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Emotion and Motivation I: Defensive and Appetitive Reactions in Picture Processing

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Emotional reactions are organized by underlying motivational states—defensive and appetitive—that have evolved to promote the survival of individuals and species. Affective responses were measured while participants viewed pictures with varied emotional and neutral content. Consistent with the motivational hypothesis, reports of the strongest emotional arousal, largest skin conductance responses, most pronounced cardiac deceleration, and greatest modulation of the startle reflex occurred when participants viewed pictures depicting threat, violent death, and erotica. Moreover, reflex modulation and conductance change varied with arousal, whereas facial patterns were content specific. The findings suggest that affective responses serve different functions—mobilization for action, attention, and social communication—and reflect the motivational system that is engaged, its intensity of activation, and the specific emotional context.

Emotion is considered here to be fundamentally organized around two motivational systems, one appetitive and one defensive, that have evolved to mediate transactions in the environment that either promote or threaten physical survival (Lang, Bradley, & Cuthbert, 1997). The defense system is primarily activated in contexts involving threat, with a basic behavioral repertoire built on withdrawal, escape, and attack. Conversely, the appetitive system is activated in contexts that promote survival, including sustenance, procreation, and nurturance, with a basic behavioral repertoire of ingestion, copulation, and caregiving. These systems are implemented by neural circuits in the brain, presumably with common outputs to structures mediating the somatic and autonomic physiological systems involved in attention and action (see Davis, 2000; Davis & Lang, 2001; Fanselow, 1994; LeDoux, 1990).

The motivational model accounts for emotion's basic parameters of (a) hedonic valence (i.e., pleasant–appetitive motivation or unpleasant–defensive motivation) and (b) arousal (i.e., degree of motivational activation), as defined by research on affective language and feeling. Multivariate studies have consistently shown that the principal variance in emotional meaning is accounted for by two predominant factors, pleasure and arousal (Mehrabian & Russell, 1974; Osgood, Suci, & Tannenbaum, 1957; Smith & Ellsworth, 1985). In the current view, these factors are seen as reflecting motivational activation. Thus, judgments of pleasure or displeasure indicate which motivational system is active, and judgments of arousal indicate the intensity of motivational activation. Reports of emotion are not, of course, direct readouts of activity in motivational circuits. They are also affected by many other factors, including personal, situational, and cultural imperatives. Nevertheless, the consistency of the two-factor view, across varying languages and cultures, encourages the hypothesis of a more general, underlying, biological determination.

For example, when people are asked to judge the hedonic valence and arousal of a wide range of evocative stimuli, including pictures, sounds, and words, the resulting distributions in affective space are con-

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sistent with the motivational model. As Figure 1 illustrates, the two-dimensional affective space is not the balanced circumplex that might be anticipated. Rather, it consistently takes on a boomerang shape, with two arms that reach toward the high arousal quadrants. These distributions are seen as reflecting the motivational foundation of affective judgments. Regression lines based on the correlation between reports of valence and arousal, separately calculated for pleasant and unpleasant stimuli, are here considered to be motivational vectors that indicate the degree to which stimuli engage the brain's motive systems, appetitive and defensive. The upper arm of the boomerang indexes appetitive motivation, in which stimuli judged to be pleasurable range in rated arousal from relatively calm to highly arousing; the lower arm indexes defensive motivation, in which unpleasant stimuli range from calm to highly arousing. Several previous studies have shown that the factors defining this Cartesian space—judgments of valence and arousal—covary systematically with the biological reflexes that are associated with activation of appetitive and defensive motive systems (Bradley, 2000; Cuthbert, Schupp, Bradley, McManis, & Lang, 1998; Greenwald, Cook, & Lang, 1989; Lang, Greenwald, Bradley, & Hamm, 1993).

