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Autonomic specificity of basic emotions: Evidence from pattern classification and cluster analysis☆

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ABSTRACT

Autonomic nervous system (ANS) specificity of emotion remains controversial in contemporary emotion research, and has received mixed support over decades of investigation. This study was designed to replicate and extend psychophysiological research, which has used multivariate pattern classification analysis (PCA) in support of ANS specificity. Forty-nine undergraduates (27 women) listened to emotion-inducing music and viewed affective films while a montage of ANS variables, including heart rate variability indices, peripheral vascular activity, systolic time intervals, and electrodermal activity, were recorded. Evidence for ANS discrimination of emotion was found via PCA with 44.6% of overall observations correctly classified into the predicted emotion conditions, using ANS variables ($z = 16.05$, $p < .001$). Cluster analysis of these data indicated a lack of distinct clusters, which suggests that ANS responses to the stimuli were nomothetic and stimulus-specific rather than idiosyncratic and individual-specific. Collectively these results further confirm and extend support for the notion that basic emotions have distinct ANS signatures.

A core area of investigation historically derived from James' (1884) inquiry into the nature and source of emotions is the degree to which different emotional states might be characterized by unique patterns of autonomic nervous system (ANS) activity (see Friedman, this issue for a review of this subject). The research literature on ANS specificity for basic emotions has been characterized as both supportive (see Ekman et al., 2003) and inconsistent (Cacioppo et al., 2000; Barrett, 2006). However, recent research using the multivariate technique of *pattern classification analysis* (PCA) has consistently reported patterning of autonomic variables allowing for differentiation among emotion conditions (Christie and Friedman, 2004; Kreibig et al., 2007; Nyklicek et al., 1997; Rainville et al., 2006). The current study is specifically directed at replicating and extending the findings of Christie and Friedman (2004) and Nyklicek et al. (1997), which represent a line of continuity in our research group (the former was based largely on the latter). Nyklicek et al. (1997) utilized music excerpts to induce emotion; Christie and Friedman (2004) used film clips for this purpose. Both induction techniques were used and compared in the present study.

A secondary goal of the present study was to examine individual-specific ANS response patterns to emotion inductions by the use of *cluster analysis*. This approach was modeled after a study that sought to quantify distinct clusters of individual-specific cardiovascular response patterns to various laboratory stressors (Allen et al., 1991). By analogy, this strategy was adopted to assess individual-specific response patterns across diverse emotion induction conditions. Methodological and analytic issues central to the study of autonomic specificity are also discussed.

1. Methodological considerations

Recent research on ANS differentiation of emotions has addressed discrepancies between studies by adopting relevant suggestions proposed by Stemmler (1989) and Cacioppo et al. (1993). For example, distinguishing physiological responses to emotion inductions from those arising from the experimental context requires a neutral "context without emotion" condition (Stemmler, 1989). Accordingly, the core studies upon which this paper is based, as well as the present investigation, included such a control (Christie and Friedman, 2004; Nyklicek et al., 1997; Kreibig et al., 2007). Such methods enhance the comparability of ANS specificity studies across different induction techniques. Furthermore,

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a common set of guidelines for psychophysiological research on emotion promotes coherence in the literature. These principles generally have been followed in the present study, as well as in similar research (Christie and Friedman, 2004; Kreibig et al., 2007; Nyklicek et al., 1997). Hence, the methodology and results are highly comparable across these studies.

2. Induction technique selection

The selection of affect induction method is of crucial importance. Seven dimensions salient to this choice have been outlined (Rottenberg et al., 2007). These considerations include: ecological validity, intensity, demand characteristics, standardization, temporal considerations, attentional capture, and complexity. Careful reflection on these dimensions is key when determining which technique best matches the aims of a study. Additionally, the emotional framework upon which the induction method was developed is of utmost importance, because this will limit interpretation of the results. For example, emotion inductions based upon a dimensional model of affect (e.g., Russell, 1980) are unlikely to yield information easily interpretable in a discrete emotion framework (e.g., Izard, 1977).

Both music and film affect induction techniques were used in the present study. In part, this choice was based on studies by Nyklicek et al. (1997) which employed music, and Christie and Friedman (2004) which used film inductions. Selection of emotion types in these two studies was based on a hybrid discrete-dimensional model of affect, which posits a hierarchical relation between lower-order discrete emotions and higher order affective dimensions. Inclusion of both music and film also allows for a direct comparison of these two induction techniques, which to date has only been accomplished indirectly through meta-analysis (Gerrards-Hesse et al., 1994; Westermann et al., 1996).

3. Multivariate studies

The question of autonomic specificity of emotions hinges on the presence of consistent response patterns between persons. To detect such activity, it is necessary to utilize analytic methods that are sensitive to multiple response systems (Fridlund and Izard, 1983). Univariate statistics disrupt the continuity of the physiological response patterns by parsing physiological events into separate non-representative pieces (Thayer and Friedman, 2000). Nonetheless, the one extant meta-analysis of ANS specificity research was based soley on univariate studies, presumably because that literature has historically been dominated by univariate methods (cf. Cacioppo et al., 2000). In contrast, PCA represents a multivariate approach with unique advantages for detecting psychophysiological patterns in affective contexts (Christie and Friedman, 2004; Fridlund et al., 1984; Kreibig et al., 2007; Nyklicek et al., 1997; Rainville et al., 2006).

Pattern classification analysis is ideal for this research question because it affords simultaneous consideration of multiple response variables (Fridlund and Izard, 1983; Fridlund et al., 1984). In this technique, classification functions are generated for each of several output classes (e.g., emotions). Cases are then assigned to classes based on a vector of input elements (e.g., ANS responses). This assignment involves generation of posterior probabilities for each emotion condition for each observation; subjects are then assigned to the emotion condition with the highest probability regardless of the condition of origin. The success of the classification functions, and thus the discriminability of the classes based upon respective input elements, is evaluated by testing the percentage of correct classifications against chance level using a standardized normal test statistic (Huberty, 1994). This approach represents the appropriate multivariate statistical technique to investigate the presence of distinct patterns of physiology for discrete emotional experiences.

The PCA applied in the current study is an internal classification analysis (ICA, Huberty, 1994). ICA classifies units whose data are used to determine the classification statistics. The alternative to this is an external classification analysis, in which data on the cases to be classified are not used in constructing the classification function (Huberty, 1994). Instead, these cases are classified by classification statistics obtained on another set of cases. It has been demonstrated that the total hit rate obtained from an internal classification analysis will generally be biased and overestimate the true hit rate (Frank et al., 1965; Hora and Wilcox, 1982; Huberty, 1984). In order to minimize this bias the number of predictors was kept small relative to the size of the sample. This step addresses the issue of tests of significance of difference between proportions accurately reflecting that the discriminant analysis classification rule results in a better-than-chance hit rate (Huberty, 1994; Panel on Discriminant Analysis, Classification, and Clustering, 1989).

