**3.70 (1.16)**	0.53 (1.01)	0.60 (1.08)
	Disgust	3.33 (1.46)	0.51 (1.02)	3.44 (1.39)	0.95 (1.32)	0.21 (0.73)	0.69 (1.08)	**3.51 (1.45)**	0.56 (0.97)
	Fear	2.74 (1.19)	0.72 (0.94)	3.26 (1.27)	0.56 (1.19)	0.21 (0.52)	0.62 (1.09)	0.41 (0.91)	**3.26 (1.33)**
	Neutral	1.21 (1.44)	2.13 (1.66)	0.46 (0.94)	0.18 (0.51)	0.90 (1.19)	0.21 (0.61)	0.10 (0.31)	0.08 (0.27)

Table 2. Paired samples tests of arousal ratings

		t	*df*	*P*
Film	Anger - Neutral	9.382	19	.00000
	Happiness - Neutral	9.748	19	.00000
	Sadness - Neutral	8.612	19	.00000
	Disgust - Neutral	17.015	19	.00000
	Fear - Neutral	12.586	19	.00000
Autobio	Anger - Neutral	6.615	19	.00000
	Happiness - Neutral	7.020	19	.00000
	Sadness - Neutral	5.282	19	.00004
	Disgust - Neutral	6.175	19	.00001
	Fear - Neutral	5.737	19	.00002

Table 3. Differences between each Emotion condition and the Neutral condition

	Anger		Disgust		Fear		Happiness		Sadness	
	*t**	*P*	*t*	*P*	*t*	*P*	*t*	*P*	*t*	*P*
Autobiographical										
Resp Amp Mean	ns	--	ns	--	ns	--	1.88	0.08	ns	--
Resp Amp Median	ns	--	ns	--	ns	--	1.91	0.07	ns	--
Resp Amp *SD*	ns	--	ns	--	ns	--	2.36	0.03	ns	--
Resp Period Mean	-2.67	0.02	ns	--	-2.66	0.02	ns	--	ns	--
Resp Period Median	-2.75	0.01	-1.82	0.08	-2.36	0.03	ns	--	ns	--
Resp Period *SD*	-2.01	0.06	ns	--	ns	--	ns	--	ns	--
Resp - High Freq PSD	-2.14	0.05	-1.87	0.08	-3.11	0.01	ns	--	ns	--
R-R *SD*	-1.81	0.09	-1.73	0.10	ns	--	ns	--	-2.58	0.02
RSA Mean	ns	--	-1.77	0.09	ns	--	ns	--	ns	--
RSA Median	-2.68	0.01	-2.04	0.06	-1.73	0.10	ns	--	ns	--
(Mean R-R / Resp Cycle) -*SD*	ns	--	ns	--	ns	--	ns	--	-1.75	0.10
(Mean R-R / Resp Cycle) -Mean	-1.96	0.06	ns	--	ns	--	ns	--	ns	--
Film										
Resp Amp Mean	ns	--	ns	--	ns	--	ns	--	-2.15	0.04
Resp Amp Median	ns	--	ns	--	ns	--	ns	--	-2.03	0.06
Resp Period Mean	-1.87	0.08	-2.35	0.03	-2.09	0.05	-2.12	0.05	ns	--
Resp Period Median	ns	--	-2.21	0.04	-2.03	0.06	-2.60	0.02	ns	--
Resp Period SD	-2.11	0.05	ns	--	ns	--	ns	--	ns	--
Resp - High Freq PSD	-1.92	0.07	ns	--	-1.75	0.10	ns	--	ns	--
R-R Mean	ns	--	ns	--	ns	--	2.04	0.06	ns	--
R-R Median	2.18	0.04	1.80	0.09	ns	--	2.46	0.02	ns	--
(Mean R-R / Resp Cycle) -Mean	2.28	0.03	ns	--	ns	--	2.10	0.05	ns	--

Table displays tests for dependent variables on which differences of $p < 0.10$ were observed.