The Research Problem

The present research was designed to more explicitly evaluate a motivational view in the domain of picture-induced affect. Specific emotional picture contents were selected for study that were expected to differentially activate primary motivational states—defensive and appetitive—based on their association with primary reinforcers essential to the survival of individuals and species. Thus, pictures that represent events that are most threatening to life and survival—pictures of attack and mutilation—were contrasted with pictures representing clearly unpleasant but less catastrophic contents, including pictures of pollution, loss, illness, and contamination. Similarly, pictures that should strongly activate appetitive motivation in healthy young adults—erotica and attractive, opposite-sex nudes—were contrasted with pictures representing other clearly pleasant but less arousing contents, including nature, families, sports, adventure, and food (in normally satiated subjects). Two additional picture contents rated as neither pleasant nor unpleasant (household objects, neutral faces) were included to allow us to evaluate the general direction of reactivity when viewing specific pleasant and un-

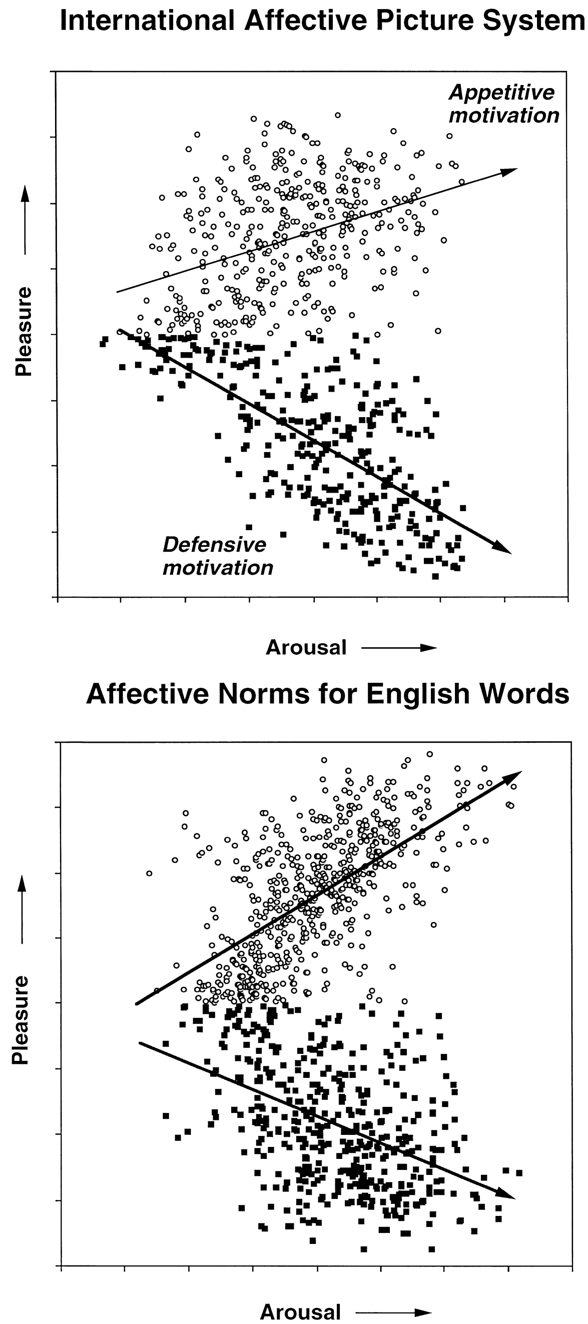

Figure 1. Plots of pictures from the International Affective Picture System (Lang et al., 1999; top panel) and words from the Affective Norms for English Words (Bradley & Lang, 1999; bottom panel) on the basis of their mean pleasure (y-axis) and arousal (x-axis) ratings. Each point in the plot represents the ratings for a picture (top panel) or a word (bottom panel). Regression lines are depicted separately in each plot for pleasant pictures (open symbols) and unpleasant pictures (closed symbols) and are assumed to reflect the underlying motivational systems of appetite and defense.

pleasant contents. Each content category included multiple exemplars, so as to minimize the influence of individual picture characteristics on responses to the content category.

The pictures were drawn from the International Picture System[1] (IAPS; Center for the Study of Emotion and Attention [CSEA], 1999; Lang, Bradley, & Cuthbert, 1999) and were selected to be similar in rated hedonic valence (e.g., pleasantness or unpleasantness) but necessarily varied in rated affective arousal (the motive intensity factor). Each picture was presented for 6 s while heart rate, skin conductance, activity over the facial corrugator, zygomatic, and orbicularis oculi muscles and ratings of pleasure, arousal, and dominance were measured. Acoustic startle probes were presented on half of the trials, and the defensive eyeblink reflex was measured. In "Emotion and Motivation I," we focus on how specific affective contexts that differ in appetitive and defensive activation modulate emotional response. In "Emotion and Motivation II," we focus on sex differences in emotional picture processing.