4. Stimulus-response specificity and individual-response specificity

The concept of autonomic specificity of emotional states can be viewed in the more general context of two basic principles in psychophysiology: *stimulus-response specificity* (SRS) and *individual-response sterotypy* (IRS). Simply stated, SRS asserts that certain stimulus contexts are associated with specific patterns of physiological responding (Lacey, 1959, 1967). For example, a well-known SRS pattern is the orienting response to novelty, which consists of heart rate deceleration, delayed respiration followed by increased amplitude and decreased frequency, peripheral vasoconstriction, and increased skin conductance (Sokolov, 1963). The notion of SRS is predicated on there being an adaptive match of the response pattern to the situation; e.g., the physiological responses observed in orienting subserve attentional and behavioral responses to novel stimuli. As such, SRS patterns have presumably evolved and possess some degree of universality within and across species.

It is in this framework of adaptation that the principle of SRS can be applied to the autonomic specificity question. A functional view of affect holds that basic emotions evolved for their adaptive value in specific contexts (e.g., Ekman, 1992; Frijda, 1994; Levenson, 1994a; Plutchik, 2000). It logically follows that distinct ANS patterns would be associated with these situations (and accompanying emotions), since these patterns subserve appropriate behavioral responses to the situation. PCA presents a technique for detecting SRS ANS patterns evoked under basic emotions.

The existence of universal response patterns (SRS) does not preclude individual differences in the expression of these patterns (IRS). In fact, the construct of IRS developed prior to that of SRS: it was hypothesized that idiosyncratic stress responses contributed to "psychosomatic" disorders such as tension headaches or essential hypertension (Malmo and Shagass, 1949). It was later shown that healthy subjects also display IRS, particularly regarding the relative contribution of various response components to the overall response patterns (Lacey et al., 1953). In general, some degree of SRS and IRS influences all psychophysiological response patterns (Engel, 1960).

The current study operates from the perspective of SRS and IRS as the two main sources of variability in physiological responding, namely situation driven responses and individual differences in response style. Thus, manifest physiological responses represent the combined effect of these two sources of variability.

In the same sense that a multivariate technique like PCA is necessary to fully capture the presence of ANS response patterns during emotional states, an instantiation of SRS, we believe the illustration of IRS likewise requires an analytic tool sensitive to response profiles. Cluster analysis is one such multivariate technique. Cluster analysis is a multivariate technique that has been used to quantify IRS in cardiovascular responses to laboratory stressors (Allen et al., 1991). This use of cluster analysis is based on the premise that, even with a modest number of physiological measures, a relatively small number of hierarchical response profiles (i.e., individual response styles) are likely to exist upon which subgroups of subjects can be formed. If a subset of individuals exhibit similar response patterns, consistently distinguishing them from other individuals across conditions, then it can be said that the individuals exhibit similar patterns of IRS. A strong tendency for subjects to form distinct cardiovascular response clusters across diverse stressors was found by Allen et al. (1991), thus illustrating IRS. The particular relevance of this study is that it demonstrates the utility of a cluster analysis for identifying the degree of IRS in ANS responding across diverse situations. As such, the cluster analytic strategy of Allen et al. (1991) was modeled in the present study.

5. The present study

The primary aim of the present study was to utilize two multivariate techniques, PCA and cluster analysis, to assess SRS and IRS, respectively, in regard to autonomic specificity of emotion. A secondary aim was to include two emotion induction techniques to address the issue of whether ANS patterns are a function of the emotion elicitation context (Stemmler, 1989). It was predicted that PCA would reveal statistically significant hit rates for each induced emotion across both techniques, providing further support for autonomic discrimination of basic emotions, and directly replicating the results of Christie and Friedman (2004) and Nyklicek et al. (1997). An exploratory cluster analysis was also performed to examine the degree of IRS in response to the emotion inductions. Toward these ends, a montage of ANS responses were acquired in subjects who viewed affective film clips and listened to music excerpts selected for their emotional qualities.

6. Method

6.1. Subjects

Fifty undergraduates (27 women and 22 men, M = 19.3, SD = 1.3 years, range = 18-26 years) were recruited using an online experiment management system and received course credit for their participation. One subject was excluded from the analysis due to technical difficulties and loss of physiological and self-report data. It has been suggested that depression and/or alexithymia may distort responses to emotional stimuli (Christie and Friedman, 2004), so subjects were screened using the Beck Depression Inventory-II (BDI-II; Beck et al., 1996) and the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994a,b). Cutoffs of 19 on the BDI-II a, the upper limit for mildly depressive symptomatology (Beck et al., 1996; sample mean = 4.5, SD = 4.8; range: 0–18), and 51 on the TAS-20, the lower limit for identification of alexithymia (Bagby et al., 1994a,b; sample mean = 47.8, SD = 6.9; range: 30–50) were employed. Subjects were likewise excluded if they indicated a history of cardiovascular or neurological problems, were currently taking medication for hypertension, depression, or anxiety, or were smokers. Subjects were instructed to abstain from consuming caffeine and/or alcohol for at least 12 h prior to the study. This study received approval from the Institutional Review Board at Virginia Tech.

6.2. Apparatus

6.2.1. Music clips

Music clips that were piloted during the selection phase were used to elicit the discrete emotions: amusement, anger, contentment, fear, sadness, surprise, and a relatively neutral state (Stephens et al., 2007). The selection criteria for the musical pieces were (a) maximal response on the discrete emotion item from self-report, (b) a small standard deviation in self-reported affect, and (c) high factor loadings on the two factors labeled valence and activation. Two musical pieces for each emotion were employed during the experimental phase of the study; six of these pieces were the same as those used in Nyklicek et al., 1997 (see Appendix A for list of music stimuli). The clips varied in length ranging from 69 to 149 s, with an average length of 113 s with loudness within the music clips varying between 50 and 90 dB and 70 dB for the “white” noise clip (125 s). Music clips and “white” noise were presented through noise-canceling headphones (Sony model #: MDR-NC6)

6.2.2. Film clips

Standardized film clips were presented to elicit the discrete emotions amusement, anger, contentment, fear, sadness, surprise and a relatively neutral state (Fredrickson and Levenson, 1998; Gross and Levenson, 1995; Rottenberg et al., 2007; see Appendix A for list of film stimuli). The clips varied in length ranging from 61 to 247 s, with an average length of 145 s and were presented on a 17-in. desktop computer monitor approximately 1.5 ft from the subject. The washout audio/video piece presented before each music and film clip consisted of 65 s of repeating colored vertical “screen test” bars. This was created using the neutral noncommercial clip standardized by Gross and Levenson (1995).

