Published in final edited form as:

Psychophysiology. 2006 January ; 43(1): 93–103.

Effects of picture content and intensity on affective physiological response

EDWARD BERNAT, CHRISTOPHER J. PATRICK, STEPHEN D. BENNING, and AUKE TELLEGEN

Department of Psychology, University of Minnesota–Twin Cities, Minneapolis, Minnesota, USA

Abstract

This study evaluated the effects of affective intensity and thematic content of foreground photographic stimuli on various physiological response systems. This was accomplished by assessing responses to pictures that varied systematically in these parameters. Along with overall effects of picture valence reported in previous work, we found effects of thematic content (i.e., specific nature of objects/events depicted) for all measures except heart rate. In addition, we found that the magnitude of startle blink, skin conductance, and corrugator muscle reactions increased with increasing affective intensity of pictures. Additionally, for these three measures, intensity effects also interacted with effects of picture content. These results indicate that stimulus parameters of intensity and thematic content exert separate—and in some cases interactive—modulatory effects on physiological reactions to emotional pictures.

Descriptors

Emotion; Affect dimensions; Startle; Skin conductance; Facial muscles; Heart rate

Physiological responses vary with the emotional qualities of picture stimuli, and there is great interest in learning more about emotional processing by studying relations between reactivity in different physiological systems and various parameters of affective pictures. Such relations have most commonly been studied in terms of orthogonal affective dimensions of valence and arousal. For example, the acoustic startle blink reflex has been shown to vary with the emotional valence (pleasantness–unpleasantness) of picture stimuli, with blinks generally potentiated during viewing of unpleasant stimuli and inhibited during viewing of pleasant stimuli (e.g., Cook, Davis, Hawk, Spence, & Gautier, 1992; Vrana, Spence, & Lang, 1988). On the other hand, the amplitude of skin conductance responses has been shown to covary with the rated arousal of picture stimuli, and modulatory effects on the startle blink reflex tend to be greatest for pleasant and unpleasant pictures that are highly arousing (Cuthbert, Bradley, & Lang, 1996). For a representative summary of physiological responses to picture stimuli, the reader is directed to Bradley, Codispoti, Cuthbert, and Lang (2001).

Aside from valence and arousal, a large body of work suggests that physiological response systems can also be understood in terms of the activation of separable positive and negative motivational systems (e.g., appetitive–defensive, approach–withdrawal; Bradley, Codispoti, Cuthbert, et al., 2001; Bradley, Cuthbert, & Lang, 1999; Cacioppo & Berntson, 1994; Cacioppo, Gardner, & Berntson, 1999; Davidson, 1992; Gray, 1987, 1991; Lang, 1995; Pickering, 1997; Watson, Wiese, Vaidya, & Tellegen, 1999). Positive affect (PA) and negative

affect (NA) rating dimensions (Watson & Tellegen, 1985) have been theorized to represent these separable positive and negative activation systems within the domain of self-report (for recent reviews of the PA–NA perspective, see Russell & Carroll, 1999a; Tellegen, Watson, & Clark, 1999a, 1999b; Watson et al., 1999). Some picture viewing (Bradley, Codispoti, Cuthbert, et al., 2001) and imagery studies (Witvliet & Vrana, 1995) have examined physiological reactivity in terms of these PA and NA dimensions, but the number of these studies is small in comparison to those conducted within the valence-arousal dimensional framework. A final key point regarding the dual activation (PA/NA) model is that the underlying motivational systems are seen to be strongly attuned to stimuli that have direct survival significance. For example, it has been demonstrated that the specific thematic content of pleasant (e.g., erotic vs. adventure) or aversive picture stimuli (e.g., threat vs. victim) can differentially modulate physiological responding (Bradley, Codispoti, Cuthbert, et al., 2001; Levenston, Patrick, Bradley, & Lang, 2000; Yartz & Hawk, 2002). Thus, valence and arousal, PA and NA, and thematic content have all been shown to exhibit significant associations with affective ratings and physiological responding. An important gap in this research is the paucity of efforts to systematically manipulate these stimulus parameters within the same study. The current investigation was undertaken to help fill this gap.

Affective Dimensions

Tellegen et al. (1999a, 1999b) recently proposed a theoretic model of affect that offers a useful framework for thinking about how stimulus parameters including valence and arousal, PA and NA, and thematic intensity might modulate affective physiological reactivity. Tellegen et al. (1999a, 1999b) characterized their model as a nested, hierarchical model. At the top of the hierarchy lies an overarching, bipolar valence dimension. The next level contains separable positive and negative activation dimensions (PA and NA). At the lowest level are individual affective exemplars within the PA and NA dimensions, corresponding to specific thematic contents in the current study. Importantly, PA and NA “activation” dimensions within the model are not isomorphic with previously proposed PA and NA “affect” dimensions (i.e., Watson & Tellegen, 1985). In particular, PA and NA are not posited to be strictly orthogonal, thus allowing for reconciliation with a bipolar valence perspective (see also Larsen, McGraw, & Cacioppo, 2001; Russell & Carroll, 1999b). This shift represents an important resolution to a long-standing debate in which the bipolar valence and PA/NA dimensional perspectives were viewed as fundamentally incompatible. In the integrative model of Tellegen et al. (1999a, 1999b), PA and NA dimensions are defined only by increasing positive or negative activation from a state of relative inactivation, rather than as having their low poles represent the opposing affect. In the earlier model of Watson and Tellegen (1985), for example, low PA was described as sadness or lethargy, whereas in the Tellegen et al. (1999a, 1999b) model low PA simply connotes lower levels of positive activation. Notably, this new PA–NA formulation is conceptually similar to the appetitive–defensive system model employed by Bradley, Codispoti, Cuthbert, et al. (2001; discussed further below), in which valence reflects which of these two motivational systems is activated and arousal level reflects the intensity of its activation.

