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The psychophysiology of mixed emotional states

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Abstract

How to conceptualize mixed emotional states is a central issue in the field of affective science. Nondifferentiation, additive, and emergence accounts of mixed emotions make divergent predictions regarding physiological responses in mixed emotions. To test these predictions, 43 women watched film clips that elicited amusement, disgust, or mixed emotions while feeling self-report, facial electromyography, cardiovascular, electrodermal, and respiratory measures were assessed. Simultaneous self-reports of amusement and disgust confirmed elicitation of a mixed emotional state. Physiologically, mixed emotions differed from pure amusement and pure disgust both in intensity and pattern. This suggests a distinct physiological response of the mixed emotional state, as predicted by the emergence account of mixed emotions. Implications for emotion theory and research are discussed.

Descriptors: Mixed emotional states, Amusement, Disgust, Autonomic response patterns, Cardiovascular, Electrodermal, Respiratory, Electromyography

Emotions are multicomponential responses that consist of coordinated changes in subjective feeling, motor expression, and physiology (Mauss, Levenson, McCater, Wilhelm, & Gross, 2005). So-called basic, prototypical, or pure emotional states have been the main focus of research on emotion. Recently, research has started to address the phenomenon of mixed emotional states, characterized by the subjective co-occurrence of two or more differing emotional feelings (Larsen & McGraw, 2011). It remains unclear, however, how mixed emotional states are characterized in terms of the physiological response.

Theoretical Accounts of Mixed Emotions

The valence–arousal model (Russell, 1980) postulates a bipolar valence dimension ranging from positive to negative, and an orthogonal arousal dimension ranging from low arousal to high arousal. This model contends that positive and negative feelings, like feelings of hot and cold (Schimmack, 2001), are mutually exclusive. The small percentage of concurrent reports of positive and negative feelings is ascribed to measurement error. The *nondifferentiation account* would thus predict that responses associated with reported mixed emotional feelings do not differ from those of one of the pure constituent emotions.

Appraisal models take a different approach to explaining mixed emotions. Appraisal is conceived to be a multistep process that evaluates the meaning and implications of an event for one's personal goals and values on a series of dimensions (Scherer, 1987, 2009) and that directly, differentially, and cumulatively affects emotional response components, including physiology. Appraisal theories view mixed emotions as the result of a complex appraisal process that combines elements of several modal emotions (Scherer, 1998). However, different versions of appraisal theory suggest different patterns of response.

An additive mechanism is suggested by the appraisal tendency framework (Lerner & Keltner, 2000). It assumes that appraisal tendencies from prior emotions carry over and influence subsequent appraisals. Mixed emotional states are predicted to form from their pure constituent emotions, with incompatible appraisal tendencies cancelling each other out, resulting in attenuation of the stronger response, and compatible appraisal tendencies enhancing each other, resulting in augmentation of the response (cf. Pe & Kuppens, 2012). The *additive account* would thus predict intensity differences of the mixed emotional state from one of its pure constituent emotions.

An emergent mechanism is suggested by Scherer's component process model of emotion, which holds that distinct combinations of appraisal outcomes constitute different emotions and mixed emotions combine appraisal outcomes that are typical for several different pure emotions (Scherer, 1984). Each mixed emotion represents a distinct emotion, which is predicted to lead to a qualitatively different emotion response compared to that of its pure constituent emotions. The *emergence account* would thus predict pattern differences of the mixed emotional state from both of its pure constituent emotions.

Physiological Effects of Pure Emotions

Physiological effects of pure emotions are relevant for predicting those of a mixed emotional state. We here draw on amusement and disgust because these two emotional states are often used as

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representatives of positive and negative emotions (Davidson, Ekman, Saron, Senulis, & Friesen, 1990; Demaree, Schmeichel, Robinson, & Everhart, 2004) and because they naturally co-occur in everyday life (Hemenover & Schimmack, 2007; Oppliger & Zillmann, 1997). Given that different emotion elicitation paradigms may impose different information processing demands that can significantly influence the physiological emotion response, we here focus on emotion elicitation through passive perception of pictures, sounds, or film clips.

Amusement is a prototypical positive approach-oriented emotion in response to humorous stimuli. Amusement manifests through increased muscle activity over the zygomaticus major, associated with smiling, and diminished activity over the corrugator supercilii, associated with frowning (e.g., Bush, Barr, McHugo, & Lanzetta, 1989; Larsen, Norris, & Cacioppo, 2003). The physiological response to amusement, summarized in Table 1, includes heart rate deceleration, albeit typically of lesser extent than to aversive material. Decreased sympathetic influence (increased pre-ejection period, decreased stroke volume and cardiac output) likely mediates this cardiac slowing, whereas indicators of cardiac vagal influence (respiratory sinus arrhythmia) are inconclusive (cf. Overbeek, van Boxtel, & Westerink, 2012). Increased vasoconstriction, indicated by increased diastolic blood pressure and total peripheral resistance and decreased pulse amplitude and finger temperature, and increased electrodermal activity are also often reported. Increased respiratory rate and depth and decreased inspiratory time and duty cycle suggest increased influence of the respiratory rhythm generator, a central control mechanism (Gautier, 1980).

Disgust is a prototypical negative withdrawal-related emotion in response to distasteful stimuli. Disgust displays strong muscle activation over the corrugator, which is a prime indicator of negative emotions (e.g., Larsen et al., 2003). The physiological response to disgust—specifically, the body-boundary-violation type—leads to the changes summarized in Table 1. The strong and consistent heart rate deceleration is likely caused by sympathetic withdrawal, as indicated by lengthening of pre-ejection period and decreased low-to-high frequency ratio of spectral power and cardiac output. Respiratory sinus arrhythmia, the high-frequency power component of heart rate variability, suggests no change in parasympathetic activity. Generally, no change in systolic and decreased diastolic blood pressure have been found. Increased total peripheral resistance and decreased pulse amplitude and finger temperature indicate increased peripheral vasoconstriction. Increased electrodermal activity points to increased attentional resource allocation to disgust stimuli (Sarlo, Buodo, Poli, & Palomba, 2005). Increased respiration rate, unchanged respiratory volume, and decreased inspiratory flow rate suggest a decrease in central inspiratory drive (Gautier, 1980).

The Present Study

The present study examined physiological effects of a mixed emotional state by contrasting hypotheses derived from nondifferentiation, additive, and emergence accounts. We elicited amusement, disgust, and a mixed emotional state by presenting film clips while assessing electromyography and cardiovascular, electrodermal, and respiratory measures.

Our primary aim was to test competing predictions regarding the physiological responses associated with mixed emotions based on a framework of physiological emotion differentiation (Kreibig, Wilhelm, Roth, & Gross, 2007; Stemmler, 1989). According to the nondifferentiation account, physiological responses of mixed emotional states should not differ from one of the pure constituent emotions but should differ in pattern from the other constituent emotion. According to the additive account, co-occurrence of appraisal tendencies of amusement and disgust should cancel each other out, resulting in attenuation of the stronger response tendency of the two; hence, physiological responses of mixed emotional states should differ from one of their constituent emotions in intensity and from the other constituent emotion in pattern. According to the emergence account, the combination of appraisal outcomes typical of amusement and disgust should result in an emergent emotional response; hence, physiological responses of mixed emotional states should differ from both of their constituent emotions in pattern. As a secondary aim, we tested the replicability of previously reported physiological response patterns of amusement and disgust.