6.2.3. Self-report questionnaire

A 23-item affect self-report scale was completed electronically via MediaLab questionnaire presentation software immediately following each emotion elicitation (ASR; modified from Christie and Friedman, 2004, and Nyklicek et al., 1997). Subjects were instructed to “Select the number on the scale that best describes how you felt during the music/film clip that you just listened to/viewed. If the word does not at all describe how you felt during the clip, select 1. If the word very accurately describes how you felt, select 7, for an intermediate amount, select 4, etc.” This computerized questionnaire was completed using the right-handed mouse of the stimulus presentation computer. The ASR contained items in accord with both discrete (content, amused, fearful, angry, sad, and neutral) and dimensional (good, bad, positive, negative, calm, agitated, pleasant, unpleasant, passive, active, relaxed, excited, and indifferent) models of affect, and so it matches well with a hybrid model of affective space. The final three questions on each ASR were regarding level of intensity and enjoyment as rated on a 7-point Likert scale and familiarity rated either ‘yes’ or ‘no’.

6.2.4. Physiological recording equipment

Physiological signals were acquired using pre-gelled electrodes (Surtrace; ConMed Co., Utica, NY) and attachment sites were prepared using 70% isopropyl alcohol. Electrocardiogram (ECG) was recorded using a BIOPAC amplifier (ECG100C; BIOPAC Systems Inc., Goleta, CA) with thoracic electrodes placed in a Lead II configuration. Impedance cardiogram (ICG) was recorded using the Minnesota Impedance Cardiograph (Instrumentation for Medicine, Minneapolis, MN) with a four spot electrode array as per Sherwood et al. (1990). Skin conductance level (SCL) was recorded using an isolated SC coupler (V71-23; Coulbourn Instruments, Allentown, PA) with electrodes placed on the thenar and hypothenar eminences of the left palm (Dawson et al., 2007). Respiratory signals were recorded from thoracic and abdominal sites using two aneroid chest bellows connected to resistive bridge strain gage couplers (V94-19 and V71-23; Coulbourn Instruments, Allentown, PA). All signals were digitized at 1000 Hz using a Biopac MP100 Data Acquisition System (12-bit resolution). An IBS SD-700A automated BP monitor (Industrial and Biomedical Sensors Corp., Waltham, MA) was used to measure systolic (SBP) and diastolic blood pressures (DBP) approximately halfway into each epoch via an automated auscultatory method at the upper left arm (level with the subject's heart). Subjects were instructed to limit the movement of their left arm during the experiment to minimize movement artifact in SCL and BP measures.

6.2.5. Quantification of physiological data

ECG, ICG, and respiration data were processed using the Vrije Universiteit-Ambulatory Monitoring System software suite (VU-AMS, Vrije Universiteit, Department of Psychophysiology, Amsterdam, The Netherlands) and heart rate variability (HRV) was processed using HRV Analysis Software v1.1 (The Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland). SCL data were analyzed using the BIOPAC AcqKnowledge software (BIOPAC Systems Inc, Goleta, CA) (BIOPAC Systems Inc, 2005).

Artifact detection was performed by software-assisted visual inspection of physiological signals, corrections were made using BIOPAC AcqKnowledge software when necessary. For heart rate variability analysis, an R-wave detection function converted the ECG to a time series of inter-beat-intervals (IBIs) using detection of the R-waves in the ECG. A graphical display of the IBI time series by the HRV Analysis Software permitted detection of possible ectopic beats or other deviations from physiologically plausible values. All beats deviating more than 30% from the previous or subsequent beat were considered suspect and ECG was examined (deGeus et al., 1995). Excessively short/long beats were corrected by removing movement artifact from the ECG.

Impedance cardiogram for each subject was analyzed using the AMSIMP program, a component of the VU-AMS software package. This software was used to view and analyze ICG recorded with BIOPAC hardware/software. The program contains an automatic scoring algorithm for detecting the upstroke (B-point), dZ/dt_{min}, and incisura (X-point) in each ICG complex. The B-point or upstroke was defined as a first or second order zero-crossing in the dZ/dt signal, close to the dZ/dt isoelectric line, and the starting point of the longest uphill slope before the dZ/dt_{min} point. The dZ/dt_{min} was defined as the highest point of the ICG complex (*y*-axis inverted) between the B- and the X-point. The X-point or incisura was defined as a local minimum after the dZ/dt_{min}; this is often but not necessarily, the lowest point in the entire signal. Due to the nature of the ICG signal quality, the automatic scoring algorithm was used to provide preliminary values. When artifact was present the automatic scoring algorithm provided a guideline for choosing the components of interest manually via the software interface.

Every effort was made to ensure that ICG recording, and scoring was performed in accordance with the standards in the literature (Sherwood et al., 1990; Turner, 2000). The cardiac pre-ejection period (PEP) was defined as the time in milliseconds (ms) between ECG Q-wave onset and B-point in the ICG. Left ventricular ejection time (LVET) was defined as the time in ms between B- and X-points in the ICG. It should be noted that the reliability of stroke volume (SV) and cardiac output (CO) computed from impedance cardiography remains a debated issue (cf. Sherwood et al., 1990; Turner, 2000). Steps were taken to limit the error attributed to parameters that influence the calculation of SV using the Kubicek formula (Kubicek et al., 1966). A constant of 135 Ω*cm was used for specific blood resistance (rho_b), and the distance between the measuring ICG electrodes was recorded for each subject and input into the analysis software. As mentioned previously all efforts to correctly score dZ/dt_{min} amplitude and measured-LVET were made. One limitation to be noted was the use of spot electrodes which pick up only half of the impedance measured by band electrodes, thus the SVs (and COs) were monitored for supraphysiological values.

Respiratory signal for each subject was analyzed using the AMSRES program, a component of the VU-AMS software package. This software was used to view and analyze data recorded with BIOPAC hardware/software: ECG, and thoracic respiration strain-gauge recording. The AMSRES program computed respiration rate (RR), inspiration time (TI), and expiration time (TE) via an automatic scoring algorithm for detecting the beginning and end of inspiration and expiration. The AMSRES program used the R-wave to R-wave intervals time series of the ECG, to extract two IBIs per breath: the shortest IBI and the longest IBI. The former during a prolonged inspiration interval, starting at the beginning of inspiration and ending 1000 ms after the end of inspiration and the latter during a prolonged expiration interval, starting at the begin of expiration and ending 1000 ms after the end of expiration.

Respiratory Sinus Arrhythmia (RSA) or heart period variability associated with respiration was derived according to the peak-trough method (Grossman et al., 1990). RSA was calculated by the subtraction of the shortest from longest IBI, provided that the shortest IBI (highest HR) was part of an accelerating series and the longest IBI (lowest HR) was part of a decelerating series. If either the longest or shortest IBI was missing for a breath cycle, or a negative value was obtained on subtraction, the RSA value was disregarded (denoted as NA) from further analyses.

From the ECG, ICG, BP, respiration, and SCL tracings mean values were taken of the last 60-s periods of each condition (washout and stimulus) for each of the following autonomic variables: IBI, mean heart rate (mHR), peak-trough respiratory sinus arrhythmia (RSA), square root of the mean squared successive differences in heart period (rMSSD), cardiac pre-ejection period (PEP), LVET, SV, CO, SBP, DBP, mean arterial pressure (MAP), total peripheral resistance (TPR), RR, TI, TE, and SCL.