The current study was designed to evaluate the impact of stimulus parameters corresponding to different levels within Tellegen et al.’s (1999a, 1999b) nested, hierarchical model. The Tellegen et al. model was used as a conceptual guide in selecting stimuli. Although normative ratings available for the International Affective Picture System (IAPS; Center for the Study of Emotion and Attention, 1999) are based on predefined dimensions of valence and arousal, PA and NA are alternative dimensions located in the same space as valence and arousal (even when nonorthogonal, as described above). Furthermore, as explained shortly, the normative (mean) affective ratings of the diverse IAPS stimuli form a distinctive pattern of gradations in this two-dimensional space that largely parallels the variations in *individual* affective experience

implied by the PA and NA vectors of self-reported affect reported in the Tellegen et al. (1999a, 1999b) study.

Effects of Thematic Contents

The impact of the thematic content of picture stimuli (i.e., the specific nature of objects or events depicted) on physiological reactivity has been investigated by several researchers. Balaban and Taussig (1994) found evidence that threat/fear pictures (e.g., weapons, attackers) produced greater startle blink responses than did disgust pictures, supporting the motivational hypothesis that the human startle blink response is most directly potentiated by stimuli that evoke fear. Additional work suggests that among pleasant stimulus contents, erotic scenes—like threat scenes in the case of unpleasant stimuli—produce the greatest modulatory effects on startle (Drobes, Hillman, Bradley, Cuthbert, & Lang, 1995; Lang, Bradley, Drobes, & Cuthbert, 1995; Schupp et al., 1996).

In an effort to more comprehensively investigate the role of thematic contents, Bradley and colleagues (Bradley et al., 1999; Bradley, Codispoti, Cuthbert, et al., 2001) assessed physiological responses to a broad range of picture contents. In both of these studies, erotic stimuli produced the greatest startle inhibition, and threatening stimuli produced the greatest startle potentiation. In addition, they found evidence that specific thematic contents produced large modulatory effects on other physiological responses. Although the earlier work of Balaban and Taussig (1994) attempted to equate the arousal level of different picture contents as a control strategy (see also Levenston et al., 2000), Bradley and colleagues found that contents that produced the greatest modulatory effects on startle blink and skin conductance response (SCR) were those with the highest rated arousal levels. Bradley et al. reasoned that this was because these stimuli have direct motivational relevance (i.e., to reproductive behavior in the case of erotic scenes and to defensive behavior in the case of threat scenes).

To date, the work of Bradley and colleagues represents perhaps the strongest effort toward considering all of the parameters of the hierarchical model described above in relation to physiological reactivity during picture viewing. However, because Bradley et al. were interested in how thematic contents varied in terms of rated affective intensity as well as physiological response (i.e., content exemplars were not preselected to be matched in terms of rated valence and arousal properties), it was not possible to separate effects of intensity and thematic content within this work.

Although effects of affective intensity and thematic content can be complicated to disentangle, recent efforts suggest that equating rated level of valence and arousal for different contents is a useful strategy for isolating effects of content. Levenston et al. (2000) took this approach in studying emotional responses of criminal psychopaths to picture stimuli. Overall content effects were found that paralleled earlier work for responses to both pleasant and unpleasant pictures. Importantly, Levenston et al. also found group differences in reactivity that were specific to certain contents, further supporting the value of investigating thematic contents. For people with psychopathy, victim pictures produced startle inhibition, compared with startle potentiation for people without psychopathy. For threat pictures, the direction of modulation was the same for both groups (i.e., relative potentiation compared with neutral), although the degree of modulation was smaller for people with psychopathy than for people without psychopathy. Among pleasant contents, thrill scenes were associated with startle potentiation for nonpsychopathic inmates, but inhibition for inmates with psychopathy. No significant psychopathy group differences were found in facial electromyography (EMG) response, but a content-specific group difference was found in SCR, for thrill scenes.

A more focused attempt to isolate the effects of stimulus content on physiological response was conducted by Yartz and Hawk (2002). These investigators examined physiological

responses for pictures in three content categories, equated in terms of average rated valence and arousal: fear, disgust–blood, and disgust–other. Their aim was to assess whether startle blink, as well as corrugator and levator EMG activity, were specifically sensitive to fear. The results suggested that startle blink potentiation was sensitive to general aversiveness of picture stimuli, rather than being specific to fear stimuli, whereas corrugator and levator activity were more sensitive to disgust than fear. However, few of the stimuli included in this study reflected scenes of direct personal threat—which are generally rated highest in arousal and are arguably the most motivationally relevant among unpleasant picture stimuli (Bradley, Codispoti, Cuthbert, et al., 2001). Nonetheless, these findings suggest that distinct thematic categories can produce differing physiological responses.

Current Study

The current study was designed to contribute to understanding the association between characteristics of emotional stimuli (i.e., pictures) and physiological response by considering three relevant parameters featured in Tellegen et al.'s (1999a, 1999b) nested, hierarchical model of affect: valence, PA and NA, and individual thematic contents. Specifically, within each of two broad picture valence conditions (pleasant and unpleasant), exemplars from two thematic contents were selected to vary progressively along an affective intensity dimension starting from a point of neutral inactivation and increasing in either positive or negative activation (Figure 1). This design enabled us to assess general and interactive influences of PA/NA intensity and thematic content on reactivity in different physiological systems. These stimulus categories were consistent with those of Bradley, Codispoti, Cuthbert, et al. (2001). Although fewer categories are included here, the most motivationally relevant (erotic and threat) are included. We hypothesized that, in general, increasing affective intensity would produce increasing modulation of physiological response. The direction of modulation was predicted to differ for PA and NA dimensions in the case of the startle blink (i.e., increasing inhibition with increasing PA, increasing potentiation with increasing NA), but to be the same in the case of SCR. For thematic contents, our primary aim was to reevaluate previous findings showing that erotic and threat/fear contents, because of their direct motivational relevance, produce the greatest effects on physiological response—and to test for interactive effects of intensity and content. With regard to the latter, our major prediction was that modulatory effects would be evident primarily for erotic and threat of highest intensity. If modulatory effects are evident primarily for erotic and threat of the highest intensity, this would offer further and more powerful support for the conclusion offered by Bradley, Codispoti, Cuthbert, et al. (2001) that these contents are motivationally important and qualitatively different from other stimuli.