Method

Participants

Forty-five women participated in a 120-min laboratory experiment for course credit or payment ($22.00). We limited our sample to women because they show stronger experiential, expressive, and physiological reactivity to emotion, specifically for amusement and disgust (Kring & Gordon, 1998; LaFrance, Hecht, & Paluck, 2003; Rohrmann, Hopp, & Quirin, 2008) and to reduce the heterogeneity of our sample. One participant terminated the study early; data collection could not be completed for another participant due to computer problems. Of the remaining 43 participants, 4 self-identified as African-American, 9 as Asian-American, 20 as Caucasian, 4 as Hispanic, and 6 declined to state. Mean participant age was 20.8 years ($SD = 2.7$). The experiment was approved by the Institutional Review Board of Stanford University.

Materials

Stimuli were 45 20–30 s film clips drawn from amateur video sharing websites that showed various forms of rule violations through unintended outcomes, ranging from humorous lapses (pure amusement), to ambiguous bloopers (mixed amusement and disgust), to painful accidents (pure disgust). All film clips included biological motion and audible speech and were edited to remove text overlay. Fifteen film clips for each category were selected based on a pilot study, in which participants rated film clips on experienced amusement and disgust. Amusing clips were rated high on amusement and low on disgust (e.g., a slip of the tongue during the wedding vows). Disgusting clips were rated low on amusement and high on disgust (e.g., hitting the head against a cliff when attempting a cliff jump into the water). Mixed clips were rated moderately high on both amusement and disgust (e.g., a boy falling while riding his skateboard on a treadmill). Mean film duration was 28.2 s ($SD = 3.8$) for amusing, 27.3 s ($SD = 3.5$) for disgusting, and 25.9 s ($SD = 4.7$) for mixed clips, which did not differ between categories, $F(2,42) = 1.27$, $p > .20$, $\eta^2 = 0.057$.

Apparatus

Stimuli were presented with a personal computer using Presentation software (Neurobehavioral Systems Inc., Albany, CA). They were displayed on a 19-inch computer monitor at a viewing distance of 55 cm under low ambient light. Responses were entered

Table 1. *Overview of Studies on Physiological Responses of Amusement and Disgust Elicited Through Passive Perception of Pictures, Sounds, or Film Clips*

Study	Duration (s)	HR	RSA	LF/HF	PEP	LVET	SV	CO	SBP	DBP	MAP	TPR	FPA	FT	EDA	RR	V_i	T_i/T_{tot}	V_i/T_i
Amusement																			
Klorman et al., 1975	10	–													$+^{SCRa}$	=	=		
Klorman et al., 1977	10	–													$+^{SCRa}$	=	=		
Giuliani et al., 2008	20	=									(+)		–	–	$=^{SCRa}$	+			
Zuckerman et al., 1981	~60	+											–		$+^{SCRa}$				
Shiota et al., 2011	90	–	$=^{HF}$		=						–				$+^{SCRa}$	+			
Fredrickson et al., 2000 (study 2)	100	+							+	=			=						
Adamowicz & Gibson, 1970	120	–														=			
Boiten, 1998	120															(+)	–	–	–
Britton et al., 2006	120	–													$+^{SCRa}$				
Demaree et al., 2004	120	–	$=^{HF}$	=											$+^{SCRL/nsSCRR}$				
Demaree, Pu et al., 2006	120		$+^{HF}$												$+^{nsSCRR}$				
Frazier et al., 2004	120	–	$-^{HF}$												$+^{nsSCRR}$				
Stephens et al., 2010	140	–	$=^{pv}$		+	+	–	–	=	=	=	=			$+^{SCL}$	+			
Overbeek et al., 2012	150	–	$-^{HFuc}/+^{RMSSDc}$													+			
Christie & Friedman, 2004	155	=	$=^{MSD}$						=	=	=				$+^{SCL}$				
Chentsova-Dutton et al., 2010	180	+												–	$+^{SCL}$	=			
Dillon et al., 2002	180	–													$+^{SCL}$				
Gross & Levenson, 1997	180	=											–*	–*	$+^{SCL}$	+*	+*		
Hamilton & Meston, 2011	180	(–)	$+^{SDRR}$																
Herring et al., 2011	210	–	$=^{HF}$		=											=	+		
Averill, 1969	360	=/+							=	+			–	=	$-^{SCL}/+^{nsSCRR}$	+			
Carruthers & Taggart, 1973	420	–	$+^{pv}$																
Hubert & de Jong-Meyer, 1990	540	=													$+..-^{SCL/nsSCRR}$	+			
Harrison et al., 2000	600	=			+			–	=	+		+							
Hubert & de Jong-Meyer, 1991	600	–													$+..-^{SCL/nsSCRR}$				
Sakuragi et al., 2002	3000		$-^{HF}$	+												+			
Summary response		–	–/=/+	=/+	=/+	+	–	–	=	=/+	=	=/+	–	–	+..–	+	=/+	–	–
Disgust																			
Oliveira et al., 2009	3	–													$+^{SCRa}$				
Bradley et al., 1993	6	–													$+^{SCRa}$				
Bradley et al., 2001	6	–													$+^{SCRa}$				
Hamm et al., 1997	6	–													$+^{SCRa}$				
Lang et al., 1993	6	–													$+^{SCRa}$				
Sarlo et al., 2005	6	–							=	–					$+^{SCRa}$				
Stark et al., 2005	8	–													$+^{SCRa}$				
Klorman et al., 1975	10	–													$+^{SCRa}$	=	=		
Klorman et al., 1977	10	–													$+^{SCRa}$				
Gomez et al., 2008	6/60																+		–
Gomez & Danuser, 2010	6/60	–					+	+	=	–		+			$+^{SCL}$				
Rohrmann et al., 2008 (study 1)	7.5/300	–													$+^{SCL}$				
Meissner et al., 2011	20/300	–	$+^{pv}$												$+^{SCRa}$				
Overbeek et al., 2012	30	–	$-^{RMSSD/HFuc}/=^{c}$													+			
Gross & Levenson, 1993	~60	–											–	–	$+^{SCL}$	+	=		
Gross, 1998	~60	–											–	–	$+^{SCL}$				
Rohrmann & Hopp, 2008	~60	–	$=^{RMSSD}$				=	–	=	=		=			$+^{SCL}$				
Rohrmann et al., 2009	~60	–													$+^{SCL}$				
Christie et al., 2004	63	=	$=^{MSD}$						=	=	=				$+^{SCL}$				
Rohrmann et al., 2008 (study 2)	63	–													$+^{SCL}$				
Demaree et al., 2004	120	–	$+^{HF}$	–											$+^{SCL/nsSCRR}$				
Demaree, Pu et al., 2006	120		$=^{HF}$												$+^{nsSCRR}$				
Demaree, Schmeichel et al., 2006	120	–	$-^{HF}$		=										$+^{SCL/nsSCRR}$	+	–		
Schmeichel et al., 2006	120	–	$+^{HF}$												$+^{SCL}$				
Palomba et al., 2000	132	–	$=^{pv}$												$+^{SCL}$	+			
Sarlo et al., 2008	320	–	$=^{HF}$		+			–	+	=		+							
Summary response		–	=	–	=/+	/	=/+	–	=	–/=	=	+	–	–	+	+	=	/	–