Theoretical Considerations and Hypotheses

Defensive Motivation

In laboratory studies of animals, threatening cues have been shown to activate a neural circuit that is initiated when relevant sensory input activates the basolateral nuclei of the amygdala. Projections from this structure to other brain sites modulate a series of reflex behaviors, autonomic and somatic, that facilitate processing of the threat context and prepare the organism for overt defensive behavior. The responses initiated by this defense–motive circuit include freezing and active flight (e.g., Fanselow, 1994), fear bradycardia (e.g., Kapp, Frysinger, Gallagher, & Haselton, 1979), blood pressure increase (e.g., LeDoux, 1990), and potentiation of the startle response (e.g., Davis, 2000).

Blanchard and Blanchard (1989), Timberlake (1993), Fanselow (1994), and Masterson and Crawford (1982) are among the animal behavior theorists who have suggested that reflex reactivity in defense is organized sequentially, reflecting the proximity or imminence of threat. Thus, some changes (hyperalertness) are associated with being in a context in which a predator might appear, whereas others (freezing, orienting and information gathering) are associated with the actual presence of a specific threat stimulus. These passive responses initially increase with proximity of the threatening stimulus, but as a predator's strike region is approached, the organism shifts to overt defense (counterthreat displays, fight or flight).

On the basis of physiological reactions measured during picture perception, we have proposed that defensive responding may be similarly staged in humans (Lang et al., 1997). That is, unpleasant picture stimuli can be ordered according to the degree to which they evoke defense system activation. This intensity dimension defines a patterned cascade of reflex responses that is consistent with patterns observed in animals at different stages of predator imminence. We suggest that the laboratory participant reacting to an unpleasant picture is in a state analogous to that of the freezing animal, that is, oriented to the sensory input and processing contextual details, retrieving relevant information from memory, and implicitly preparing for possible action. Pictures are not, of course, real-life events, and overt emotional actions seldom occur; nonetheless, stimuli do vary in their degree of symbolic threat and thus, in the extent to which they prompt activation of defensive motivation.

According to the defense cascade model (see Figure 2; Bradley & Lang, 2000; Lang, 1995; Lang et al., 1997), facilitation of perceptual processing characterizes the early stages of defense, when activation is still relatively low. Classical physiological indices of orienting are evident, such as cardiac deceleration (Graham, 1979), moderate electrodermal increases (Vasey & Thayer, 1987), and relative inhibition of the probe startle reflex, responses indicative of sensory intake and prompted by detection and processing of the aversive cue. At this stage, there is coactivation of sympathetic and parasympathetic systems (Cacioppo & Berntson, 1994; Cacioppo, Gardner, & Berntson, 1999), which may both be enhanced with moderate increases in defense engagement. With more pronounced activation, however, oriented attention starts to give way to metabolic mobilization for active defense and sympathetic reflex innervation dominates. This is signaled initially by greater electrodermal activity and a change in the startle response. Significantly, the startle response is now potentiated (e.g., Vrana, Spence, & Lang, 1988; see Bradley, Cuthbert,

[1] The International Affective Picture System (CSEA, 1999) is available on CD-ROM and as photographic slides. The stimulus sets and technical manual (Lang, Bradley, & Cuthbert, 1999) can be obtained on request from the authors at the Center for the Study of Emotion and Attention, PO Box 100165, Health Sciences Center, University of Florida, Gainesville, FL 32610-0165.