Method

Participants

Fifty-eight males were recruited from psychology classes and through advertisements in the student newspaper at the University of Minnesota. Participants were free of visual and hearing impairments, as assessed via a screening questionnaire. Seven participants were excluded due to insufficient startle responses, and 3 due to equipment failure, resulting in 48 participants for analysis (mean age = 19.81 years, $SD = 2.52$). Also, within different statistical comparisons, participants were deleted listwise within a given analysis due to missing data for specific conditions, resulting in some variation in the number of participants in some comparisons. This variation was due to the small number of trials present at the lowest level of aggregation, where some cells were empty due to artifact rejection. Participants received either course credit or \$7.50/h as compensation.

Experimental Stimuli

Each participant viewed 54 pictures from the IAPS selected to represent specific thematic contents and to systematically vary in affective intensity.¹ Pleasant contents were erotic scenes ($n = 9$; e.g., nude females, intimate couples) and adventure scenes ($n = 9$; e.g., cliff diving, motorcycle racing). Unpleasant contents were scenes of victimization ($n = 9$; e.g., aggression, physical brutality, and combat) and threatening figures or weapons ($n = 9$; e.g., pointed guns, looming attackers). Neutral contents were inactive people, neutral human faces, household objects, or kitchen utensils ($n = 18$). Individual pleasant and unpleasant picture contents were varied equally and systematically in affective intensity (with greater intensity defined by higher arousal combined with greater difference in valence from neutral). Intensity was defined in terms of three levels (low, medium, and high). Mean valence and arousal ratings for each content category at each intensity level are plotted in Figure 1 based on the norms for the IAPS (Center for the Study of Emotion and Attention, 1999).²

Startle probes (50 ms, 105 dB, $<10 \mu\text{s}$ rise time) were presented during the 6-s viewing interval for each of the 54 pictures. The probes occurred 3, 4, or 5 s after picture onset. Interspersed with the 54 startled trials were 9 additional picture trials in which no probe was delivered. During these 9 trials probes were delivered at varying times within the intertrial interval (ITI) instead. This was done to reduce the predictability of the noise stimulus. Additionally, three probed picture trials (IAPS numbers 4650, 7080, and 9252) were included at the very beginning of the series to familiarize participants with the stimuli and to habituate large initial startle reactions (cf. Graham, 1979). Habituation trials and nonprobed picture trials were excluded from analyses. Thus a total of 66 trials were presented with 66 probes: 54 probes during the presentation of the experimental stimuli, 9 during the ITI of the 9 nonprobed trials, and 3 during habituation trials that were not analyzed.

Twelve stimulus orders were used to balance the presentation of pictures and startle probes across participants. As noted, each order included 3 habituation trials followed by 54 probed picture trials, interspersed with 9 nonprobed picture trials. Within and between orders, the positioning of pictures and startle probes was counterbalanced such that all valence, content, and intensity conditions were represented equally across orders at each serial position. Not more than two pictures of the same valence occurred consecutively within any stimulus order, and pictures of the same content never appeared consecutively. Additionally, across orders, stimuli were rotated such that pictures served in both probed and nonprobed trials.

Stimulus Delivery and Physiological Response Measurement

Data collection took place in two waves. As a function of this, stimulus control and data acquisition were accomplished under differing systems for the first 24 and last 24 participants. The first system utilized two IBM-compatible computers running VPM data presentation and acquisition software (Cook, 1997), with Coulbourn transducers and amplifiers. Signals collected with the Coulbourn system were digitized at 20 Hz during data collection, with the

¹The 54 probed pictures, listed by their IAPS identification numbers, were as follows: *erotic*—2381, 4000, 4233 (4617), 4274, 4230, 4653 (4750), 4690, 4687, 4290 (4651); *adventure*—4533 (8032), 8041, 8033, 5622 (8250), 5626, 5623, 8370 (8180), 8080, 8042; *neutral*—2190, 2210, 2214, 2372, 2480, 2495, 2850, 2890, 9700, 7002, 7030, 7034, 7040, 7050, 7150, 7205, 7705, 7710; *victim*—6010, 2520, 9594 (4621), 6571, 9400, 6530 (3550), 9250, 3400, 6350 (3500); *threat*—2100 (6241), 2682, 2130, 6242 (6244), 6370, 6243, 6510 (6250), 6260, 6230. The pictures in parentheses are alternate exemplars from the same content category that were substituted within some stimulus orders to achieve counterbalancing of conditions (valence, content, intensity) across run orders.

²It is important to note that while valence and arousal normative ratings can be used to equate stimuli for a given categories, choosing the categories is less definitive. Currently researchers discuss choosing stimuli that represent particular categories, but the categories, and exemplars for those categories, do not follow a clear and accepted metric. Thus, although some categories can seem clear (e.g., imminent threat) and some exemplars of categories seem clear (e.g., opposite sex nude pictures for an erotic category), optimal categories and exemplars are not always straightforward. This difficulty was evident in the work to choose categories and exemplars for the current study, particularly for the lowest intensity stimuli where low levels of affective content were to be distinguished. Thus, although stimuli were carefully chosen, the need for a more systematic approach to this problem in the field is noted.

exception of orbicularis oculi (for startle reflex), which was digitized at 1000 Hz. The second system utilized one IBM-compatible computer running E-Prime software (MEL software Inc.) for stimulus delivery and another IBM-compatible computer running Neuroscan Acquire software for data acquisition with a 32-channel Neuroscan SynAmps amplifier. All signals collected with the Neuroscan system were digitized at 2000 Hz during data collection. During the experiment, participants sat in a padded recliner and viewed the pictures on a 21-in. computer monitor. The first 24 participants sat 120 cm from the monitor, and the last 24 sat 70 cm from the monitor.

Electrode usage was identical across the systems. Orbicularis oculi (left eye), zygomaticus major (left cheek), and corrugator (left eye) EMG activity were each measured with a pair of Med Associates 0.25 cm Ag–AgCl electrodes filled with electrolyte paste. Orbicularis electrodes were placed over the orbicularis oculi muscle under the left eye. Corrugator and zygomatic EMG electrodes were placed using recommendations from Fridlund and Cacioppo (1986). Skin conductance was measured from two 1-cm Med Associates Ag–AgCl electrodes, filled with the recommended 0.05-m NaCl unibase paste, placed next to each other on the hypothenar eminence of the palmar surface of the non-dominant hand. Electrocardiogram was recorded from the left and right forearms, using two 1-cm Med Associates Ag–AgCl electrodes filled with electrolyte paste. For the last 24 participants, collected with the Neuroscan system, scalp electrodes for EEG/ERP were also recorded using a Quick-Cap. Results from the scalp electrodes are reported elsewhere.