Note. HR = heart rate; RSA = respiratory sinus arrhythmia; HF = high-frequency spectral power; pv = peak–valley method; MSD = mean successive differences; RMSSD = root mean square of successive differences; SDRR = standard deviation of R–R intervals; LF/HF = low-to-high-frequency ratio of spectral power; PEP = pre-ejection period; LVET= left ventricular ejection time; SV = stroke volume; CO = cardiac output; SBP = systolic blood pressure; DBP = diastolic blood pressure; MAP = mean arterial pressure; TPR = total peripheral resistance; FPA = finger pulse amplitude; FT = finger temperature; SCL = skin conductance level; nsSCRR = nonspecific skin conductance response rate; SCRa = skin conductance response amplitude; RR = respiration rate; V_i = inspiratory tidal volume; T_i/T_{tot} = duty cycle; V_i/T_i = inspiratory flow rate. Effects are indicated as follows: + increase; (+) marginal increase; – decrease; (–) marginal decrease; = relatively unchanged; +..– temporal change from increase to decrease; *summary measure.

via keyboard. Participant compliance was monitored through a hidden camera. Physiological data were recorded and amplified with a multichannel BioNex 8-slot chassis (Mindware Technologies, Grahanna, OH) equipped with a BioNex impedance cardiograph and skin conductance amplifier (Model 50-371100-00), a BioNex 4-channel biopotential amplifier (Model 50-371102-00), a BioNex 4-channel transducer amplifier (Model 50-371106-00), and a BioNex 4-channel high level interface module (Model 50-371103-00). Data were sampled at 1000 Hz, 16-bit digitized, and transmitted to a computer for viewing and storage using the Mindware computer software BioLab 2.4.

Procedure

Data collection took place individually. After obtaining informed consent, participants were seated in front of a computer screen and sensors for physiological assessment attached. Participants read definitions of the rating scales and watched and rated two example film clips. Next, participants completed a respiratory volume calibration using fixed volume bags (Morel, Forster, & Suter, 1983). The experimenter then left the room, and participants started watching the set of 45 film clips in randomized order. Each film clip was preceded by a 20–30 s rest period (varying independently of subsequent film clip length), during which participants were instructed to sit quietly, clear their mind, and avoid moving or speaking. After each film clip, participants rated their current emotional feelings. Upon completing the film viewing session, participants performed a second respiratory volume calibration and a paced breathing task for vagal assessment at 8, 10.5, 13, and 18 cycles per minute (Ritz, Thöns, & Dahme, 2001). After participants were unhooked from physiological recording equipment, they completed demographic and personality questionnaires (not reported here) and were debriefed.

Measures

Subjective feelings. After each film clip, participants rated their emotional feelings on six items (listed in the order presented and followed by the scale definition): amusement (amused, exhilarated, delighted, or pleased), disgust (disgusted, repelled, repulsed, or displeased), valence (happy, pleased, satisfied, contented, hopeful vs. unhappy, annoyed, unsatisfied, melancholic, despaired, bored; Bradley & Lang, 1994), arousal (stimulated, excited, frenzied, jittery, wide awake, aroused vs. relaxed, calm, sluggish, dull, sleepy, unaroused; Bradley & Lang, 1994), compassion, and perceived pain (results of the latter two items not reported here). Participants were instructed to rate items according to "how you feel right now" on a 6-point Likert scale ranging from *not at all* (1) to *very strong* (6) for all but the valence rating, which ranged from *very negative* (1) to *very positive* (6).

Facial expressions. Surface electromyography (EMG, in μV) was recorded with 4-mm miniature Beckman Ag/AgCl electrode pairs filled with Teca electrode gel (Oxford Instruments, Hawthorne, NY) from the zygomaticus major and corrugator supercilii muscles on the left side of the face. Before electrode application, designated skin sites were cleaned with alcohol pads (Curity, Kendall Company, Mansfield, MA), abraded with Nuprep (Weaver and Company, Aurora, CO), and washed with water and cotton pads to lower interelectrode impedance to 10 kΩ, which was measured with an impedance meter. The signal was subjected to a 500-Hz antialiasing hardware filter, 60-Hz notch filtered, and 20–500-Hz digital band-pass filtered, rectified, and smoothed using a running average with 10-ms time constant.

Physiology. Measures were selected to represent cardiovascular, electrodermal, and respiratory systems, which are known to be influenced by emotional responding and to reflect both sympathetic and parasympathetic functioning of the autonomic nervous system.

The electrocardiogram (ECG) was recorded using three disposable pregelled 3.8 cm diameter Ag/AgCl spot electrodes (TraceRite LT430S, Forth-Rite Technologies, Austin, TX) positioned in a three-lead unipolar modified chest configuration. The signal was amplified and band-pass filtered at 10–40 Hz. Heart rate (HR, in beats per minute) was determined by a program that detects R spikes in the ECG and calculates interbeat intervals (IBIs). Beat-to-beat values were edited to exclude outliers due to artifacts or ectopic myocardial activity. Skipped or spurious beats were identified by flagging intervals larger than 1,500 ms or 175% of the mean value of the preceding 10 intervals or smaller than 400 ms or 60% of the mean value of the preceding 10 intervals. Interpolated R spikes were inserted or removed as appropriate.

HR and respiratory sinus arrhythmia (RSA) were derived from corrected IBI time series. RSA was scored using the peak–valley method (Eckberg, 1983), which gives a breath-by-breath index of HR fluctuations reflecting the difference between the longest and shortest IBIs within a given respiratory cycle. While other RSA measures require recording intervals of at least 2 min, the peak–valley method has previously been applied to recordings as short as 12 s (e.g., Ritz, Alatupa, Thöns, & Dahme, 2002; Ritz, Thöns, Fahrenkrug, & Dahme, 2005). Calculated RSA was corrected for within-individual effects of respiration rate and tidal volume based on measurements from the paced breathing task (Schulz, Ayala, Dahme, & Ritz, 2009). We report both uncorrected (RSA_{uc}, in ms) and corrected measures (RSA_c, in ms/l).

Impedance cardiography (ICG) was recorded using a four-spot electrode configuration over the neck and thorax with disposable pregelled 3.8 cm-diameter Ag/AgCl electrodes (TraceRite LT430S). After exclusion of abnormal beats, the ICG was ensemble-averaged over 20–30 s task intervals in synchrony with the ECG R wave. Characteristic points were identified automatically and visually confirmed. Pre-ejection period (PEP, in ms) was calculated as the interval from the ECG R peak onset to the ICG B-point (Lozano et al., 2007). Left ventricular ejection time (LVET, in ms) was calculated as the interval from B- to X-point in the ICG, estimating the time interval from the opening to the closing of the aortic valve (mechanical systole). Stroke volume (SV, in ml) was calculated using the Bernstein formula.

Mean arterial blood pressure (MAP, in mm of mercury) was calculated beat to beat from the continuous arterial pressure waveform (Finapres 2300, Ohmeda, Madison, WI) recorded at the first finger of the nondominant hand. Total peripheral resistance (TPR, in $dyne \cdot s \cdot cm^{-5}$) was calculated as mean arterial pressure divided by cardiac output, which was calculated as the product of ICG-derived SV and HR.

Blood volume waveform was measured with an infrared pulse plethysmograph (1020 FC, UFI, Morro Bay, CA) clipped to the thumb of the nondominant hand. Pulse wave amplitude (PA, in volts) was scored as the difference between peak (maximal value) and foot (25% of maximal slope) of the pulse waveform.

A thermistor (409B YSI, Yellow Springs, OH) attached at the distal phalange of the nondominant hand's fifth finger measured surface finger temperature (FT, in degrees Fahrenheit).

Skin conductance was recorded by applying constant 0.5 volts DC through two disposable 1 cm-diameter Ag/AgCl electrodes pregelled with isotonic paste (EL507, Biopac, Goleta, CA) attached to the palmar surface of the middle phalanges of the second and third fingers of the nondominant hand. Data were low-pass filtered and down-sampled to 10 Hz to calculate skin conductance level (SCL, in μSiemens).