Due to differential lengths of music clips and film clips, change scores were calculated by subtracting the mean scores from the last 60 s of the preceding washout period from the mean scores of the last 60 s of the music/film stimulus for each autonomic variable (emotion induction minus baseline). Absolute values of SV, CO, and TPR are unreliable for inter-subject comparisons (Smith and Kampine, 1990). Therefore, responses for these variables were defined as percent-change scores between stimulus condition and the preceding washout condition. The following variables were used for the PCA: IBI (ms), RSA (ms), PEP (ms), LVET (ms), SV (%Δ), CO (%Δ), SBP (mmHg), DBP (mmHg), MAP (mmHg), TPR (%Δ), RR (bpm), TI (ms), TE (ms), and SCL (μS). A smaller subset of variables was used for the exploratory cluster analysis in line with previous research (Allen et al., 1991): mHR (bpm), rMSSD (ms), PEP (ms), SV (%Δ), SBP (mmHg), DBP (mmHg), MAP (mmHg), and TPR (%Δ).

6.2.6. Procedure

All experimental sessions were conducted in a sound attenuated room with subjects seated in a comfortable chair and the experimenter in a separate room observing via a two-way mirror. Experimenter-subject communication was possible via an audio intercom. Stimuli were presented in one of two sequences with music pieces and film clips alternating in a partially counterbalanced fashion. Consistent with Christie and Friedman (2004), negatively valenced film clips alternated with positively or neutrally valenced film clips. The two sequences of presentation were the reverse of each other. Each emotion was evenly distributed throughout the entire experiment and the same emotion induction was not experienced two times in a row.

Subjects were instructed to pay close attention to how they felt as they watched the film clips and listened to the music pieces, and were told that following each clip they would be asked to describe how they felt. After a 10-min laboratory adaptation period, a 1-min baseline recording, during which subjects were presented with the 1-min and 5-s washout clip, confirmed proper equipment functioning and subjects completed a baseline ASR followed by the first clip. After each music/film stimulus, subjects completed the ASR scale to assess affective response during the presentation. Upon completion of the scale, subjects were presented with the same 1-min and 5-s washout clip, during which they were instructed to sit quietly and clear their mind of all thoughts, feelings, and memories. The next stimulus presentation then commenced. This procedure was repeated for the remaining stimuli conditions in a manner closely approximating that of both Nyklicek et al. (1997) and Christie and Friedman (2004).

7. Results

7.1. Univariate analysis of discrete ASR variables—manipulation check

Paired *t*-tests were used to explore the effectiveness of the affect manipulations with respect to the discrete ASR items. For the amusement, contentment, fear, sadness, and surprise emotion conditions, ratings on discrete item for the respective conditions were significantly greater than all other discrete items (all $ps < .05$). Means and standard deviations for all discrete ASR variables can be found in Table 1. No statistically significant differences were found for responses on the discrete or dimensional ASR items with regard to the subject gender or the presentation sequence of the emotion inductions.

7.2. Comparison of music and film induction techniques

The most informative means to compare across music and film emotion inductions techniques is via hit rates from pattern classification analysis. An initial component of this study was to monitor both self-report and autonomic responses to music and film within the same sample to allow for the best possible conditions for comparisons.

Pattern classification using ANS variables revealed that overall 37.6% of observations were correctly classified into the predicted emotion conditions during music stimuli, whereas 40.2% of observations were correctly classified during film induction. As depicted in the diagonals of Table 2, classification hit rates for individual emotion conditions ranged from 22.4% to 59.2%. The overall classification hit rate, indicating overall classification success, was significantly greater than chance for both music induction ($z = 12.34$, $p < .0.001$) and film induction ($z = 13.73$, $p < .001$). The 95% confidence interval for the probability of correct classification for music and film induction is 0.325 to 0.427 and 0.350 to 0.454 respectively.

Pattern classification using ASR variables revealed that overall 55.1% of observations were correctly classified into the predicted emotion conditions during music stimuli, whereas 59.5% of observations were correctly classified during film induction. As depicted in the diagonals of Table 3, classification hit rates for individual emotion conditions ranged from 26.5% to 89.8%. The overall classification hit rate, indicating overall classification success, was significantly greater than chance for both music induction ($z = 21.60$, $p < .001$) and film induction ($z = 23.92$, $p < .001$). The 95% confidence interval for the probability of correct classification for music and film induction is 0.498–0.604 and 0.542–0.647 respectively.

7.3. Pattern classification using variables from aggregated music and film inductions

Overall, 44.6% of observations were correctly classified into the predicted emotion conditions. Hit rates for individual emotion conditions ranged from 32.7% for sadness to 63.3% for surprise. The overall classification hit rate occurred at significantly greater than chance levels ($z = 16.05$, $p < .001$). Individual emotion conditions were successfully classified at significantly greater than chance levels: amusement ($z = 6.94$, $p = .001$), anger ($z = 4.49$, $p < .001$), contentment ($z = 6.94$, $p < .001$), fear ($z = 4.90$, $p < .001$), neutral ($z = 5.72$, $p < .001$), sadness ($z = 3.67$, $p < .001$), and surprise ($z = 9.80$, $p < .001$). Distinct patterning of physiology can be seen across emotion conditions (Fig. 1).

The overall ASR classification hit rate was 60.6% with individual emotion condition hit rates ranging from 36.7% for fear to 71.4% for amusement. All hit rates, both overall classification ($z = 23.31$, $p < .001$) and each of the emotion conditions were significantly

Table 1
Mean (SD) of ASR variables by emotion condition across emotion induction techniques.