Facial EMG data collected using the Coulbourn system were filtered using hardware analog filters. Raw EMG signals were band-pass filtered between 90 and 1000 Hz with a Coulbourn S75-01 bioamplifier, and then rectified and integrated using a Coulbourn S76-01 contour-following integrator, with a nominal time constant of 500 ms. Startle reflex EMG responses were band-pass filtered, rectified, and integrated in the same manner, but a shorter (80 ms) time constant was used for integration. All data collected using the Neuroscan system were 500 Hz low-pass filtered before digitization. For this data, a digital single pole recursive filter was implemented within Matlab (The Math-works, Inc.) to simulate the Coulbourn contour-following filter. In addition, a digital third-order Butterworth filter was used for the band-pass filtering. Statistical comparisons of main effects for all EMG data collected under the two systems (as well as startle and SCR) revealed no significant differences, supporting the similarity of the data recorded with the two systems.

To assess the impact of the differing data collection equipment, we conducted a repeated-measures ANOVA for each measure, comparing values from the two systems and additionally examining whether the equipment interacted with the affective valence of the stimuli. We found significant main effects of equipment on mean corrugator EMG amplitudes, $F(1,46) = 12.8$, $p = .001$, and mean heart rate activity, $F(1,46) = 15.10$, $p < .001$ (all other $F_s < 2$, $p_s > .15$). Participants tested under the Neuroscan system had greater overall corrugator EMGs and lower mean heart rate activity than those tested under the Coulbourn system. However, there was no interaction between equipment and valence modulation for any of the psychophysiological measures (all $F_s < 1.6$, $p_s > .2$). Therefore, we pooled the data from both sets of participants to maximize our statistical power to detect effects.

Pleasure, arousal, and dominance ratings of each picture stimulus were obtained using the Self-Assessment Manikin (SAM; Lang, 1980), implemented with an animated, interactive computer display that is part of the VPM software package (Cook, Atkinson, & Lang, 1987). Participants also completed a 9-point rating indicating their interest in each picture (cf. Levenston et al., 2000), ranging from not at all to very interested. For reasons of brevity, the interest rating data are not presented.

Procedure

After providing informed written consent, participants completed a biographical form that screened for physical ailments, medication use, and visual and auditory impairments. Following electrode attachment, participants were advised they would be viewing a series of pictures and rating their reactions to each. They were instructed to watch each picture the entire time it was on the screen and disregard occasional brief noises they would hear through earphones. Participants were then given a demonstration of the rating procedure, in which reactions to each picture based on its pleasantness (valence), arousal, and dominance via the SAM, and interest would be obtained.

Each of the 66 pictures was presented for 6 s. For the last 24 participants a fixation plus sign appeared randomly between 2 and 3 s before picture onset to minimize movement for the EEG recordings. Seven seconds after picture offset, the ratings display appeared, allowing the participant to complete the four ratings previously described. The period of time between completion of the ratings and the beginning of the baseline period for the next picture was varied between 5 s and 11 s, averaging 8 s.

Data Reduction

SCR was measured from the onset to peak of the response within a 0.9–4-s window following picture onset. SCR values were log transformed ($\log[\text{SCR}+1]$) to normalize the data, and then scored by visual inspection. Startle blink magnitude was measured as the difference between peak orbicularis activity 15–120 ms post-stimulus and the median of a 50-ms prestimulus baseline; negative values were scored as zero. To equate individual participants for mean startle response, startle blink values were converted to t scores separately for each participant ($t \text{ score} = 50 + (z \text{ score} * 10)$; $z \text{ score} = (\text{raw blink} - \text{mean}(\text{raw blinks})) / \text{SD}(\text{raw blinks})$). This creates standardized scores with a mean of 50 and a standard deviation of 10 (cf. Bradley, Codispoti, Cuthbert, et al., 2001; Levenston et al., 2000). Corrugator and zygomatic EMG responses were measured as the difference in mean activity during the 6-s viewing interval compared with that during a 1-s prestimulus baseline. Cardiac R-spikes were detected and converted to beats per minute (BPM) estimates for successive 500-ms intervals prior to and during each picture presentation. Heart rate (HR) reactions to pictures were measured as the difference from a 1-s prestimulus baseline to the mean activity during the 6-s picture period. For each response measure, outlying scores (i.e., those falling more than 3 SD from the mean) were corrected by setting the scores to a value equal to 3 SD from the mean.

Statistical Analysis

For each dependent measure (startle blink, SCR, corrugator and zygomatic EMG, and HR) the same set of four analyses was performed. Within each analysis, omnibus main effects are reported first in terms of repeated-measures analysis of variance (ANOVA) statistics, followed by univariate linear and quadratic contrasts to elucidate the nature of the omnibus multivariate effects. The first ANOVA included one 3-level factor, Valence (pleasant, unpleasant, neutral). The second ANOVA was a two-way Valence (pleasant, unpleasant) $\times$ Intensity (low, medium, high) analysis. The linear contrast for the one-way Valence analysis is equivalent to the omnibus Valence effect for the two-way ANOVA analysis, and thus only the former is reported. The third and fourth ANOVAs were conducted to assess the effects of picture content and intensity for pleasant and unpleasant pictures separately. These two ANOVAs were each conducted as two-way Content (erotic and adventure in the analysis of pleasant pictures and threat and victim in the analysis of unpleasant pictures) $\times$ Intensity (low, medium, high) analyses. Simple effects of stimulus intensity were also tested separately for each picture content using one-way repeated-measures ANOVAs. Linear and quadratic terms from these ANOVAs are reported to assess the nature of Intensity effects. Effects of stimulus content and intensity were also assessed using t tests that contrasted each condition against neutral.