*df=19

Table 4. Differences between Emotion conditions

	*F** (*df*)	*P*	η^2	Paired Comparisons A vs. D		A vs. F		A vs. H		A vs. S		D vs. F		D vs. H		D vs. S		F vs. H		F vs. S		H vs. S	
Autobiographical																							
Resp Amp Mean	1.14 (4, 76)	.34	.06	-.92	ns	-1.27	ns	-2.08	ns	-2.52	(.02)	-.27	ns	-1.11	ns	-.50	ns	-.66	ns	-.35	ns	.41	ns
Resp Amp Median	.94 (4, 76)	.44	.05	.02	ns	-.73	ns	-2.23	(.04)	-1.60	ns	-.53	ns	-1.37	ns	-.91	ns	-1.17	ns	-.59	ns	.89	ns
Resp Period Mean	2.69 (4, 76)	.04	.12	-1.73	ns	.92	ns	-1.47	ns	-1.92	ns	2.12	(.05)	-.38	ns	-.83	ns	-2.58	(.02)	-2.47	(.02)	-.25	ns
Resp Period *SD*	5.92 (4, 76)	.0004	.25	-1.98	ns	.35	ns	-3.14	(.01)	-1.43	ns	3.24	(.00)	-2.09	ns	.41	ns	-3.70	(.00)	-1.86	ns	2.11	(.05)
Resp - High Freq PSD	2.69 (2.8, 51.5)	.06	.12	-.82	ns	1.83	ns	-1.34	ns	-1.01	ns	2.04	ns	-.99	ns	-.31	ns	-2.68	(.01)	-2.29	(.03)	.49	ns
Resp - Low Freq PSD	3.08 (2.6, 45.9)	.04	.15	-.86	ns	2.38	(.03)	-1.85	ns	.63	ns	1.89	ns	-.80	ns	1.01	ns	-2.80	(.01)	-1.32	ns	2.07	ns
R-R Median	2.55 (4, 76)	.05	.12	1.12	ns	-1.70	ns	-.15	ns	-1.25	ns	-2.53	(.02)	-1.45	ns	-1.78	ns	1.72	ns	.82	ns	-1.12	ns
Film																							
Resp Amp Mean	4.28 (2.1, 37.3)	.02	.19	.76	ns	-.85	ns	-1.80	ns	1.68	ns	-1.67	ns	-2.18	(.04)	1.87	ns	-1.26	ns	2.33	(.03)	3.31	(.00)
Resp Amp Median	4.02 (2.8, 53.1)	.01	.17	-.55	ns	-.90	ns	-1.51	ns	2.20	(.04)	-.22	ns	-1.46	ns	3.08	(.01)	-1.04	ns	2.88	(.01)	3.20	(.00)
Resp Period Mean	1.15 (4, 72)	.34	.06	.50	ns	1.13	ns	.90	ns	-1.16	ns	.31	ns	.50	ns	-1.66	ns	.08	ns	-1.57	ns	-2.10	(.05)
Resp Period Median	3.23 (4, 72)	.02	.15	.79	ns	1.83	ns	2.83	(.01)	-.54	ns	.48	ns	2.31	(.03)	-1.26	ns	1.09	ns	-1.70	ns	-3.61	(.00)
Resp Period SD	1.18 (4, 72)	.33	.06	-.91	ns	-1.46	ns	-2.12	(.05)	-2.16	(.04)	-.30	ns	-1.09	ns	-.88	ns	-.73	ns	-.24	ns	.78	ns
Resp - High Freq PSD	1.46 (1.9, 34.3)	.25	.01	-.43	ns	-1.48	ns	-1.42	ns	-2.34	(.03)	-.51	ns	-1.18	ns	-1.62	ns	-.85	ns	-.79	ns	.47	ns
Resp - Low Freq PSD	1.81 (2.3, 4.5)	.17	.09	-1.09	ns	-.82	ns	-1.61	ns	-2.41	(.03)	.34	ns	-1.10	ns	-1.08	ns	-1.39	ns	-1.83	ns	.33	ns
R-R *SD*	1.61 (4, 68)	.2	.09	.99	ns	1.22	ns	-.47	ns	.44	ns	.41	ns	-1.01	ns	-.64	ns	-2.37	(.03)	-.19	ns	.72	ns
RSA Mean	1.14 (2.3, 42)	.34	.06	.71	ns	1.97	ns	2.24	(.04)	1.08	ns	.79	ns	.65	ns	.14	ns	-.67	ns	-.12	ns	-.38	ns
RSA Median	1.76 (4, 76)	.15	.09	1.12	ns	.75	ns	2.51	(.02)	2.35	(.03)	-.44	ns	1.52	ns	.61	ns	1.44	ns	1.08	ns	-.69	ns
(*SD* R-R / Resp Cycle) -Mean	.97 (2.6, 48.9)	.41	.05	.67	ns	.35	ns	.45	ns	3.36	(.00)	-.18	ns	-.20	ns	1.58	ns	.04	ns	1.48	ns	1.51	Ns