		Emotion condition						
		am	an	co	fe	ne	sa	su
Dimensional variables	ac	3.43 (2.02)	2.69 (2.09)	2.13 (1.6)	2.54 (1.81)	1.79 (1.28)	1.81 (1.35)	2.38 (1.76)
	ag	1.59 (1.3)	3.5 (2.15)	1.56 (1.15)	2.69 (1.91)	3.22 (2.23)	2.19 (1.62)	2.32 (1.67)
	ba	1.16 (0.6)	3.41 (1.87)	1.36 (0.74)	2.82 (1.9)	1.5 (1.05)	2.88 (1.62)	2.00 (1.54)
	ca	3.72 (1.62)	2.09 (1.37)	4.68 (1.64)	1.99 (1.36)	3.98 (2.06)	3.23 (1.72)	2.49 (1.61)
	ex	3.83 (2.04)	2.56 (2.01)	2.23 (1.66)	2.66 (2.02)	1.52 (1.12)	1.93 (1.39)	2.54 (1.94)
	go	5.01 (1.45)	1.93 (1.2)	4.19 (1.66)	1.78 (1.21)	2.38 (1.55)	2.38 (1.36)	2.11 (1.37)
	ne	1.31 (0.91)	3.27 (1.88)	1.55 (1.09)	2.8 (1.86)	2.23 (1.6)	2.73 (1.63)	2.27 (1.56)
	pa	2.33 (1.54)	2.22 (1.51)	2.72 (1.96)	2.72 (1.74)	2.4 (1.76)	2.68 (1.77)	2.41 (1.68)
	pl	4.16 (1.93)	2.05 (1.57)	4.11 (1.8)	2.12 (1.72)	2.16 (1.52)	2.14 (1.45)	1.97 (1.36)
	po	4.27 (1.88)	1.99 (1.53)	3.77 (2.05)	1.98 (1.53)	1.99 (1.44)	1.93 (1.37)	1.95 (1.28)
	re	1.45 (1.07)	3.54 (2.04)	1.73 (1.39)	3.26 (2.05)	2.8 (2.07)	2.96 (1.76)	2.63 (1.79)
	un	1.45 (1.07)	3.54 (2.04)	1.73 (1.39)	3.26 (2.05)	2.8 (2.07)	2.96 (1.76)	2.63 (1.79)
Discrete variables	am	4.59 (2.25)	1.15 (0.56)	3.99 (1.78)	1.33 (0.84)	2.41 (1.75)	1.05 (0.25)	2.45 (1.79)
	an	2.43 (1.97)	3.12 (1.9)	2.26 (1.52)	2.67 (1.62)	2.26 (1.66)	3.15 (1.4)	2.84 (1.85)
	co	2.29 (1.67)	1.31 (0.67)	4.61 (1.9)	1.5 (1.05)	3.34 (1.96)	1.63 (1.08)	1.95 (1.31)
	fe	2.16 (1.64)	1.67 (1.11)	2.49 (1.86)	3.59 (2.02)	2.42 (1.73)	1.73 (1.2)	2.68 (1.8)
	ne	1.88 (1.29)	1.83 (1.37)	2.31 (1.58)	2.07 (1.9)	3.52 (2.24)	1.07 (0.24)	1.86 (1.54)
	sa	2.02 (1.49)	1.68 (1.22)	2.53 (1.62)	2.09 (1.51)	2.56 (1.73)	4.26 (1.63)	1.87 (1.37)
	su	2.1 (1.54)	1.51 (1.14)	2.33 (1.46)	3.01 (1.77)	2.77 (1.83)	1.41 (0.88)	4.29 (2.24)

Abbreviations: active = ac, agitated = ag, bad = ba, calm = ca, excited = ex, good = go, negative = neg, passive = pa, pleasant = pl, positive = po, relaxed = re, unpleasant = un, amusement = am, anger = an, contentment = co, fear = fe, neutral = ne, sadness = sa, surprise = su.

Table 2
Pattern classification matrix using ANS variables during music (top) and film (bottom) inductions (refer to Table 1 for abbreviations).

			Predicted emotion condition						
			am	an	co	fe	ne	sa	su
Actual emotion condition	Music induction	am	**16 (32.7)****	5 (10.2)	8 (16.3)	4 (8.2)	2 (4.1)	5 (10.2)	9 (18.4)
		an	4 (8.2)	**24 (49)****	5 (10.2)	3 (6.1)	1 (2)	8 (16.3)	4 (8.2)
		co	8 (16.3)	1 (2)	**18 (36.7)****	7 (14.3)	0 (0)	8 (16.3)	7 (14.3)
		fe	4 (8.2)	2 (4.1)	6 (12.2)	**16 (32.7)****	10 (20.4)	4 (8.2)	7 (14.3)
		ne	6 (12.2)	3 (6.1)	2 (4.1)	5 (10.2)	**22 (44.9)****	5 (10.2)	6 (12.2)
		sa	6 (12.2)	6 (12.2)	8 (16.3)	5 (10.2)	0 (0)	**17 (34.7)****	7 (14.3)
		su	9 (18.4)	6 (12.2)	5 (10.2)	4 (8.2)	5 (10.2)	4 (8.2)	**16 (32.7)****
	Film induction	am	**23 (46.9)****	5 (10.2)	1 (2)	4 (8.2)	4 (8.2)	7 (14.3)	5 (10.2)
		an	8 (16.3)	**14 (28.6)****	3 (6.1)	7 (14.3)	6 (12.2)	8 (16.3)	3 (6.10)
		co	6 (12.2)	0 (0)	**25 (51)****	6 (12.2)	3 (6.1)	1 (2)	8 (16.3)
		fe	8 (16.3)	4 (8.2)	5 (10.2)	**11 (22.4)**	9 (18.4)	4 (8.2)	8 (16.3)
		ne	9 (18.4)	5 (10.2)	0 (0)	4 (8.2)	**19 (38.8)****	2 (4.1)	10 (20.4)
		sa	8 (16.3)	3 (6.1)	4 (8.2)	6 (12.2)	5 (10.2)	**17 (34.7)****	6 (12.2)
		su	3 (6.1)	2 (4.1)	6 (12.2)	3 (6.1)	2 (4.1)	4 (8.2)	**29 (59.2)****

** $p < .01$.

greater than chance (amusement: $z = 11.43$, $p < .001$; anger: $z = 8.98$, $p < .001$; contentment: $z = 13.06$, $p < .001$; fear: $z = 4.49$, $p < .001$; neutral: $z = 6.09$, $p < .001$; sadness: $z = 9.39$, $p < .001$; and surprise: $z = 7.76$, $p < .001$).

7.4. Cluster Analysis of ANS variables

Previous research of this sort (e.g., Allen et al., 1991) has employed hierarchical clustering using a squared Euclidean definition of distance with Ward's linking method for forming clusters. Allen et al. specified *a priori* clusters based on an understanding of underlying physiological mechanisms represented by the derived autonomic variables. The clustering process begins with the same number of clusters as there are cases then a step wise method procedure combines a given case or cluster with another at each step to form one less cluster than the previous step. The objective of Ward's method is to find, at each stage, those two clusters whose merger gives the minimum increase in the total within group sum of squares (Ward, 1963). This approach mirrors an ANOVA and is preferred by many researchers for this reason.

A point is reached where clusters that are not similar are combined by this method. When this occurs there is a rapid increase in the within-group sum of squares, as reported in the agglomeration schedule and graphically depicted in a dendrogram. The rapid increase in within-group error accompanying the combination of dissimilar groups determines the appropriate number of clusters, that is, the number of clusters present just prior to the increase in within group error is considered the "natural" grouping scheme (Hair et al., 1995). Thus, if the natural number of clusters across the emotion conditions is greater than the number demonstrated by Allen et al. (1991), then the groups are not based on the underlying adrenergic mechanisms previously described. The existence of fewer clusters than demonstrated or a single cluster would indicate that the stimulus response stereotypy is more powerful than the individual differences, which exist in the experience of emotions.

The agglomeration schedule and the dendrograms from the cluster analysis for each emotion condition using the same autonomic variables used in previous research (Allen et al., 1991) reveal no dramatic change in the within group sum of squares. The overall outcome of the cluster analysis indicate the existence of one major cluster, into which the majority of subjects naturally fit with regard to physiological response patterns representing sympathetic and parasympathetic activity during experiences of emotion. The results of hierarchical clustering on each of the emotion conditions are presented in Table 4.