In addition, to assess effects of affective intensity as a continuous variable, we examined correlations between the magnitude of physiological responses and normative intensity ratings for individual IAPS stimuli. For this purpose, intensity was calculated as: $\sqrt{(2 \cdot (\text{MDVAL} - \text{Valence}))^2 + \text{Arousal}^2}$, where MIDVAL is the midpoint of the valence scale. Specifically, normative ratings for the 12 IAPS picture stimuli within each content were correlated with the magnitude of physiological responses to those stimuli. The PROC MIXED routine in the SAS statistics package was employed for this purpose, which adjusted the degrees of freedom of each correlation to account for the dependence of intensity observations within each participant (cf. Liang and Zeger, 1986). This procedure also allowed imputation of missing data associated with the stimulus counterbalancing scheme, in which subgroups of 6 participants received somewhat differing sets of pictures.

Results

Affective Ratings

Analyses of the valence and arousal ratings yielded results consistent with the a priori (normative ratings based) grouping of pictures within each content into low, medium, and high PA and NA subsets (means across content and intensity are presented in Table 1 and Content $\times$ Intensity detailed means in Figure 2). The only departure from expectation was that erotic pictures evidenced greater mean arousal for the medium intensity condition than for the high intensity condition. Although this difference was not significant, it should be noted as being at variance with the a priori manipulation. All other results were consistent with the a priori groupings based on normative IAPS ratings. In the one-way ANOVA for valence (pleasantness) ratings (see Table 2), the linear contrast effect was significant, reflecting the large difference between pleasant and unpleasant pictures. For arousal ratings, only the quadratic contrast was significant, with pleasant and unpleasant both rated as more arousing than neutral. In the two-way ANOVA for arousal ratings, a significant Valence $\times$ Intensity interaction was found, reflecting the fact that arousal increased with increasing valence in the case of pleasant pictures, whereas arousal increased with decreasing valence in the case of unpleasant pictures.

The Content $\times$ Intensity ANOVAs conducted separately for pleasant and unpleasant pictures yielded results consistent with the above-noted effects. For pleasant pictures, a significant main effect of intensity was found for both valence and arousal ratings, with most of the effect carried by the linear component (i.e., for both erotic and adventure scenes, valence and arousal ratings increased monotonically with increasing intensity; see Figure 2). Arousal ratings additionally evidenced a significant quadratic effect, reflecting a smaller distance between medium and high intensity pictures than between medium and low intensity pictures. In addition, the Content $\times$ Intensity interaction, which was not significant for valence ratings, did achieve significance for arousal ratings, owing to the fact that adventure scenes showed greater increases in arousal ratings across intensity levels than did erotic scenes. The analyses for unpleasant pictures, like those for pleasant, revealed clear linear effects of intensity for both valence and arousal ratings (i.e., for both threat and victim scenes, valence ratings decreased monotonically with increasing intensity and arousal ratings increased monotonically with increasing intensity; see Figure 2). In the analyses of unpleasant pictures, these were the only significant effects.

Startle Reflex

The one-way ANOVA revealed significant differentiation in startle blink magnitude across pleasant, unpleasant and neutral pictures (see Table 2 and Figure 3). As expected, the linear effect (unpleasant > pleasant) was highly significant whereas the quadratic effect was not. Content $\times$ Intensity ANOVAs conducted separately for pleasant and unpleasant contents

revealed both content and intensity differences. Specifically, Adventure and Erotic contents differed within the category of pleasant pictures, and Victim and Threat were different within the category of unpleasant. In addition, Intensity evidenced a linear main effect for unpleasant stimuli, with increasing intensity yielding increasing startle magnitude. Correlations based on intensity values for individual pictures (Table 3) provided a further look at these effects. For the unpleasant contents, a significant positive correlation between picture intensity and startle magnitude was found for Threat scenes, but not Victim scenes. For pleasant contents, Erotic and Adventure scenes evidenced trend level correlations in opposite directions. A t test for the difference between dependent correlations (cf. Steiger, 1980) revealed a significant difference between these coefficients, $t(313) = 2.30, p < .022$. Thus, for pleasant stimuli, adventure scenes showed increasing startle magnitude with increasing stimulus intensity, whereas erotic stimuli showed the opposite pattern (i.e., increasing startle *inhibition* with increasing stimulus intensity).

Skin Conductance

The one-way ANOVA revealed significant SCR differentiation among pleasant, unpleasant, and neutral pictures (see Table 2 and Figure 4). Both quadratic (pleasant and unpleasant > neutral) and linear (pleasant > unpleasant) contrasts were significant. In the two-way ANOVA, Intensity evidenced a significant overall linear effect (high > low) and a nonsignificant quadratic effect, suggesting that across all content categories, stimuli of higher intensity prompted larger SCRs. The Content $\times$ Intensity ANOVAs for both pleasant and unpleasant pictures revealed significant Content $\times$ Intensity interactions, which were carried by the linear (as opposed to quadratic) component of the intensity factor. Simple effects tests for each individual picture content revealed significant linear effects of stimulus intensity for erotic, $F(1,46) = 27.0, p < .001$, and threat scenes, $F(1,46) = 18.9, p < .001$, but not for adventure or victim scenes, $F_s < 0.7, p_s > .5$. This simple effects analysis was supported by the intensity correlations (Table 3), which evidenced significant positive relationships between intensity and SCR magnitude for both Erotic and Threat contents, but not for Adventure or Victim scenes.

Corrugator EMG

The one-way ANOVA revealed significant differentiation between pleasant, unpleasant, and neutral pictures (see Table 2 and Figure 3). The predicted linear Valence effect (pleasant < unpleasant) was significant, whereas the quadratic effect was not. The two-way ANOVA revealed no main effect of picture intensity. However, the presence of a significant Valence $\times$ Intensity interaction, with both linear and quadratic components contributing, suggested differing intensity effects for pleasant versus unpleasant pictures. In this regard, the Content $\times$ Intensity ANOVAs revealed a significant Content $\times$ linear Intensity interaction specifically for unpleasant pictures, with simple effects tests showing a significant linear Intensity effect for victim stimuli, $F(1,47) = 15.8, p < .001$, but not threat scenes, $F < 1$. The same pattern was evident in the intensity correlations (Table 3), where Victim contents, but not Threat, evidenced a significant positive correlation between rated picture intensity and corrugator response magnitude.