* For dependent variables violating sphericity, Greenhouse-Geisser correction was applied.

**df = 19

Table displays tests for dependent variables on which differences of $p < .05$ were observed.

Table 5. Principal component analysis of physiological measures: Rotated component matrices

Part 1: Autobiographical session

	Component			
	1	2	3	4
Resp- high freq PSD	**.926**	.021	-.106	.129
Resp- low freq PSD	**.815**	-.175	.031	.022
Resp Period SD	**.787**	-.029	.037	.225
Resp Period Mean	**.768**	.353	.032	.088
(Mean R-R / Resp Cycle) -Mean	.073	**.907**	-.068	-.161
R-R Median	-.117	**.882**	-.103	-.100
RespAmp Mean	.009	.002	**.930**	-.030
RespAmp SD	-.029	-.131	**.887**	.197
R-R SD	.120	-.069	-.043	**.905**
(Mean R-R / Resp Cycle) -SD	.155	-.294	.291	**.695**
RSA Mean	.330	**.554**	.096	**.560**

Part 2: Film session

	Component		
	1	2	3
Resp- low freq PSD	**.930**	.194	-.061
Resp- high freq PSD	**.914**	.293	-.041
Resp Period Mean	**.882**	.062	-.006
Resp Period SD	**.740**	.404	-.048
RespAmp SD	**.526**	.489	-.372
RespAmp Mean	.425	.242	-.358
R-R SD	.277	**.925**	-.020
(Mean R-R / Resp Cycle) -SD	.137	**.919**	-.042
RSA Mean	.537	**.601**	.102
R-R Median	-.029	.028	**.950**
(Mean R-R / Resp Cycle) -Mean	-.007	-.012	**.944**

Table 6. **:omparisons between Emotion conditions on Component1 for the Autobiographical Condition**

LSD

(I) Emotion	(J) Emotion	Mean Difference (I-J)	Std. Error	Sig.
Anger	Disgust	-.2815982	.30687378	.361
	Fear	.3997833	.30687378	.196
	Happiness	-.5194751	.30687378	.094
	Sadness	-.2011496	.30687378	.514
Disgust	Anger	.2815982	.30687378	.361
	Fear	.6813814*	.30687378	.029
	Happiness	-.2378770	.30687378	.440
	Sadness	.0804485	.30687378	.794
Fear	Anger	-.3997833	.30687378	.196
	Disgust	-.6813814*	.30687378	.029
	Happiness	-.9192584*	.30687378	.003
	Sadness	-.6009329	.30687378	.053
Happiness	Anger	.5194751	.30687378	.094
	Disgust	.2378770	.30687378	.440
	Fear	.9192584*	.30687378	.003
	Sadness	.3183255	.30687378	.302
Sadness	Anger	.2011496	.30687378	.514
	Disgust	-.0804485	.30687378	.794
	Fear	.6009329	.30687378	.053
	Happiness	-.3183255	.30687378	.302

*. The mean difference is significant at the .05 level.