As can be seen across all of the emotion conditions the majority of cases exist within a single cluster with one or two cases forming the three other clusters. Based on the hierarchical clustering, the natural formation is one large cluster. These results do not conform to those of previous research from cardiovascular stress literature (Allen et al., 1991) but in the greater context of psychophysiological studies of emotion these results, which emphasize the commonality of cases and reveals a lack of heterogeneous response, fits well with the concept of autonomic specificity of emotion. The Statistical Package for Social Sciences (SPSS) XVII was used for all statistical analyses reported.

Table 3
Pattern classification matrix using ASR variables during music (top) and film (bottom) inductions (refer to Table 1 for abbreviations).

			Predicted emotion condition						
			am	an	co	fe	ne	sa	su
Actual emotion condition	Music induction	am	**35 (71.4)****	0 (0)	9 (18.4)	2 (4.1)	0 (0)	3 (6.1)	0 (0)
		an	2 (4.1)	**13 (26.5)****	3 (6.1)	9 (18.4)	0 (0)	11 (22.4)	11 (22.4)
		co	4 (8.2)	1 (2)	**35 (71.4)****	0 (0)	0 (0)	5 (10.2)	4 (8.2)
		fe	0 (0)	11 (22.4)	2 (4.1)	**22 (44.9)****	2 (4.1)	5 (10.2)	7 (14.3)
		ne	0 (0)	0 (0)	0 (0)	1 (2)	**44 (89.8)****	1 (2)	3 (6.1)
		sa	2 (4.1)	4 (8.2)	9 (18.4)	2 (4.1)	3 (6.1)	**20 (40.8)****	9 (18.4)
		su	2 (4.1)	3 (6.1)	4 (8.2)	12 (24.5)	0 (0)	8 (16.3)	**20 (40.8)****
	Film induction	am	**41 (83.7)****	0 (0)	4 (8.2)	0 (0)	0 (0)	0 (0)	4 (8.2)
		an	1 (2)	**32 (65.3)****	1 (2)	7 (14.3)	1 (2)	5 (10.2)	2 (4.10)
		co	3 (6.1)	1 (2)	**30 (61.2)****	1 (2)	10 (20.4)	0 (0)	4 (8.2)
		fe	4 (8.2)	9 (18.4)	4 (8.2)	**16 (32.7)****	1 (2)	5 (10.2)	10 (20.4)
		ne	6 (12.2)	2 (4.1)	10 (20.4)	2 (4.1)	**24 (49)****	0 (0)	5 (10.2)
		sa	0 (0)	4 (8.2)	1 (2)	6 (12.2)	2 (4.1)	**33 (67.3)****	3 (6.1)
		su	2 (4.1)	2 (4.1)	2 (4.1)	4 (8.2)	7 (14.3)	4 (8.2)	**28 (57.1)****

** $p < .01$.

Table 4
Number (percent) of subjects cluster groupings resulting from cluster analysis of physiological change scores by emotion conditions (refer to Table 1 for abbreviations).

		Cluster number			
		1	2	3	4
Emotion condition	am	45 (91.8)	2 (4.1)	1 (2)	1 (2)
	an	1 (2)	46 (93.9)	1 (2)	1 (2)
	co	46 (93.9)	1 (2)	1 (2)	1 (2)
	fe	44 (89.8)	1 (2)	1 (2)	3 (6.1)
	ne	46 (93.9)	1 (2)	1 (2)	1 (2)
	sa	1 (2)	46 (93.9)	1 (2)	1 (2)
	su	45 (91.8)	1 (2)	2 (4.1)	1 (2)

8. Discussion

As demonstrated by previous research (Christie and Friedman, 2004; Gross and Levenson, 1995; Kreibig et al., 2007; Nyklicek et al., 1997; Rottenberg et al., 2007) standardized emotion eliciting music clips and film clips must be verified via some other means (i.e., self-report of emotional experience) in order to determine that the emotion each clip elicited matches the expected emotion. The use of the ASR provided a means to verify if the subject was experiencing the emotion that the stimulus was intended to elicit. Paired *t*-tests were used to explore the effectiveness of the affect manipulations with respect to the discrete ASR items. For the amusement, contentment, fear, sadness, and surprise emotion conditions, ratings on discrete item for the respective conditions were significantly greater than all other discrete items (all $ps < .05$).

8.1. Implications of results comparing music and film induction

Based upon a comparison of the percentage of correct classification from PCA of ANS and ASR variables during music induction alone or film induction alone there are small differences between the inductions. There is no statistical test available to examine the difference between the hit rates for the two induction methods since the samples are non-independent, a limitation of this study. The overlap reported in the confidence intervals limits making any casual inference regarding the differing effect of these two emotion inductions. Future investigations of music and film emotion induction should consider investigating specific components of each stimulus to allow for parsing of common and contrasting features. While these differences should not be overstated, it does give reason to pause and consider the effect different emotion induction techniques may have in producing specific emotional states.

The differences that exist between these induction techniques calls for investigation aimed at distinguishing these techniques based on the seven dimensions noted in the literature (Rottenberg et al., 2007). Both techniques have been previously used to induce emotion and match the goals and questions of the study at hand. As these dimensions are so salient to the selection and use of these procedures it is proposed that distinctions should map on to one or more of the dimensions. This would allow for more precise emotion elicitation, which could be of great importance in a context where emotion is an independent variable.

8.2. Implications of results from pattern classification analysis

The present study represents yet another independent replication of PCA of ANS responses in support of the concept of autonomic specificity of basic emotions (cf. Kreibig et al., 2007). The robustness of this finding is attested to not only by its consistency with prior studies, but also by its present replication across two different emotion induction modalities. Furthermore, however effective these inductions may be, they are undoubtedly less potent than the "real life" situations in which basic emotions are experienced (e.g., James' (1884) proverbial encounter with a bear in the woods). As such, the classification accuracies of ANS variables obtained in lab studies such as this likely underestimate those that would be obtained in the field.

The present results further demonstrate the unique sensitivity of multivariate techniques such as PCA for capturing the gestalt of diverse ANS responses in emotion. These findings, along with those from other similar PCA studies, highlight the limitations of a univariate approach to the study of ANS specificity in emotion. The weak effect sizes for somatovisceral activity in regard to emotion experience that were reported in a meta-analysis may be a function of the exclusive reliance on univariate studies (cf. Cacioppo et al., 2000). Multivariate techniques are inherently receptive to coordinated ANS activity across multiple organ systems, and so are compatible with a functional view of emotion (Ekman, 1992; Frijda, 1994; Levenson, 1994a; Plutchik, 2000).