On the other hand, the Content $\times$ Intensity ANOVA for pleasant pictures yielded a main effect for Intensity but no main effect of Content, suggesting that corrugator activity decreased with increasing intensity for both erotic and adventure scenes. The presence of a significant quadratic as well as linear component to this overall Intensity effect seemed to reflect the fact that although high intensity pleasant scenes consistently yielded less corrugator activity than low intensity scenes, medium intensity scenes yielded the least activity for the Adventure content specifically (Figure 3). Substantiating this interpretation was a significant quadratic Content $\times$ intensity effect, indicating that the quadratic Intensity term was different between

pleasant contents. Further, simple effects tests for adventure and erotic contents revealed a significant quadratic effect of Intensity for adventure scenes only, $F(1,47) = 9.94, p = .003$. The linear decrease in relation to Intensity was also evident in the correlations between rated picture intensity and corrugator response magnitude for the two pleasant contents (Table 3): Both correlations were negative; however, only the correlation for Adventure scenes was statistically significant.

Zygomatic EMG

Effects of valence, affective intensity, and picture content on zygomatic EMG activity were largely nonsignificant (see Table 2 and Figure 3). The only significant effect, obtained in the separate two-way ANOVAs for pleasant and unpleasant pictures, was a significant Content main effect for pleasant pictures, reflecting greater zygomatic EMG increase for adventure scenes in comparison to erotic scenes. Notably, for the current stimulus set as a whole, mean zygomatic response to pictures was generally smaller than mean corrugator activity, $F(1,47) = 23.6, p < .001, M_s = 0.09$ and $64, SD_s = 0.16$ and 0.77 , respectively. Responses in the zygomatic EMG may thus represent a floor effect: Responses were generally small, smaller than corrugator responses, and thus differences were more difficult to detect.

HR

For mean HR activity, the only significant effect was the main effect of picture valence—specifically, the linear Valence contrast, lower mean cardiac activity for unpleasant pictures compared with pleasant (see Table 2 and Figure 4). Because a fixation point was presented prior to picture onset for the second set of participants tested, but not the first, the effect of the fixation point on HR response was evaluated. There was a significant main effect of the fixation manipulation on mean HR activity, $F(1,46) = 15.10, p < .001$, with lower mean HR occurring when pictures were preceded by a fixation point than when they were not. However, this effect did not interact with picture valence, $F(2,45) = 0.71, n.s.$, indicating that valence modulation for HR did not differ as a function of the fixation manipulation.³

Discussion

Replicating and extending previous work, all levels of the hierarchical model of affect (Tellegen et al., 1999a, 1999b) evidenced meaningful relationships with recorded physiological responses. Several findings stand out in this regard. The most commonly reported valence effects for startle blink, SCR, corrugator, and HR were replicated (cf. Bradley, Codispoti, Cuthbert, et al., 2001; Levenston et al., 2000). This suggests that the current findings, at the broadest level of analysis, are comparable with previous work. The current findings also offer more powerful support to the idea that erotic and threat stimuli hold important motivational significance (Bradley, Codispoti, Cuthbert, et al., 2001). That is, even while equating for stimulus intensity, significantly greater modulation of startle blink and SCR was found for erotic and threat pictures compared with other contents. Significant effects of picture intensity (i.e., degree of positive [PA] or negative activation [NA]) were also found, but these tended to interact with specific picture content.

Among pleasant pictures, opposing effects of stimulus intensity on startle blink magnitude were found for adventure contents and erotic contents. Specifically, blink magnitude *increased* as a function of increasing intensity for the former, whereas it *decreased* as a function

³We found significant effects of equipment on mean corrugator EMG magnitudes, $F(1,46) = 12.8, p = .001$, and mean heart rate activity, $F(1,46) = 15.10, n.s.$ (all other $F_s < 2, p_s > .15$). Participants tested under the Neuroscan system had greater overall corrugator EMGs and lower mean heart rate activity than those tested under the Coulbourn system. However, there was no interaction between equipment and valence modulation for all psychophysiological measures (all $F_s < 1.6, p_s > .2$). Therefore, we pooled the data from both sets of participants to maximize our statistical power to detect effects.

of intensity for the latter. The implication is that the inhibitory effect of positive activation on the startle reflex may be specific to certain thematic contents. A key difference between the adventure scenes and the erotic scenes is that the latter are more directly tied to an appetitive drive system. Thus, foreground scenes that directly activate appetitive drive systems may be most effective in terms of inhibiting the startle response.

Among unpleasant pictures, a positive association between intensity and magnitude of corrugator EMG response was found for victim pictures, but not threat pictures, whereas the reverse was true for startle blink and SCR measures (i.e., responses in these systems increased with intensity for threat scenes, but not victim scenes). This suggests that facial expressive elements of emotional response may reflect different underlying processes than elements involving reflex priming and autonomic activation.

In summary, our findings indicate that picture intensity can be a significant moderator of physiological reactivity even when controlling for thematic content and vice versa. In addition, the current findings support the idea that picture content and intensity can have interactive effects on the startle response.

Affective Intensity

Significant linear effects of affective intensity indicate a role for PA and NA activation dimensions in modulating physiological response. For the blink reflex, increasingly intense unpleasant stimuli produced increasing startle potentiation. Linear effects of intensity were also evident for pleasant pictures, but as noted, the direction of this effect was opposite for erotic and adventure scenes. For SCR, a significant overall linear effect reflected the fact that pictures of higher intensity evoked greater SCR across both pleasant and unpleasant scenes.

Intensity effects obtained for the corrugator and zygomatic EMG measures suggest that the degree of motivational significance can modulate overt facial expression. In general, corrugator activity increased as a function of intensity for unpleasant stimuli and decreased with intensity for pleasant stimuli. The relationship between zygomatic responses and intensity was weaker, possibly because the current study included only men, and modulatory effects of picture valence on zygomatic activity tend to be less robust for men than women (Bradley, Codispoti, Sabatinelli, & Lang, 2001). It is worth noting that heart rate was not sensitive to picture intensity in the current study. This could be due to the specific categories that may not have tapped the content most likely to modulate heart rate, or possibly the included exemplars did not achieve a threshold sufficient to modulate heart rate.