Table 7. **ercent of correct classifications based on stepwise discriminant analyses of Autobiographical session**

			Predicted Group Membership					
		Emotion	Anger	Disgust	Fear	Happiness	Sadness	Total
Original	%	Anger	15.0	5.0	35.0	30.0	15.0	100.0
		Disgust	10.0	15.0	35.0	35.0	5.0	100.0
		Fear	10.0	.0	50.0	20.0	20.0	100.0
		Happiness	15.0	10.0	20.0	50.0	5.0	100.0
		Sadness	.0	5.0	30.0	55.0	10.0	100.0
Cross-validated	%	Anger	15.0	5.0	35.0	30.0	15.0	100.0
		Disgust	10.0	15.0	35.0	35.0	5.0	100.0
		Fear	10.0	.0	50.0	20.0	20.0	100.0
		Happiness	15.0	10.0	20.0	50.0	5.0	100.0
		Sadness	.0	5.0	30.0	55.0	10.0	100.0

Appendix 1. List of film clips and mean ratings of emotional responses

		Valence		*Typicality*				
	Arousal	*Positive*	*Negative*	*Anger*	*Happiness*	*Sadness*	*Disgust*	*Fear*
Anger								
Crash - Shouting match between store owner and locksmith	3.44	0.56	3.50	2.89	0.44	1.22	2.44	0.78
Memento - Woman tries to anger man with insults	3.33	0.33	4.22	3.00	0.33	1.22	2.56	0.89
Pretty Woman - Man insults and attacks female protagonist	3.09	0.27	3.09	2.64	0.00	0.73	2.18	0.55
Crash - Man argues with health insurance agent	2.89	0.22	3.67	3.11	0.11	1.78	2.22	0.44
Hotel Rwanda - Army officer threatens hotel manager	2.27	0.82	2.00	1.55	0.36	1.18	0.55	0.73
Remember the Titans- Racial tensions in community	2.09	1.82	2.64	1.55	0.91	0.73	1.64	0.00
	2.82	**0.70**	**3.12**	**2.40**	**0.37**	**1.12**	**1.88**	**0.55**
Happiness								
Little Miss Sunshine - Beauty pageant; family goes onstage	3.78	4.67	0.33	0.22	4.44	0.22	0.44	0.22
Love Actually - English / Spanish marriage proposal	3.67	4.22	0.11	0.11	4.00	0.22	0.11	0.33
Pursuit of Happyness - Final sequence (job offer)	3.09	4.27	0.00	0.45	3.36	0.91	0.00	0.00
August Rush - Boy plays guitar	2.56	3.78	0.11	0.11	3.22	0.11	0.11	0.11
Finding Neverland - Little boys learn to fly a kite	1.91	3.45	0.27	0.00	2.00	0.55	0.09	0.00
Sound of Music - Family members ride bikes and sing	1.91	3.27	0.45	0.91	2.27	0.45	0.82	0.45
	2.77	**3.92**	**0.22**	**0.32**	**3.15**	**0.43**	**0.27**	**0.18**
Sadness								
Crash - Little girl accidentally shot	4.78	0.67	4.56	3.00	0.44	4.78	1.44	2.56
Finding Neverland - Boy discusses death of his mother	4.36	2.09	1.64	0.00	0.82	2.91	0.00	0.27
Green Mile - Innocent inmate dies	3.78	0.67	3.78	1.56	0.33	4.11	2.00	1.22
Bambi - Mother deer dies	2.89	1.00	3.44	1.11	0.44	3.67	0.67	1.56
We Are Marshall - Funeral scenes	2.82	0.09	3.18	0.00	0.09	2.82	0.18	0.09
The Notebook - Woman reads love letters	2.00	0.82	1.73	0.45	0.64	2.00	0.55	0.36
	3.40	**0.90**	**2.97**	***0.93***	**0.47**	**3.30**	**0.75**	**0.93**