Respiration was measured using piezo-electric respiration transducers (model 1310, Ambu Sleepmate, Glen Burnie, MD) attached around the upper chest near the level of maximum amplitude for thoracic respiration and at the height of the umbilicus for abdominal respiration. Raw signals were converted to calibrated lung volume change using data from the fixed volume bag calibration procedure. A least squares multiple regression was used to establish weighting coefficients to best predict bag volume from output of the two bands (Morel et al., 1983). Respiratory rate (RR, in cycles per minute) and tidal volume (V_i, in ml) were calculated breath by breath. Duty cycle (T_i/T_{tot}) was calculated as the ratio of inspiratory to total breath time and inspiratory flow rate (V_i/T_i, in ml/s) as the ratio of V_i to inspiratory time.

Data Reduction

For each subject and each film clip, we calculated a measure of mixed feelings that quantifies coactivation of self-reported amusement and disgust. This measure relies on the intensity of the weaker of the two feelings, that is, $I[MF] = minimum(I[AMU], I[DIS])$, with $I[MF]$ being the intensity of mixed feelings, $I[AMU]$ the intensity of experienced amusement, and $I[DIS]$ the intensity of experienced disgust (Schimmack, 2001). Values greater than zero indicate presence of mixed emotional feelings.

Physiological data were processed with a biosignal analysis software written in R (R Development Core Team, 2007, http://www.r-project.org/). Period averages were derived for each rest and film period. For facial expression, reactivity was quantified as percent of baseline level of the mean EMG level during the rest condition immediately preceding each film clip. For all other physiological measures, reactivity values were calculated by subtracting the average over the immediately preceding rest period from each film period.

Prior to analysis, data from individual film clips within each emotion category were averaged. Missing data resulted in a variable number of degrees of freedom for different response variables: EMG (2 subjects), ECG (1 subject), RSA (3 subjects), ICG (4 subjects), blood pressure (2 subjects), respiration (1 subject), and skin conductance (6 subjects).

Preliminary Data Analyses

Determining a mixed emotional state. To test for successful elicitation of mixed emotions, we subjected measures of self-reported emotional experience to repeated measures analysis of variance (ANOVA) with Greenhouse-Geisser correction. Tukey honestly significant difference (HSD) tests and effect sizes (Cohen's *d*) were calculated when the ANOVA was significant for contrasts of amusing versus disgusting, mixed versus amusing, and mixed versus disgusting conditions.

Comparability of emotional intensities between conditions. Tukey HSD tests were calculated to test (a) whether self-reported amusement in response to amusing film clips differed from self-reported disgust in response to disgusting film clips (i.e., target emotion); (b) whether disgust in response to amusing film clips differed from amusement in response to disgusting film clips (i.e., nontarget emotion); and (c) whether amusement differed from disgust in response to mixed film clips (i.e., mixed emotions).

Absence of prefilm baseline differences. Repeated measures ANOVAs with Greenhouse-Geisser correction were calculated to test whether prefilm baseline activation of electromyographic and physiological measures differed between conditions.

Primary Data Analyses

Univariate effects on facial expressions. Electromyographic responses were tested for significant deviation from baseline using two-sided *t* tests and effect sizes (Cohen's *d*) and for between-film effects using repeated measures ANOVAs with Greenhouse-Geisser correction, Tukey HSD post hoc tests, and effect sizes (η^2).

Univariate effects on physiological reactivity. The same analysis plan as for facial expressions was applied to test for effects on physiological reactivity.

Physiological response profiles. To test whether univariate physiological differences between conditions represent differences in profile elevation (intensity) or profile nonparallelism (pattern), we applied multivariate analyses of variance (MANOVAs) to these data. This represented the central test of our hypotheses. The MANOVA main effect for condition tests whether profile levels (i.e., intensity) are equal between conditions, whereas the MANOVA interaction effect of Condition $\times$ Variable tests whether profiles are parallel (i.e., will be significant if differences in pattern, i.e., profile scatter and shape, exist; cf. Tabachnick & Fidell, 2007). Physiological reactivity scores were transformed to *C* scores ($M = 100$, $SD = 10$) using within-subject standardization (Stemmler, 1987) and variables were reverse scored such that higher scores relate to higher physiological activation.

To control for familywise inflation of Type I error rate, α level was set to .01 for all tests.

Results

Preliminary Analyses

Determining a mixed emotional state. Analysis of self-report data suggested successful elicitation of target emotions. As summarized in Table 2, self-reported amusement was highest in the amusing film condition and higher in the mixed than in the disgusting film conditions. Conversely, self-reported disgust was highest in the disgusting film condition and higher in the mixed than in the amusing film conditions. Mixed feelings were higher in the mixed than in the amusing or disgusting film conditions, which did not differ. Self-reported valence followed the expected pattern of positive feelings in the amusing film condition, negative feelings in the disgusting film condition, and intermediate feelings in the mixed film condition. Self-reported arousal was lower for the mixed than for the amusing and disgusting film conditions, which did not differ.

Comparability of emotional intensities between conditions. For target emotions, intensity of self-reported amusement for the amusing film condition did not differ significantly from intensity of self-reported disgust for the disgusting film condition, $p = .13$, $d = -0.24$. For nontarget emotions, intensity of self-reported

Table 2. *Means (*M*), Standard Deviations (*SD*), Results of Repeated Measures Analysis of Variance (rm ANOVA), Significance Levels of Tukey Honestly Significant Difference (HSD) Post Hoc Tests, and Effect Sizes (Cohen's* d*) for Subjective Feelings in Response to Film Conditions*

	Amusing films		Mixed films		Disgusting films		rm ANOVA			Post hoc HSD tests			Effect sizes		
Self-report	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	ε	η^2	A vs. D	M vs. A	M vs. D	$d_{A\text{–}D}$	$d_{M\text{–}A}$	$d_{M\text{–}D}$
Amusement	3.95	1.29	2.69	1.32	1.62	1.03	265.53***[a]	0.94	0.915	***	***	***	3.24	2.17	1.68
Disgust	1.38	0.83	2.56	1.38	4.17	1.41	364.51***[b]	0.93	0.933	***	***	***	–3.63	–1.81	–2.64
Mixed feelings	1.31	0.69	1.76	0.92	1.50	0.89	17.04***[a]	0.88	0.545		***	**	–0.34	–1.01	0.56
Valence	4.26	1.10	3.25	1.14	2.33	0.94	180.71***[b]	0.87	0.864	***	***	***	2.48	1.58	1.64
Arousal	2.94	1.23	2.76	1.20	3.01	1.40	3.89*[a]	0.80	0.261		*	**	–0.11	0.38	–0.49

Note. A = amusing film clips; M = mixed film clips; D = disgusting film clips. Degrees of freedom (*df*) are indicated by the following superscript letters: [a]*df* = 2,82; [b]*df* = 2,84. Significance level is indicated by the following notation: *$p < .05$; **$p < .01$; ***$p < .001$.

disgust for the amusing film condition was lower than intensity of self-reported amusement for the disgusting film condition, $p = .042$, $d = 0.32$. Intensity of self-reported amusement and disgust for the mixed film condition did not differ, $p = .52$, $d = 0.10$, supporting its conceptualization as one of a mixed emotional state.

Absence of prefilm baseline differences. As summarized in Table 3, electromyographic and physiological activity during rest periods preceding each film condition did not differ, suggesting successful randomization and recovery.