Thematic Contents

Significant effects of picture content were found for all physiological measures except HR, suggesting that specific categories of scenes may be especially effective at activating underlying motivational systems. For example, erotic and threat contents generated the strongest modulatory effects on the startle blink reflex. Threat pictures yielded the greatest blink potentiation, increasing with intensity, and erotic pictures yielded the greatest inhibition, increasing with intensity. This result contrasts with Yartz and Hawk's (2002) proposal that the startle blink is generally sensitive to unpleasant stimuli, rather than specifically sensitive to threat/fear stimuli. Instead, our findings are more consonant with those of Bradley, Codispoti, Cuthbert, et al. (2001), who found that pictures of threatening animals or weapons aimed at the viewer generated the largest startle blink potentiation. A potential explanation for these differences relates to the choice of fear stimuli: The pictures that Yartz and Hawk (2002) labeled as "fearful" would have fallen mainly into our "victim" category. This points to the need for a more formal scheme for classifying pictures of different types into meaningful content categories, as noted earlier. Until such a scheme is developed, it will remain important for

researchers to report the specific picture exemplars used in psychophysiological studies and to conduct appropriate analyses for different picture contents in order to reach firm conclusions about the content specificity of physiological responses.

The fact that adventure scenes generated *increasing* startle blink magnitude with increasing affective intensity invites differing interpretations. One possibility is that some of these scenes (particularly those of highest intensity), although rated as high in pleasantness and arousal, tended to engage the defensive motivational system. The adventure scenes of highest intensity depicted physically risky activities, such as skydiving and swimming with sharks, from the perspective of a participant in the scene. Indeed, scenes of this type may be rated as pleasantly exciting specifically because they engage the defensive system in a simulated context—as is true with scary movies or thrilling carnival rides. From this perspective, scenes of this type may be especially useful for investigating individual differences in sensation seeking and risk aversion. For example, Levenston et al. (2000) reported that, in terms of startle response to pleasant pictures, psychopathic prisoners differed from controls only in reactivity to “thrill” (adventure) scenes—that is, showing robust inhibition for these scenes in contrast with potentiation for controls.

For SCR, a positive effect of stimulus intensity on response magnitude was found only for threatening and erotic contents. In particular, erotic contents generated greater electrodermal reactivity than all other stimuli in the current, male sample. This content effect is consistent with previous findings (e.g., Bradley, Codispoti, Cuthbert, et al., 2001; Levenston et al., 2000). However, only in the current study was the parameter of stimulus intensity systematically varied along with content. Because of this, the current findings offer unique support for the hypothesis that threatening and erotic contents represent categories of stimuli that are more motivationally relevant than scenes of other types, such as adventure and victim pictures.

Facial EMG responses were also significantly modulated by thematic content. Consistent with the findings of Bradley, Codispoti, Cuthbert, et al. (2001) and Yartz and Hawk (2002), the thematic contents that produced maximal overt emotional expression as indexed by facial EMG were different from those that yielded maximal startle blink and SCR effects. Corrugator reactions were greatest for victim pictures, particularly those of high intensity. In contrast, no effect of intensity was found for threat pictures. Both erotic and adventure pleasant pictures yielded decreases in corrugator activity, particularly as affective intensity increased. For zygomatic EMG, the main finding was that adventure pictures yielded more activity compared with erotic pictures, suggesting greater overt expression of pleasure for these thrilling action scenes. Thus, the pattern of results for the facial EMG measures was strikingly at odds with those for startle and SCR measures. In general, the scenes that evoked the greatest facial reactivity were vicarious emotional scenes, as opposed to depictions of threat and sexuality that were associated with maximal autonomic and reflex modulation. This divergence in results may reflect the overt, communicative function of facial expression.

Limitations and Future Directions

The current sample consisted only of men, and so an important question is whether the current findings will generalize to women. Prior work has suggested that men and women tend to have similar startle blink and SCR patterns to pictures of different thematic contents, and that women show stronger overall EMG responses to pictures and greater modulation of zygomatic muscle EMG to pleasant pictures than men (Bradley, Codispoti, Sabatinelli, et al., 2001). This suggests that the current results would likely replicate in women, and that the findings for facial muscle activity might actually be stronger, particularly for the zygomatic EMG measure. However, because men and women differ systematically in their ratings of pleasant and unpleasant stimuli, it may be a challenge to identify gender-balanced picture sets with comparable

manipulations of content and intensity. Nevertheless, it will be valuable in future studies to investigate the effects of other intensity-matched picture contents (e.g., family or disgusting scenes) that have previously been shown to exert selective effects on particular response systems (Bradley, Codispoti, Cuthbert, et al., 2001; Yartz & Hawk, 2002).

Acknowledgements

This study was supported by grants MH52384 and MH65137 from the National Institute of Mental Health, Grant AA12164 from NIAAA, and by funds from the Hathaway endowment at the University of Minnesota. We are grateful to Daniel Blonigen and Brian Hicks for their assistance with stimulus selection, counterbalancing, and collection of data.

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Figure 1.

Dimensional model that served as the basis of the current study, with PA and NA depicted as separate intensity dimensions sharing a common origin of low-arousal neutrality (cf. Tellegen et al., 1999a, 1999b). Gray data points in the background represent male normative valence and arousal ratings for the IAPS picture set from which the stimuli of the current study were selected. Darker points represent mean male IAPS normative valence and arousal ratings for each content-intensity pairing used in the current study, with accompanying letters indicating contents: A: action; E: erotic; N: neutral; V: victim; T: threat.

Figure 2. Means for each content-intensity level for the affective ratings data. Bar graphs contain error bars (*SEM*) from paired *t* tests comparing each content-intensity level against neutral.

Figure 3.

Means for each content-intensity level for the EMG measures. Bar graphs contain error bars (*SEM*) from paired *t* tests comparing each content-intensity level against neutral.

Figure 4.

Means for each content-intensity level for the autonomic measures. Bar graphs contain error bars (*SEM*) from paired t tests comparing each content-intensity level against neutral.