The results of this and other PCA studies place the construct of ANS specificity for emotion squarely in the larger psychophysiological framework of SRS. With each subsequent replication, it becomes abundantly clear that laboratory inductions of basic emotions are reliably discriminable by their autonomic patterns. This evidence suggests that the ANS response patterns for basic emotions (e.g., fear, anger, sadness, joy) should be viewed in the same light as other well documented patterns such as the orienting, startle, and defensive responses (Graham, 1979). Research in this area should move beyond the question of *if* basic emotions have distinct ANS patterns to exploring the nature of these patterns, which are likely to have both similarities and differences across basic emotions (Cacioppo et al., 1993; Levenson, 1994b).

Empirical demonstration of emotion-specific ANS patterns supports the existence of basic emotion prototypes (Ekman, 1994). James' (1884) assertion that "coarser" emotions have distinct bodily expression is consistent with contemporary theoretical models of basic emotions and its foundational research base. PCA studies of affect, the present study included, indicate that basic emotions can be discriminated by physiological patterns; thus, physiology is the underlying connection supporting the idea that emotions are "natural kinds".

Natural kinds refer to a class of natural phenomena that share observable features and are similar in a significant way (Izard, 2007). Many contemporary theorists hold that basic emotions exist as natural kinds (e.g., Ekman et al., 2003; Izard, 2007; Panksepp, 2007). This view has been challenged as inconsistent with the preponderance of evidence (Barrett, 2006, Barrett et al., 2007), but this contention in turn has been questioned as a misrepresentation of the evidence (Panksepp, 2008). Although the range of this debate is beyond the scope of this paper, abundant reports of reliable discrimination of emotions using autonomic variables from this and other studies of the same type clearly support the concept of emotions as natural kinds (cf. Kreibig et al., 2007).

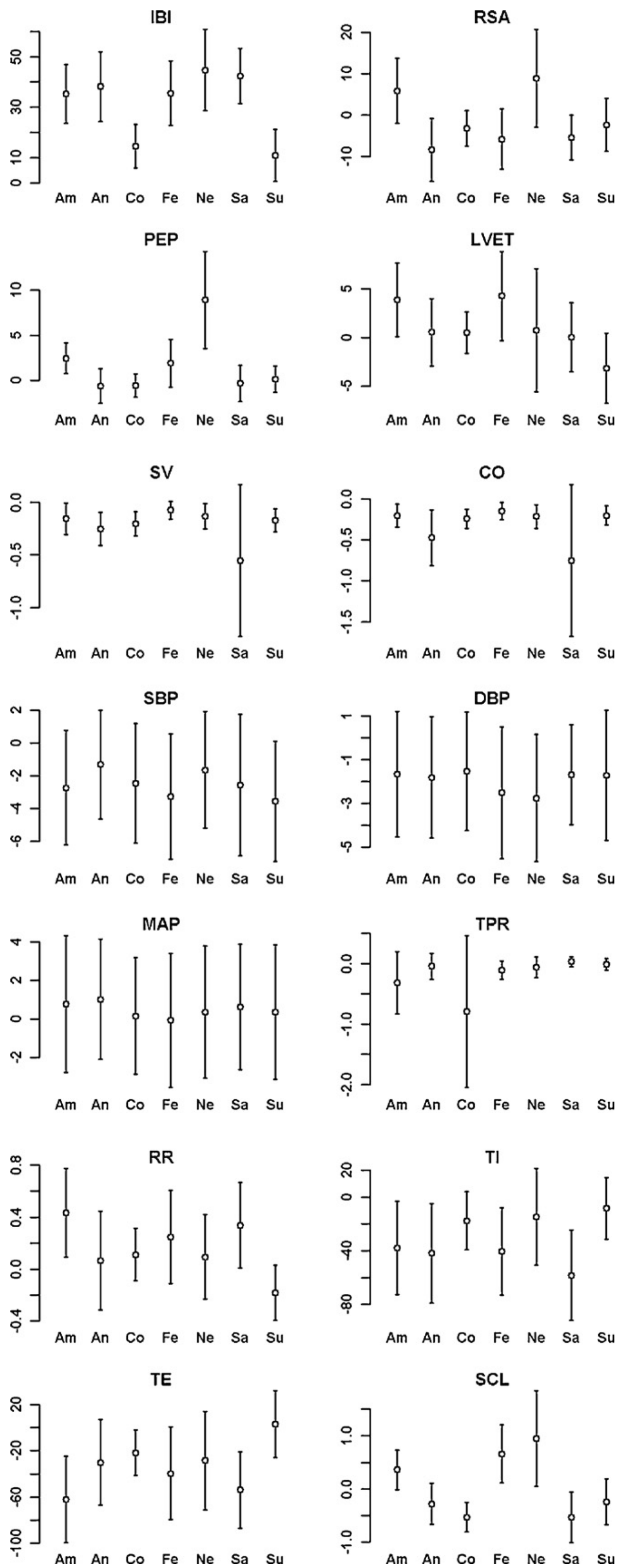

Fig. 1. Mean change scores and 95% confidence intervals by emotion condition for physiological variables used in the study. Scores are based on aggregation across music and film conditions. Units are identified in text (refer to Table 1 for abbreviations).

8.3. Implications of results from cluster analyses

Based on previous research and the principle of IRS, it was hypothesized that emotion elicitation over a wide range of emotions should allow for clustering of individuals based on their IR-specific emotion responses. However, the cluster analysis indicates that basic emotions entail a predominant response pattern that trumps individual variability. Buttressed by previous findings from the stress literature (Allen et al., 1991) and fundamental principles of psychophysiology (Lacey et al., 1953), it was initially proposed that cluster analysis would reveal distinct groups of individuals with similar IRS patterns embedded within the larger SRS patterns. On the contrary, the results yielded no evidence for distinct response clusters, which essentially provides further support for the notion of SRS in autonomic patterns of emotion.

Minimally, IRS does not appear to operate in emotion inductions to the same degree that it does across cardiovascular stressors (cf. Allen et al., 1991).

Distinct clusters of individuals were found in the latter study based on individual response tendencies that were characterized as extreme beta-adrenergic, extreme alpha-adrenergic, or relatively nonreactive. It may be that IRS is more manifest in response to stressors, which may share more in common than diverse affective states. Additionally, the screening of individuals for depression and alexythymia in the present study may have diminished the likelihood of obtaining a non-reactive cluster.

8.4. Limitations and future directions

There are a variety of factors that limit the interpretation and generalization of the findings of this study. One such factor was the limited age range of the participants; it is not known to what degree these results would be replicated in younger or older samples. However, the student sample in our study was similar in age to that of other PCA emotion studies (Christie and Friedman, 2004; Kreibig et al., 2007; Nyklicek et al., 1997). Another limitation is that the musical and cinemagraphic emotion stimulus materials differed in their physical (i.e., auditory and visual) characteristics such as pitch and brightness, which could not be controlled. Yet these features presumably contribute to the affective qualities of the stimuli in ways that are not easily assessed. Hence, attempts to equate stimuli on such variables might be at odds with the goal of using stimuli that evoke distinct emotional states. Furthermore, the authors relied on previous validation by Gross and Levenson (1995) in regard to film stimuli and performed validation of music stimuli based on requirements noted in previous work with music induction (Etzel et al., 2006; Nyklicek et al., 1997).