Primary Analyses

Univariate effects on facial expressions. As shown in Figure 1, zygomaticus activity increased from baseline for amusing, $t(40) = 5.70$, $p < .001$, decreased for disgusting, $t(40) = -2.90$, $p = .006$, and did not differ for mixed films, $t(40) = 1.40$, $p = .17$. Zygomaticus activity differed significantly between film conditions, $F(2,80) = 48.50$, $p < .001$, $\varepsilon = .63$, $\eta^2 = 0.612$, increasing more in response to amusing than mixed films, $p < .001$, $d = 0.99$, and more in response to mixed than disgusting films, $p < .001$, $d = 0.72$ (amusing vs. disgusting, $d = 1.21$).

Figure 1 further shows that corrugator activity increased from baseline for mixed, $t(40) = 7.00$, $p < .001$, and disgusting films, $t(40) = 10.00$, $p < .001$, and did not differ for amusing films, $t(40) = -1.10$, $p = .27$. Corrugator activity also demonstrated a significant film condition effect, $F(2,80) = 102.91$, $p < .001$, $\varepsilon = .62$, $\eta^2 = 0.747$, increasing more in response to disgusting than to mixed films, $p < .001$, $d = -1.43$, and more in response to mixed than to amusing films, $p < .001$, $d = -1.43$ (disgusting vs. amusing, $d = -1.69$).

Table 3. *Means (*M*), Standard Deviations (*SD*), and Results of Repeated Measures Analysis of Variance (rm ANOVA) for Facial Expression and Physiological Baseline Activation during Rest Periods Preceding the Respective Film Condition*

		Film conditions									
		Amusing		Mixed		Disgusting		rm ANOVA			
Response variable	Abbreviation	*M*	*SD*	*M*	*SD*	*M*	*SD*	*F*	*p*	ε	η^2
Electromyographic											
Zygomaticus major	ZM	1.46	0.65	1.43	0.55	1.43	0.59	0.84[c]	*ns*	0.95	0.039
Corrugator supercilii	CS	2.49	1.30	2.43	1.21	2.44	1.20	0.79[c]	*ns*	0.86	0.046
Cardiac											
Heart rate	HR	73.57	10.97	73.69	10.81	73.67	10.63	0.16[b]	*ns*	0.91	0.011
Respiratory sinus arrhythmia (uncorrected)	RSA_{uc}	101.86	63.88	99.54	66.20	102.92	67.21	1.41[c]	*ns*	0.96	0.077
Respiratory sinus arrhythmia (corrected)	RSA_c	115.90	123.25	109.70	118.03	110.48	125.49	0.57[e]	*ns*	0.94	0.038
Preejection period	PEP	113.47	11.24	113.67	11.57	113.14	12.23	1.01[e]	*ns*	0.80	0.073
Left ventricular ejection time	LVET	327.78	85.62	322.85	84.33	322.66	83.87	1.36[e]	*ns*	0.95	0.063
Stroke volume	SV	254.58	124.80	251.53	121.31	249.75	119.93	0.93[e]	*ns*	0.90	0.060
Vascular											
Mean arterial pressure	MAP	94.24	17.85	94.18	18.06	94.32	17.13	0.05[d]	*ns*	0.81	0.003
Total peripheral resistance	TPR	526.04	334.99	534.61	354.22	529.31	333.78	0.72[g]	*ns*	0.97	0.048
Pulse amplitude	PA	0.19	0.13	0.19	0.13	0.19	0.13	0.21[b]	*ns*	0.99	0.010
Finger skin temperature	FT	84.14	4.97	84.18	4.97	84.04	4.85	0.80[a]	*ns*	0.86	0.027
Electrodermal											
Skin conductance level	SCL	5.31	3.31	5.33	3.25	5.34	3.22	0.10[f]	*ns*	0.97	0.006
Respiratory											
Respiratory rate	RR	15.06	3.77	15.26	3.70	14.88	3.76	2.40[b]	*ns*	0.99	0.113
Tidal volume	V_i	300.93	138.36	299.37	133.20	301.55	125.56	0.07[b]	*ns*	0.93	0.004
Duty cycle	T_i/T_{tot}	57.21	8.67	57.30	8.61	56.76	8.70	0.86[b]	*ns*	0.95	0.045
Inspiratory flow rate	V_i/T_i	12.44	4.48	12.52	4.89	12.52	4.76	0.10[b]	*ns*	0.99	0.006

Note. Degrees of freedom (*df*) are indicated by the following superscript letters: [a]*df* = 2,84; [b]*df* = 2,82; [c]*df* = 2,80; [d]*df* = 2,78; [e]*df* = 2,74; [f]*df* = 2,72; [g]*df* = 2,70.

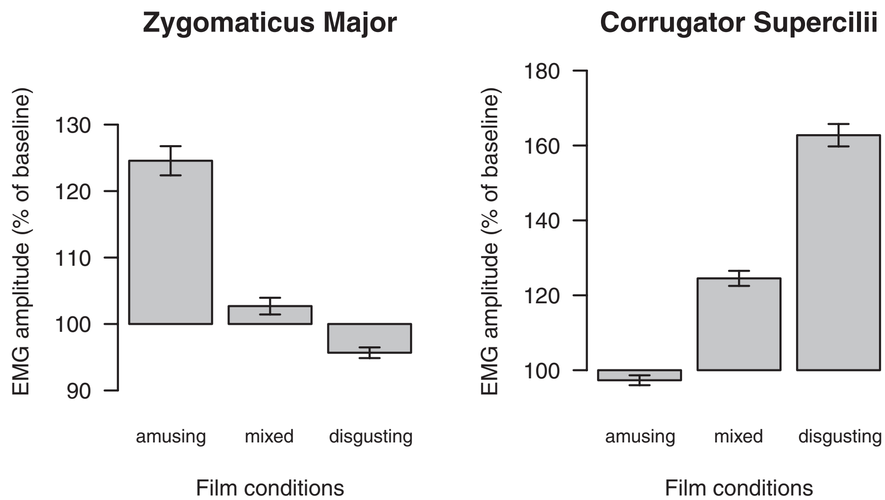

Figure 1. Condition means of amusing, mixed, and disgusting film clips for electromyographic (EMG) measures over zygomaticus major and corrugator supercilii muscle regions. Illustrated values depict change in EMG amplitude during film clips in percent of prefilm baselines. Error bars indicate ± 1 standard error of the mean (*SE*).

Univariate effects on physiological reactivity. Tests of significant deviation from baseline of physiological reactivity for amusing, mixed, and disgusting film conditions are summarized in Table 4 and illustrated in Figure 2. Whereas significant physiological change of the mixed condition showed the same response direction as for significant changes in amusing and disgusting conditions in HR, RSA_{uc}, FT, RR, and V_i, it conformed to that of disgust for SCL, and remained unchanged for PEP, SV, and TPR, where amusement and disgust showed diverging response directions.

Analysis of univariate differences of physiological reactivity among amusing, mixed, and disgusting film conditions, summarized in Table 4 and illustrated in Figure 2, identified significant effects on the following 11 (out of 15) variables: HR, PEP, LVET, SV, TPR, PA, FT, SCL, RR, T_i/T_{tot}, V_i/T_i (p values of MAP and V_i were .046 and .035, respectively).