Table 1
Means of EMG, Autonomic, and Self-Report Ratings by Picture Valence

Measure	Pleasant	Neutral	Unpleasant
EMG			
Startle blink	49.0	49.6	51.1
Corrugator	0.480	0.670	0.760
Zygomatic	0.093	0.088	0.080
Autonomic			
Skin conductance	0.130	0.070	0.105
Heart rate	-1.83	-2.21	-2.59
Self-report			
Valence rating	5.61	4.96	4.11
Arousal rating	5.13	3.72	5.14

Table 2

F Values and Significance Levels from Omnibus Repeated-Measures MANOVA and Univariate Linear and Quadratic Contrasts for All Psychophysiological Measures

Analysis	Effect	Contrast	Startle		SCR		Corrugator		Zygomatic		Heart rate		Valence		Arousal		
			df	F	df	F	df	F	df	F	df	F	df	F	df	F	
Overall valence																	
Pleasant and unpleasant contents	Valence (pleasant/neutral/unpleasant)																
	Omnibus			2,46	13.3***	2,46	16.0***	2,46	4.61*	2,46	0.09	2,46	4.76*	2,46	12.2***	2,46	22.7***
	Linear			1,47	26.6***	1,47	13.0***	1,47	9.13**	1,47	0.11	1,47	9.13**	1,47	24.8***	1,47	0.01
	Quadratic			1,47	0.97	1,47	21.1***	1,47	0.41	1,47	0.01	1,47	0.00	1,47	1.86	1,47	45.3***
Pleasant contents	Valence (pleasant/unpleasant)																
	Omnibus			1,47	26.6***	1,46	12.8***	1,47	9.13**	1,47	0.11	1,47	9.13**	1,47	24.8***	1,47	0.01
	Intensity (low/medium/high)																
	Omnibus			2,46	2.70	2,45	6.78	2,46	0.70	2,46	1.78	2,46	1.22	2,46	1.05	2,46	23.1***
Unpleasant contents	Valence (low/medium/high)																
	Linear			1,47	4.26*	1,45	13.8**	1,47	0.06	1,47	3.22	1,47	0.55	1,47	1.42	1,47	32.5***
	Quadratic			1,47	1.79	1,45	0.06	1,47	1.36	1,47	0.78	1,47	2.00	1,47	1.23	1,47	7.07*
	Valence × Intensity																
Pleasant contents	Valence × Intensity																
	Omnibus			2,46	1.24	2,45	0.25	2,46	6.43**	2,46	2.38	2,46	0.63	2,46	26.8***	2,46	2.04
	Linear			1,47	2.10	1,45	0.44	1,47	11.8**	1,47	1.44	1,47	1.19	1,47	50.7***	1,47	0.00
	Quadratic			1,47	0.86	1,45	0.03	1,47	4.29*	1,47	4.34*	1,47	0.46	1,47	0.01	1,47	3.11
Unpleasant contents	Content (erotic/adventure)																
	Omnibus			1,47	8.78**	1,46	20.4***	1,47	0.28	1,47	5.76*	1,44	0.01	1,47	0.42	1,47	0.41
	Intensity (low/medium/high)																
	Omnibus			2,46	1.77	2,45	6.16**	2,46	4.12*	2,46	2.47	2,43	0.31	2,46	9.98***	2,46	21.1***
Unpleasant contents	Intensity (low/medium/high)																
	Linear			1,47	0.59	1,45	11.888	1,47	6.88*	1,47	3.94	1,44	0.24	1,47	10.2***	1,47	28.8***
	Quadratic			1,47	2.78	1,45	0.00	1,47	5.45*	1,47	3.00	1,44	0.25	1,47	0.55	1,47	12.1**
	Content × Intensity																
Unpleasant contents	Content × Intensity																
	Omnibus			2,46	1.22	2,45	18.3***	2,46	3.52*	2,46	2.81	2,43	0.52	2,46	1.10	2,46	2.41
	Linear			1,47	2.49	1,45	16.1888	1,47	0.78	1,47	0.73	1,44	0.04	1,47	2.25	1,47	4.36*
	Quadratic			1,47	0.00	1,45	5.29*	1,47	7.02*	1,47	5.53*	1,44	0.91	1,47	0.07	1,47	0.88
Unpleasant contents	Content (threat/victim)																
	Omnibus			1,47	10.0**	1,46	0.13	1,47	22.5***	1,47	0.56	1,43	1.87	1,47	1.51	1,47	2.68
	Intensity (low/medium/high)																
	Omnibus			2,46	2.89	2,45	4.40*	2,46	4.20*	2,46	0.46	2,42	1.11	2,46	18.0***	2,46	132.5***
Unpleasant contents	Intensity (low/medium/high)																
	Linear			1,47	5.86*	1,45	7.91**	1,47	8.51*	1,47	0.52	1,43	1.72	1,47	36.6***	1,47	24.4***
	Quadratic			1,47	0.10	1,45	0.11	1,47	0.54	1,47	0.58	1,43	0.79	1,47	0.30	1,47	0.44
	Content × Intensity																
Unpleasant contents	Content × Intensity																
	Omnibus			2,46	0.85	2,45	8.36***	2,46	4.91*	2,46	0.10	2,42	0.12	2,46	1.50	2,46	2.37
	Linear			1,47	1.54	1,45	15.4***	1,47	9.77**	1,47	0.18	1,43	0.01	1,47	0.93	1,47	2.40
	Quadratic			1,47	0.18	1,45	0.36	1,47	0.04	1,47	0.03	1,43	0.24	1,47	1.43	1,47	2.21

* $p < .05$;** $p < .01$;*** $p < .001$.

Table 3
Correlations of Picture Intensity with Psychophysiological Responses by Picture Content

Measure	Erotic	Adventure	Victim	Threat
Startle	-.10 ⁺	.10 ⁺	.02	.13 [*]
SCR	.14 [*]	.04	.01	.14 [*]
Corrugator	-.07	-.11	.22 ^{***}	-.03
Zygomatic	.04	.07	.01	.07
HR	-.09	.02	.07	.04

Note:

⁺ $p < .10$;

^{*} $p < .05$;

^{***} $p < .001$. The significance of each correlation is adjusted for the dependence of each physiological response across experimental trials within subjects.