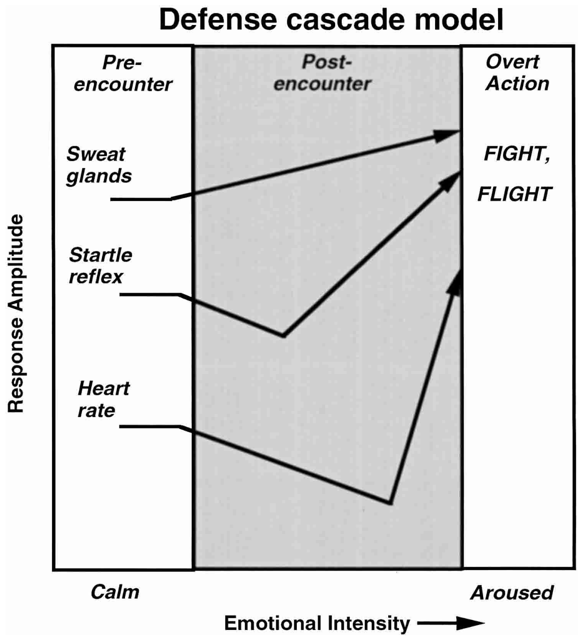

Figure 2. A schematic diagram illustrating the defense cascade model, which proposes that different patterns of change occur for specific response systems (e.g., illustrated here with electrodermal, startle, cardiac) as activation of defensive motivation increases. The abscissa reflects the intensity of defensive activation, corresponding to the stages of pre-encounter, postencounter, and overt action, as defined in theories of animal behavior. Reports of arousal serve as a rough measure of defensive activation. Lang et al. (1997) suggested that picture viewing is analogous to the postencounter stage—the participant is immobile, vigilant, with escape blocked, like a freezing animal. Responses change in different ways at different levels of defensive activation. Whereas skin conductance (sympathetic activity) monotically increases, the startle reflex first decreases (indicating increased attentional intake at lower levels of activation) and then increases (indicating priming of defensive reflexes at higher levels of motivational activation). Similarly, the cardiac response is initially decelerative (indicating heightened orienting and attention—fear bradycardia—in animal research) and then shifts to acceleration (preparation for action) at higher levels of motivational intensity. The shift in cardiac and startle responding occurs at different levels of motivational activity, however, with startle facilitation evident at lower levels of motivational activation than cardiac acceleration. When overt action is initiated (e.g., fight, flight), metabolic requirements will dominate, and the major physiological changes in electrodermal, somatic, and cardiac systems will support the selected action.

& Lang, 1999, for an overview). This change from inhibition to potentiation mirrors the switch from orienting to defense described by Sokolov (1963). Furthermore, it can also be considered the effect of motivational priming for action, in which the startle reflex to a secondary stimulus is the beneficiary of the defense system's general behavioral mobilization (Lang et al., 1997).

In animal models, *predator imminence* (Fanselow, 1994) controls the degree of defensive activation, such that an imminent threat involves a shift from cardiac deceleration (orienting and freezing) to acceleration (preparation for action and fight or flight) and subsequently, the overt defensive actions that then override startle reflex priming. In the picture-viewing context, this level of defensive activation is rare, with cardiac acceleration apparent only when highly fearful subjects view pictures of phobic stimuli (Klorman, Weissbert, & Wiessenfeld, 1977). However, both electrodermal reactions and the startle probe reflex are augmented when phobic subjects view pictures of their feared stimuli, indexing the relatively greater defensive activation when these highly fearful subjects attend to threatening cues (Hamm, Cuthbert, Globisch, & Vaitl, 1997).

Both attack and evidence of the death and mutilation of a species member strongly engage defensive motivation in animals. Hebb (1949) noted that primates react to a representation of mutilation—for instance, a model of a severed monkey head—with fear, agitation, and avoidance. When confronted by a predator, animals invariably freeze, mobilizing for defense and, if the threat is proximal, for fight or flight. In humans, pictures of mutilated victims of violence or pictures of attacking animals or people (particularly those oriented toward the viewer) symbolically represent imminent threat and thus are expected to engage the defense system strongly. Both contents are expected to prompt marked autonomic and somatic indices of moderate defensive activation, such as large cardiac deceleration, increased skin conductance, and potentiated startle reflexes, as well as reports of high arousal and low pleasure.

Reactions to pictures of attack and mutilation were compared here with reactions to unpleasant pictures that are presumed to engage defensive motivation less strongly. These contents are similarly rated as highly unpleasant but less arousing because they involve less imminent or less catastrophic negative consequences and included pictures of pollution, loss, illness, and contamination. From a motivational perspective, these later unpleasant contents should primarily prompt simple orienting, signaled by modest skin conductance changes and cardiac deceleration, and significantly less potentiation of the startle reflex.

Appetitive Motivation

The study of appetitive motivation is often complicated by the fact that the attractiveness of a specific stimulus (e.g., food or drug) depends, to some extent, on a co-occurring aversive state (e.g., hunger or deprivation; see Rolls, 2000). Thus, motivational activation is often mixed. One clear exception involves sexual stimuli. Viewing attractive members of the opposite sex or observing the sexual congress of other species members evokes a strong appetitive motivational state in sexually mature primates, even without deprivation. Here, we compared somatic and autonomic reactivity when people viewed pictures depicting erotica—either pictures of erotic couples or opposite-sex erotica—with reactivity elicited when people viewed pictures rated similarly high in pleasantness—pictures of nature scenes, families, appetizing food, sports, and adventurous recreation. In this context, the latter contents are less related to species survival. Presumably, these contents are related to more highly evolved aesthetic (e.g., beautiful nature scenes, an attractively prepared table viewed by satiated subjects) or social (e.g., unrelated families, sports, or recreational themes) sensibilities and thus will not strongly activate the primitive appetitive motivation system.