Post hoc tests indicated significant differences between amusing and disgusting film conditions on the 8 variables HR, PEP, SV, TPR, FT, SCL, T_i/T_{tot}, and V_i/T_i (LVET, PA, MAP differed at $p = .013, .019, .033$, respectively). Significant differences between mixed and amusing film conditions were present on 5 variables: SV, TPR, PA, SCL, and RR (LVET differed at $p = .031$). Mixed and disgusting film conditions differed with respect to a set of 3

Table 4. *Results of* t*-Tests, Repeated Measures Analysis of Variance (rm ANOVA), Post Hoc Tukey Honestly Significant Difference (HSD) Tests, and Effect Sizes (Cohen's* d*) for Physiological Reactivity in Response to Film Conditions*

	Deviation from baseline			rm ANOVA				Post hoc HSD tests			Effect sizes		
Physiological variable	t_A	t_M	t_D	F	p	ε	η^2	A vs. D	M vs. A	M vs. D	$d_{A–D}$	$d_{M–A}$	$d_{M–D}$
Cardiac													
HR	−6.88***	−7.75***	−9.55***	9.38^{b}	***	0.94	0.348	***	–	**	0.66	0.21	0.48
RSA_{uc}	−5.16***	−5.00***	−3.92***	0.96^{c}		0.90	0.068				−0.07	0.14	−0.26
RSA_c	0.78	−0.40	0.50	1.06^{e}		0.98	0.051				0.05	0.21	−0.18
PEP	−2.01	−0.37	3.27**	7.77^{e}	***	0.98	0.297	***	–	–	−0.64	−0.24	−0.38
LVET	−1.98	0.44	1.21	6.11^{e}	**	0.94	0.210	*	*	–	−0.49	−0.43	−0.12
SV	−2.23*	1.73	4.61***	18.66^{e}	***	0.95	0.480	***	**	**	−0.94	−0.52	−0.50
Vascular													
MAP	0.44	−0.88	−1.98	3.27^{d}	*	0.96	0.151	*	–	–	0.41	0.21	0.18
TPR	5.18***	0.10	−2.40*	22.79^{g}	***	0.84	0.481	***	***	*	0.95	0.74	0.42
PA	1.93	−1.97	−0.81	10.50^{b}	***	0.88	0.275	*	***	–	0.44	0.61	−0.32
FT	−5.10***	−6.20***	−9.47***	6.38^{a}	**	0.97	0.263	**	–	–	0.59	0.26	0.27
Electrodermal													
SCL	−6.55***	2.60*	3.35**	35.25^{f}	***	0.80	0.570	***	***	–	−1.09	−1.05	−0.35
Respiratory													
RR	4.41***	7.48***	7.61***	5.80^{b}	**	0.91	0.237	–	**	–	−0.35	−0.55	0.10
V_i	−3.89***	−4.00***	−5.71***	3.73^{b}	*	0.87	0.154	–	–	*	0.32	0.02	0.41
T_i/T_{tot}	−1.82	−1.36	1.88	13.34^{b}	***	0.94	0.444	***	–	***	−0.73	−0.11	−0.71
V_i/T_i	1.49	0.16	−1.20	6.36^{b}	**	0.99	0.218	**	–	–	0.52	0.28	0.29

Note. See Table 3 for abbreviations of physiological variables. A= amusing film clips; M = mixed film clips; D = disgusting film clips. Degrees of freedom (*df*) are indicated by the following superscript letters: $^{a}df = 2{,}84$; $^{b}df = 2{,}82$; $^{c}df = 2{,}80$; $^{d}df = 2{,}78$; $^{e}df = 2{,}74$; $^{f}df = 2{,}72$; $^{g}df = 2{,}70$. Significance level is indicated by the following notation: $*p < .05$; $**p < .01$; $***p < .001$.

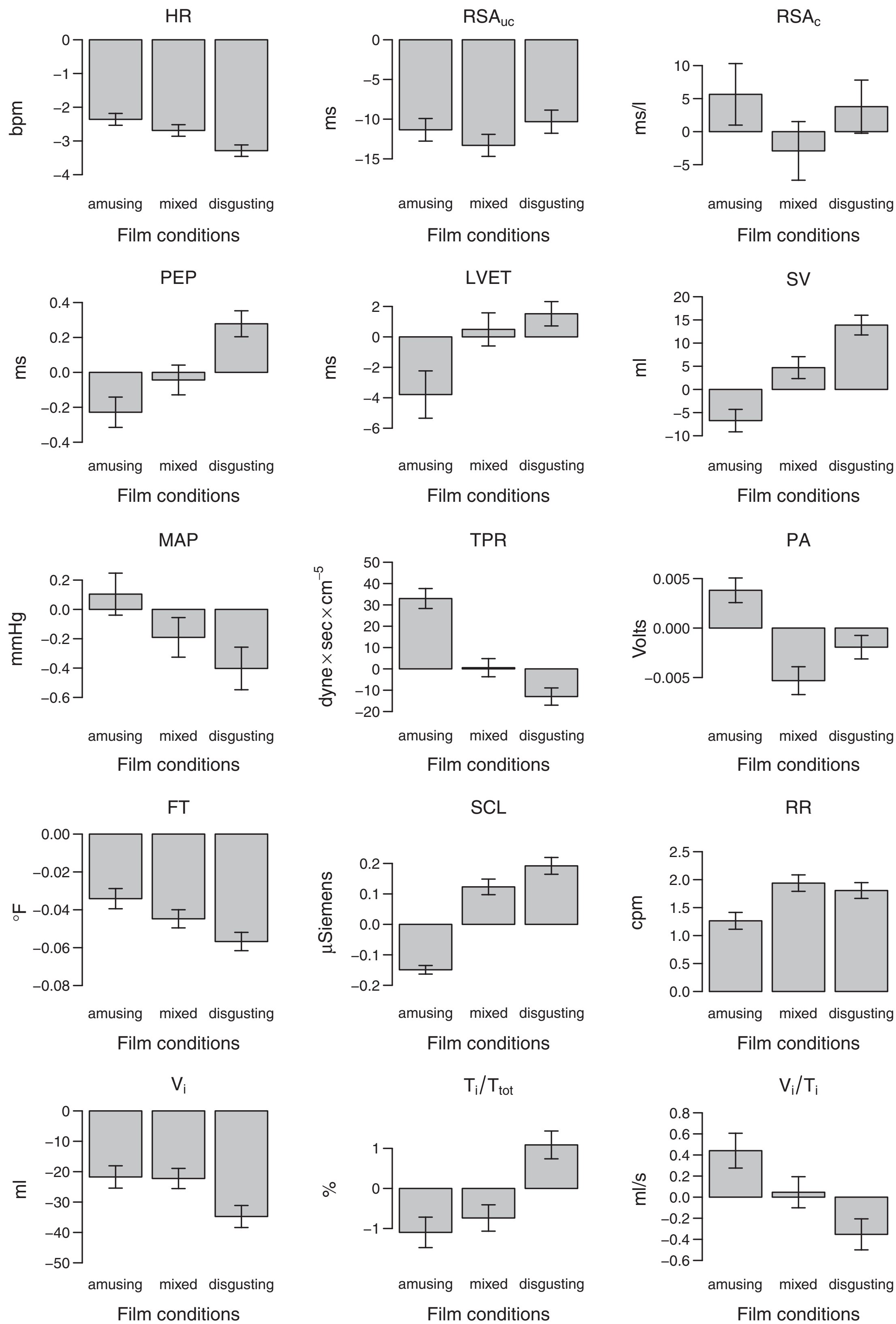

Figure 2. Condition means of amusing, mixed, and disgusting film clips for cardiovascular, electrodermal, and respiratory variables. Illustrated values depict change in physiological activation during film clips from prefilm baselines. Error bars indicate ± 1 standard error of the mean (*SE*). HR = heart rate; RSA_{uc} = uncorrected respiratory sinus arrhythmia; RSA_c = breathing-corrected RSA; PEP = pre-ejection period; LVET = left ventricular ejection time; SV = stroke volume; MAP = mean arterial pressure; TPR = total peripheral resistance; PA = pulse amplitude; FT = finger temperature; SCL = skin conductance level; RR = respiration rate; V_i = inspiratory volume; T_i/T_{tot} = duty cycle; V_i/T_i = inspiratory flow rate.