Disgust								
Hannibal - Man eats own brain	4.78	0.11	4.33	0.89	0.11	1.22	4.78	3.33
Pink Flamingos - Person eats dog feces	4.36	0.09	3.64	0.64	0.09	0.45	4.55	0.36
American History X - Thugs ransack grocery store	4.33	0.11	4.67	3.67	0.11	2.78	4.11	3.00
Night of the Living Dead - Girl vomits internal organs	4.27	0.09	4.00	0.18	0.09	0.45	4.64	2.64
Squeezing Pimple – Person squeezes pimple	3.55	0.55	2.82	0.18	0.64	0.00	3.73	0.09
Eye surgery – Close-up of laser surgery	3.22	0.78	3.00	0.33	0.22	0.67	3.44	1.56
	4.08	**0.28**	**3.72**	**0.92**	**0.22**	**0.87**	**4.22**	**1.75**
Fear								
28 Weeks Later - Children travel through dark subway station	4.44	0.22	4.33	0.56	0.11	1.33	3.22	4.44
The Ring - Child comes out of television	4.44	0.22	4.00	0.44	0.22	0.89	2.78	4.33
I Know What You Did... - Man chases girl through dress shop	4.22	0.44	4.00	0.67	0.33	0.78	2.00	4.33
Scream - Phone call scene	3.73	0.91	3.27	1.00	0.36	0.73	1.55	3.09
The Shining - Boy finds twins in the hallway	3.73	0.73	3.00	0.00	0.45	0.64	1.91	3.09
Spring Break Shark Attack - Shark chases swimming girl	2.91	1.36	2.27	0.45	1.18	0.36	0.18	3.00
	3.87	**0.68**	**3.42**	**0.52**	**0.47**	**0.77**	**1.87**	**3.65**
Neutral								
Allergies - Informational on seasonal allergies	0.67	0.78	0.78	0.33	0.11	0.56	0.44	0.22
Health – Documentary on women's health	0.64	1.73	0.45	0.27	0.73	0.18	0.09	0.18
The Sum of All Fears - Man gives advice to govt. committee	0.56	1.22	0.67	0.22	0.56	0.22	0.22	0.22
Ink Press - Documentary on printing presses	0.45	1.55	0.18	0.27	0.09	0.64	0.73	0.45
Google - Developer explains a new tool	0.27	1.00	0.36	0.82	0.55	0.64	0.64	0.45
English Exam – Teacher explains English Language course	0.11	0.56	0.56	0.11	0.22	0.11	0.22	0.11
	0.45	**1.17**	**0.48**	**0.35**	**0.38**	**0.40**	**0.40**	**0.28**

Appendix 2. Autobiographical Form

Please fill out each box below with two emotional memories of your past. For each memory, include a sentence or two describing each event/occurrence during which you STRONGLY felt the listed emotion. An example of this might be, "The time that I can remember feeling the saddest was when my dog Sallie passed away…" These descriptions will aid you when you have to provide more in-depth information about each memory during the first experimental session. Keep in mind that you want to select memories that still evoke a strong emotional reaction that is specific to the emotion listed at the top of the box. For example, if you were afraid and disgusted when you had to get stitches in your arm, then you would not want to select that event for this experiment. Similarly, if you were angry that your brother ate all of your halloween candy in 4th grade, but you currently do not feel angry when you think about the event, then you would want to select a memory that is more emotionally evocative.

For the last box ('Neutral'), please list two memories which describe specific times in which you were engaged in a non-emotional activity, such as a time that you cooked dinner recently, or went for a walk, or a specific morning when you were preparing to leave the house and get to work/school. Please choose neutral and emotional events that you remember very vividly.

You should choose emotional and neutral memories from specific time periods. **In each box, list one memory from the recent past and one memory from the far past.** The memory from the recent past should be an event that occurred in the most recent 3 years of your life. The memory from the far past should be an event that occurred earlier than 3 years ago. It may help you to think of this in terms of what year you were in school 3 years ago, and use that as your cut-off point.

Anger:

- ______________________________
  ____
- ______________________________
  ____

Disgust:

- ______________________________
  ____
- ______________________________
  ____

Fear:

- ____
  ____
- ____
  ____

Happiness:

- ____
  ____
- ____
  ____

Sadness:

- ____
  ____
- ____
  ____

Neutral:

- ____
  ____
- ____
  ____