We also examined reactions to pictures of erotically posed members of the same sex. In general, men and women judge pictures of same-sex erotica to be near neutral in valence and nonarousing (Lang et al., 1999). Here we explore whether this picture content is indeed low in appetitive motivation or whether instead, pictures of same-sex erotica cue appetitive motivation, either directly or because of their general association with sexual behaviors. Another possibility, stemming from folk psychology, is that the predominantly heterosexual sample assessed here will respond negatively to erotic pictures of the same sex.

We presume that increasing activation of appetitive motivation, like defensive motivation, involves a shift from initial attention to ultimate action. As with unpleasant pictures, social constraints and the fact that the stimulus is only symbolically represented preclude overt action. Thus, measures of attentional involvement, such as initial cardiac deceleration, are expected to be greatest when appetitive motivation is high, that is, while viewing erotic pictures. In our previous research (e.g., Lang et al., 1993), we noted that deceleration was not sustained during pleasant-picture viewing (unlike the case with the fear bradycardia found with unpleasant stimuli). Rather, the heart rate component that best characterized pleasant-picture viewing and differentiated these from unpleasant input was a brief, midinterval acceleration. In this research, we re-evaluated this acceleratory component with more motivationally relevant appetitive input to determine its reliability as a valence measure and to more directly test its potential modulation with increased motivational engagement.

Previous studies have found that the startle reflex is inhibited when people view pleasant pictures and that the greatest startle inhibition occurs for stimuli that are rated as the most arousing (Bradley, Cuthbert, & Lang, 1999; Cuthbert, Bradley, & Lang, 1996). When pleasant pictures engage the appetitive system, it is presumed that this state inhibits noncongruent defensive reflexes (e.g., the startle reflex). Thus, the greatest startle inhibition in the current study is expected during the viewing of erotic stimuli. Because an increase in the intensity of appetitive motivation, like increased defensive motivation, is associated with greater sympathetic activity, we expected that the largest skin conductance changes should occur for the most arousing pleasant contents, that is, erotica.

Facial Electromyographic (EMG) Measurement

Like the autonomic reflexes, facial expressions in emotion evolved as reactions to motivationally significant events (Darwin, 1872). Davis (2000) noted that the amygdala projects to the facial motor nucleus, linking emotional expressions to the motive circuit that mediates survival responses. Furthermore, from a behavioral perspective (Ursin & Olff, 1993), counterthreat displays are clearly reflexively defensive in many animals. However, human facial expressions are highly varied and subtle and appear to be variously determined. That is, rather than covarying in a direct way with activation of the strategic, motivational systems, facial displays are more often tactical responses to a specific context, serving both social–instrumental and communicative functions.

A number of studies have found that the processing of unpleasant events is associated with greater activity over the corrugator (frown) muscle and that processing pleasant events prompts greater activity over the zygomatic muscle (Lang et al., 1993; Schwartz, Brown, & Ahern, 1980; Tassinary, Cacioppo, & Geen, 1989), recalling the stylized masks of comedy and tragedy. Moreover, observers reliably label facial expressions as representing fear, disgust, joy, or other specific emotions (Ekman, 1973; Lundqvist & Dimberg, 1995). Nevertheless, neither facial EMG activity nor different facial expressions are expected to vary in a monotonic fashion, as are measures of motivational intensity. Indeed, equivalent motivational engagement may prompt very different emotional expressions, such as anger or fear, depending on whether a context calls for counteraggression or flight. Thus, whereas facial muscle actions may differ broadly in response to pleasant and unpleasant stimuli, differences in reactions to specific contents[2] are expected to be more dramatic (e.g., between contamination and attack stimuli), and a systematic covariance with emotional arousal is not anticipated.