Table 5. *Multivariate Analysis of Variance (MANOVA) using Wilks' lambda (λ) for Profile Analysis of Physiological Responses Between Film Conditions*

	Condition				Condition × Variable			
Condition	λ	$F(1,42)$	p	η^2	λ	$F(10,33)$	p	η^2
Amusing vs. disgusting	0.34	80.77***	2.46^{-11}	0.658	0.17	16.63***	3.55^{-10}	0.834
Mixed vs. amusing	0.38	69.09***	2.06^{-10}	0.622	0.25	10.13***	1.64^{-7}	0.754
Mixed vs. disgusting	0.84	7.82**	7.76^{-3}	0.157	0.44	4.25***	7.65^{-4}	0.563

Note. MANOVAs were calculated on variables that had a significant univariate omnibus effect. Condition effects test for differences in profile elevation (intensity); condition × variable effects test for differences in profile parallelism (pattern).

variables: HR, SV, and T_i/T_{tot} (TPR and V_i differed at $p = .040$ and .028, respectively).

Similar results, albeit of lower significance, were obtained when (a) analyzing absolute response values; (b) splitting the participant sample into half (i.e., odd vs. even participant numbers; first half of participants vs. second half of participants); (c) inspecting the response pattern for each participant individually; and (d) analyzing a subset of film stimuli that were found particularly effective in inducing each of the three target emotions.

Physiological response profiles. To test whether univariate differences of physiological reactivity between film conditions present differences in profile elevation or profile parallelism, MANOVAs were calculated for (1) amusing and disgusting films, (2) mixed and amusing films, and (3) mixed and disgusting films on variables that had a significant univariate omnibus effect. For all three contrasts, we found significant condition main effects and Condition × Variable interaction effects (Table 5). As illustrated in Figure 3, this indicates that physiological profiles in response to amusing, disgusting, and mixed film conditions differed from each other in profile elevation (intensity) and profile parallelism (pattern).

Discussion

The present study investigated the psychophysiology of mixed emotional states by examining physiological responding to conditions that elicited either pure emotions of amusement and disgust or a mixed emotional state. In the following, we first discuss the psychophysiology of amusement and disgust, which lays the ground for discussing the psychophysiology of mixed emotions and further implications.

Psychophysiology of Amusement and Disgust

Consistent with prior research on facial expressions in positive emotions, particularly amusement (Bush et al., 1989; Cacioppo, Petty, Losch, & Kim, 1986; Larsen et al., 2003), we found increased zygomaticus and relatively unchanged corrugator muscle activity for amusement. Disgust led to decreased zygomaticus and increased corrugator muscle activity. This finding demonstrates the possibility of inhibited zygomaticus activity during negative emotion and further supports facilitation of corrugator muscle activity as a highly sensitive indicator of negative emotions, particularly disgust (Cacioppo et al., 1986; Vrana, 1993).

By integrating several physiological measures that have previously not been concurrently assessed in the study of amusement and disgust (cf. Table 1), our results extend prior research. With this approach, we found that amusement led to decreased cardiac activity (decreased HR and RSA_{uc}), peripheral vasoconstriction (increased TPR, decreased FT), decreased electrodermal activity (decreased SCL), and faster and shallower breathing (increased RR, decreased V_i). The cardiac slowing, which is generally

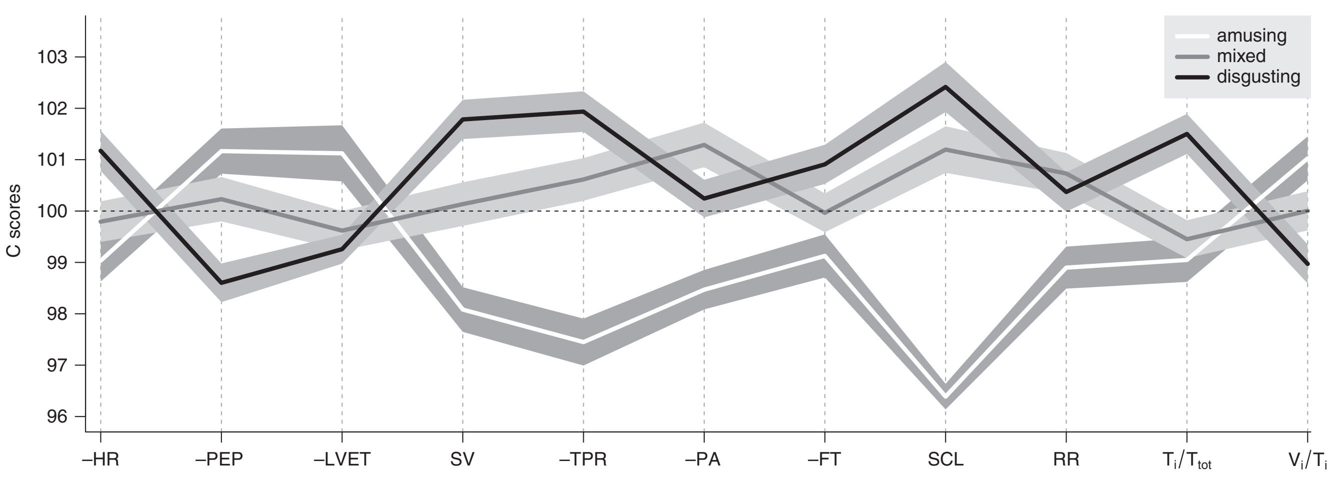

Figure 3. Physiological response profiles for amusing, mixed, and disgusting film conditions. Change scores were transformed onto a *C* scale ($M = 100$, $SD = 10$) and variables were reverse scored such that higher scores relate to higher physiological activation. Gray bands illustrate ± 1 standard error of the mean (*SE*). Because we consider, for example, a decrease in heart rate (HR) and a decrease in pre-ejection period (PEP) as higher activation in the present context, it is plotted as -HR and -PEP. Hence, as illustrated, disgusting films elicit the largest decrease in HR and largest increase in PEP of the three conditions. HR = heart rate; PEP = pre-ejection period; LVET = left ventricular ejection time; SV = stroke volume; TPR = total peripheral resistance; PA = pulse amplitude; FT = finger temperature; SCL = skin conductance level; RR = respiration rate; T_i/T_{tot} = duty cycle; V_i/T_i = inspiratory flow rate.

observed for amusement (cf. Table 1), appeared to be mediated by an afterload effect, as indicated by increased TPR and decreased FT (see Averill, 1969; Chentsova-Dutton, Tsai, & Gotlib, 2010; Harrison et al., 2000, for similar reports of broad vasoconstriction). We found decreased SCL in response to amusement, as did Averill (1969) and Hubert and de Jong-Meyer (1990, 1991), although others have found increased SCL (Chentsova-Dutton et al., 2010; Demaree et al., 2004; Gross & Levenson, 1997). Our finding of increased RR for amusement is consistent with prior reports (e.g., Giuliani, McRae, & Gross, 2008; Shiota, Neufeld, Yeung, Moser, & Perea, 2011; Stephens, Christie, & Friedman, 2010; Overbeek et al., 2012). Decreased V_i for amusement deviates from the generally observed increase in this measure (but see Boiten, 1998).