It should also be noted that the analyses were limited to brief epochs of induced emotional experience, in line with previous work upon which this study is based (Christie and Friedman, 2004; Nyklicek et al., 1997). Other possibilities regarding sampling epochs analyzed were considered, since ours is not the only possible approach (see Kreibig et al., 2007). It was ultimately determined that longer clips could result in larger change scores for some ANS variables, rendering comparisons to Christie and Friedman (2004) and Nyklicek et al. (1997) problematic. Another concern was that subjects might not have experienced strong emotions from the beginning of the stimulus or maintained those feelings at a constant level to the end, as noted by Kreibig et al. (2007). Mauss et al. (2005) have demonstrated a novel method for accounting for the fluctuations of emotion experience. Future ANS specificity research, which captures the necessary components of this method, could address this temporal dilemma in emotion induction research.

Several other analytic strategies may be worth exploring in future PCA studies. For example, it may be possible to specify which combination of ANS indices contributes most to characterizing different emotional states; it is likely that these indices vary by specific emotions. It also may be possible to classify emotional states induced with one method using functions derived from the other (i.e., cross-validate one PCA solution on the other). Such variations may further elucidate method- and variable-specific relationships among discrete emotions.

The cluster analytic strategy employed in this study, modeled after Allen et al. (1991), is but one among many approaches to address the IRS aspect of emotion-ANS specificity. For example, a review by Marwitz and Stemmler (1998) suggested examining IRS with regard to constitutional, situational, and psychological influences, affording further specification of IRS. This approach also entails multiple testing occasions, which allows for assessment of within-subject consistency in IRS. Others have identified a motivation-specific component of responding that also may be important to consider (Foerster et al., 1983). Moreover, the use of multiple observations is consistent with idiographic perspectives on responding, and may be an optimal way to study IRS. In sum, the single-occasion design of the present study may have limited its ability to detect IRS; future studies in this area may consider the potential of idiographic (e.g., Fahrenberg, 1986) and longitudinal designs in this regard (e.g., Foerster, 1985). Hence, IRS of autonomic responses to affective stimuli may indeed be revealed by these various approaches; cluster analysis may not be the optimal strategy.

Respiration was not directly controlled in this study, so the potential influence of respiratory between-condition differences on effects of RSA cannot be ruled out. However, there exists considerably controversy over this issue in the field (e.g., Grossman and Taylor, 2007; Ritz, 2009; cf. Allen et al., 2007; Denver et al., 2007). It should be noted that no talking or significant motor demands occurred during the tasks that might have substantially altered respiratory parameters across baselines and induction conditions; subjects remained seated throughout the experiment and were instructed to sit quietly. Another important consideration is that respiration was not directly controlled in the studies we were replicating (Christie and Friedman, 2004; Nyklicek et al., 1997). In sum, it seems unlikely that the current PCA results, which were replicated across multiple studies, could be explained by respiration confounds.

9. Summary and conclusion

The PCA findings of this study replicate and extend previous findings of this kind, which support the concept of autonomic-specific basic emotions. Furthermore, the results from cluster analysis strengthen the case for emotions as natural kinds by indicating that individuals do not display wide variations in response patterns to basic emotions. The fact that these results emerged across two distinct emotion induction techniques further attests to the generalizability of the findings, and indicate that the phenomenon of ANS specificity is not a function of the type of affective manipulation. In sum, the case for ANS specificity for basic emotions becomes increasingly compelling when examined under the sensitive lens of multivariate analyses.

The major goal of this paper was replication of ANS specificity of emotion induced by music and film stimuli. This goal was accomplished and the physiological evidence adds support to the discrete somatic bodily response pattern corollary of James–Lange theory of emotion (see Friedman, this issue). The specific patterns of basic emotions were identified but were not compared against previous findings. The necessity to establish strict methodologies for inducing emotions and defining specific physiological variables of interest remain a challenge for future research. Until this is accomplished, comparison of physiological patterns of emotion for the purposes of *a priori* identification of emotion (e.g. external classification analysis) will be an elusive goal.

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Appendix A. Music and film inductions

Induction Technique:	Induced Emotion:	Stimulus Label	Length (sec):	Stimulus Reference	Previous use
Music:	Amusement	Bizet: Carmen (Les Toréadors)	69	Bizet (1872)	Nyklicek et al. (1997)
		Codolban: E. Nikitka (Traditional Romanian folksong)	128	Codolban (n.d.)	Nyklicek et al. (1997)
	Anger	Mansell: Requiem for a Dream (Southern Hospitality)	83	Mansell (2000)	NA
		Penderecki: Threnody for the Victims of Hiroshima	129	Penderecki (1961)	Rickard (2004)
	Contentment	Bizet: Carmen (Intermezzo)	100	Bizet (1872)	Nyklicek et al. (1997)
		Dvorak: 9th Symphony (Largo)	109	Dvorak (1893)	Nyklicek et al. (1997)
	Fear	Penderecki: Threnody for the Victims of Hiroshima	69	Penderecki (1961)	Rickard (2004)
		Zimmer: Crimson Tide Score (Alabama)	130	Zimmer (1995)	Etzel et al. (2006)
	Neutral	"White" Noise	125	NA	Nyklicek et al. (1997)
	Sadness	Chopin: Marche funèbre	100	Chopin (1837)	Nyklicek et al. (1997)
		Mansell: Requiem for a Dream (Marion Barfs)	142	Mansell (2000)	NA
	Surprise	Ligeti: Eyes Wide Shut (Musica ricercata II)	74	Ligeti (1953)	NA
		Bartok: Concerto for two pianos, percussion and orchestra	136	Bartok (1937)	NA
Film:	Amusement	Robin Williams Live	205	Morra et al. (1986)	Gross and Levenson (1995)
		When Harry Met Sally	156	Reiner et al. (1989)	Gross and Levenson (1995)
	Anger	Cry Freedom	154	Spencer et al. (1987)	Gross and Levenson (1995)
		My Bodyguard	247	Devlin and Bill (1980)	Gross and Levenson (1995)
	Contentment	Beach scene with seagulls and waves	82	Gross and Levenson (1995)	Gross and Levenson (1995)
		Waves crashing on beach	134	Gross and Levenson (1995)	Fredrickson and Levenson (1998)
	Fear	Silence of the Lambs	216	Saxon et al. (1991)	Gross and Levenson (1995)
		The Shining	84	Kubrick (1980)	Gross and Levenson (1995)
	Neutral	Screensaver "Sticks"	92	Gross and Levenson (1995)	Gross and Levenson (1995)
	Sadness	The Champ	171	Lovell and Zeffirelli (1979)	Gross and Levenson (1995)
		Return to Me	139	Tugend and Hunt (2000)	Rottenberg et al. (2007)
	Surprise	Capricorn One	65	Lazarus and Hyams (1978)	Gross and Levenson (1995)
		Sea of Love	63	Bregman et al. (1989)	Gross and Levenson (1995)

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