Disgust led to decreased cardiac activity (decreased HR and RSA_{uc}, increased PEP and SV), vasoconstriction (decreased FT), increased electrodermal activity (increased SCL), and fast and shallow breathing (increased RR, decreased V_i). Pronounced HR deceleration and increased SCL in disgust replicate this response pattern from a long list of previous studies (cf. Table 1). Cardiac deactivation in disgust has been related to cardiac sympathetic withdrawal (e.g., Sarlo, Buodo, Munafò, Stegagno, & Palomba, 2008), which was supported by lengthened PEP and increased SV that we found (cf. Gomez & Danuser, 2010). Decreased FT indicates local diversion of blood in the hands, which conforms to previous findings (Gross, 1998; Gross & Levenson, 1993). Increased RR (Demaree, Pu et al., 2006; Gross & Levenson, 1993; Overbeek et al., 2012; Palomba, Sarlo, Angrilli, Mini, & Stegagno, 2000) and decreased V_i (Demaree, Pu et al., 2006) are also consistent with prior reports for disgust.

Amusement differed from disgust by less pronounced HR deceleration and decreased PEP and SV, while disgust showed an increase in these measures (for similar findings, see Britton, Taylor, Berridge, Mikels, & Liberzon, 2006; Demaree et al., 2004; Herring, Burleson, Roberts, & Devine, 2011; Overbeek et al., 2012; Shiota et al., 2011). Hence, whereas β-adrenergic sympathetic activation increased in amusement, it decreased in disgust. Uncorrected RSA decreased, as is consistent with previous studies (Demaree, Pu et al., 2006; Palomba et al., 2000; Rohrmann & Hopp, 2008; Sarlo et al., 2008), suggesting parasympathetic withdrawal, but showed no emotion-specific effect. However, when RSA was corrected for effects of changes in respiration rate and tidal volume, it did not decrease from baseline. Extending prior research, we additionally found that amusement differed from disgust by higher afterload (higher TPR) but less pronounced digital vasoconstriction (smaller decrease in FT). As in prior studies (Demaree et al., 2004; Klorman, Weissberg, & Wiesenfeld, 1977; Klorman, Wiesenfeld, & Austin, 1975), we observed lower electrodermal activity (SCL) in amusement than disgust. Fast and shallow breathing characterized both emotions, however, with different underlying mechanisms: Lower T_i/T_{tot} in amusement (cf. Boiten, 1998) suggests increased influence of the respiratory rhythm generator, bringing about a shift to expiration, whereas lower V_i/T_i in disgust (cf. Gomez, Shafy, & Danuser, 2008) suggests decreased central inspiratory drive.

Taken together, our analysis suggests that physiological response components of amusement and disgust generally replicate. Cardiac, vascular, and respiratory frequency components of the physiological amusement response replicated robustly across studies, whereas electrodermal and respiratory volume components were more variable. Similarly, cardiac, peripheral vascular, electrodermal, and respiratory response components of the physiological disgust response replicated robustly across studies, whereas TPR, an indicator of systemic resistance, was more variable. Results of multivariate profile analysis support the view that the physiology of amusement and disgust are distinct. Whereas analyses of deviation from baseline identified a number of cardiac, vascular, and respiratory measures that showed the same response direction for amusement and disgust, magnitude of change in these and differential response direction in other physiological measures constitute pronounced response differences between amusement and disgust.

Psychophysiology of Mixed Emotions

The facial expression of the mixed emotional state was characterized by increased corrugator muscle activity. Physiologically, the mixed emotional state was characterized by cardiac deactivation (decreased HR and RSA_{uc}; RSA_c, however, did not decrease from baseline), peripheral vasoconstriction (decreased FT), and fast and shallow breathing (increased RR, decreased V_i). It differed from the physiological response of amusement by higher SV, lower TPR, decreased PA, higher SCL, and higher RR. This response pattern distinguished the mixed emotional state from amusement by lower β-adrenergic sympathetic cardiac influence, lower systemic resistance, but higher peripheral vasoconstriction, higher electrodermal activity, and higher respiratory rate. It differed from the physiological response of disgust by smaller HR deceleration, smaller increases in SV, and decreased T_i/T_{tot}. In other words, in contrast to disgust, mixed emotions elicited less β-adrenergic sympathetic cardiac withdrawal and a shift to expiration.

Results of multivariate profile analysis indicated intensity and pattern differences between mixed emotions and both amusement and disgust. This result supports the emergence account of mixed emotions, which predicted that physiological responses of mixed emotional states should differ from both of their constituent emotions in pattern. In contrast, this result is inconsistent with both the nondifferentiation account, which predicted that physiological responses of mixed emotional states should not differ from one of the pure constituent emotions but should differ in pattern from the other constituent emotion, and the additive account, which predicted that physiological responses of mixed emotional states should differ from one of their constituent emotions in intensity and from the other in pattern. Thus, our results suggest that the mixed emotional state constitutes a unique state with distinct characteristics including a differential physiological response from those of its pure constituent emotions (cf. Scherer, 1984).

Taken together, our results showed that the psychophysiology of mixed emotions in the present study consisted of (a) subjective co-occurrence of feelings of amusement and disgust, (b) increased corrugator activation, and (c) a distinct physiological response pattern from those of amusement and disgust. Our analyses indicated that the emergence account adequately predicted the physiological response component of a mixed emotional state. Similar analyses are necessary to clarify the nature of feeling and expressive components of mixed emotional states. Clarification of the response function of the various emotional response components represents an important basis for the further investigation of mixed emotional phenomena, which has so far mainly been restricted to the feeling component.

Limitations and Directions for Future Research

The present study represents the first attempt to investigate the psychophysiology of mixed emotional states. Several limitations of the study warrant comment.

First, our results are based on young adult female participants. It will be important to test whether results generalize to male participants, who have been found to show weaker experiential, expressive, and physiological reactivity to disgust and amusement elicitation than women (Kring & Gordon, 1998; LaFrance et al., 2003; Rohrmann et al., 2008). Both younger and older age groups than our sample may vary in their emotional responses, as there exists developmental change, particularly with respect to mixed emotions (Charles & Carstensen, 2010; Harter & Buddin, 1987). Ethnicity and cultural background may also influence emotional responding (Williams & Aaker, 2002).

Second, we studied a mixed emotional state of amusement and disgust because prior research has demonstrated reliable co-occurrence of this pair of emotions (Hemenover & Schimmack, 2007; Oppliger & Zillmann, 1997) and extensively studied the psychophysiology of the constituent emotions (Britton et al., 2006; Demaree et al., 2004), often as representatives for positive and negative emotions (Davidson et al., 1990). Still, future research will need to address whether inferences drawn from the here-studied mixed emotional state generalize to other forms of both different- and same-valence mixed emotions (Harter & Buddin, 1987).

Third, film clips are a standard laboratory method for eliciting pure (Rottenberg, Ray, & Gross, 2008) as well as mixed (Hemenover & Schimmack, 2007) emotions. They are readily standardized, low in demand characteristics, and elicit emotions of a high degree of ecological validity (Rottenberg et al., 2008). Still, films may differ from one another on various, potentially confounding, stimulus characteristics, may induce multiple emotions in sequence, rather than simultaneously, and may make individuals passive observers of events rather than active engagers. Future research thus needs to test generalization of results to other emotion contexts.

Finally, we assessed multiple measures in each of three response domains. While facial expression and physiology were measured during emotion induction, emotional experience was assessed afterwards. We can thus not make inferences regarding the simultaneity of mixed emotional feelings—an aspect that is at the core of mixed emotions and thus represents an important avenue for future research.

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