Pictures in Color

From a motivational perspective, variation in specific pictorial features, such as whether the information is portrayed in color or in black and white, should have little impact on emotional reactivity because we presume that it is the cue's semantic information, in terms of threat or survival, that drives motivational activation. However, in this highly symbolic context (e.g., pictures), cues that share more of the perceptual features of the actual object (e.g., the red color of blood) may better elicit emotional reactions. Thus, we explored how color affects evaluative, somatic, and autonomic responses to pictures and determined whether color is more important as a motivational cue for some picture contexts (e.g., mutilation) compared with others. Thus, for half the participants, pictures were presented in natural colors, whereas the other half of the participants viewed the pictures in grayscale.

Method

Participants

Participants were 95 students (50 women and 45 men) from a University of Florida introductory psychology class who received course credit. Of these, 47 students (24 women, 23 men) viewed pictures displayed in color, and 48 students (26 women, 22 men) viewed pictures displayed in black and white (grayscale) while physiological measures and self-reports of pleasure, arousal, and dominance were measured. Because of computer or experimenter error, some participants were excluded from analyses of some dependent measures. Final *N*s were as follows: corrugator EMG, $n = 95$; zygomatic EMG, $n = 95$; heart rate, $n = 94$; skin conductance responses, $n = 95$; startle blink reflexes, $n = 85$; orbicularis oculi EMG, $n = 92$; and Self-Assessment Manikin (SAM) ratings, $n = 94$.

Materials and Design

Seventy-two pictures were selected from the IAPS, a collection of standardized photographic materials (CSEA, 1999; Lang et al., 1999). Pictures were chosen to comprise 18 different picture contents, including 8 that are typically rated pleasant (nature, families, food, sports, adventure, attractive men, attractive women, erotic couples), 2 typically rated neutral (household objects, mushrooms), and 8 typically rated unpleasant (pollution, illness, loss, accidents, contamination, attacking animals, attacking humans, mutilated bodies). Pictures of attractive women comprised the opposite-sex erotica for men and same-sex erotica for women, and the case was vice versa for pictures of attractive men. Each of the 18 contents included 4 different picture exemplars.

Digitized versions of the IAPS pictures were displayed on a Macintosh computer. Pictures were presented on a 19-in. (48.3 cm) monitor, situated approximately 0.5 m from the participant. Picture onset was virtually instantaneous, and each picture was presented for 6 s. For the group receiving color versions of the IAPS pictures, pictures were displayed in 32-bit color; for the group receiving black-and-white versions, 8-bit grayscale was used.

For each participant, a different order of picture presentation was constructed, with each order arranged in blocks of 18, such that there was 1 exemplar from each of the 18 stimulus contents in each block of 18 (as well as 4 pleasant, 1 neutral, and 4 unpleasant within each half-block of 9), and with the constraint that no more than 3 pictures of the same hedonic valence were presented consecutively. In each block of 18 pictures, startle probes were presented on half of the trials in each valence category (e.g., pleasant, neu-

[2] Activity was measured over the corrugator, zygomatic major, and orbicularis oculi muscles. Including the orbicularis oculi muscle allowed us to assess whether picture viewing elicits an authentic Duchenne smile (Ekman et al., 1990), which is held to involve coactivation of both the zygomatic and orbicularis oculi muscles, as opposed to a nonauthentic smile that involves only zygomatic activity. Similarly, coactivation in the corrugator and orbicularis oculi muscles is a component of a facial grimace associated with disgust (Tassinary & Cacioppo, 1992), suggesting that this pattern of activity may be uniquely obtained for pictures involving contamination (e.g., spoiled food, feces).

tral, unpleasant). The 72 pictures were divided into 2 sets of 36 (balanced for picture content and affective valence), such that approximately half the participants received startle probes during one set of pictures (distributed across the entire series) but not during the other set, and the set of pictures probed with a startle stimulus was reversed for the other half of the participants. This manipulation allowed us to determine whether presenting a startle probe affects other affective reactions during picture viewing.[3]

The acoustic startle stimulus consisted of a 50-ms presentation, 95 dB (A, re 20 $\mu N/m^2$) burst of white noise with instantaneous rise time. This stimulus was generated by a Coulbourn S81-02 white-noise generator and presented over matched TDH-49 headphones. The startle probe was presented between 3 and 5 s after picture onset.

Physiological Response Measurement

Stimulus control and physiological data acquisition were accomplished using an IBM-compatible computer running VPM data acquisition and reduction software (Cook, 1997). Physiological signals were sampled at 20 Hz for 3 s before picture onset, for 6 s during picture presentation, and for 2 s after picture offset. Corrugator (left eye) and zygomaticus major (left cheek) EMG activity were both measured with Sensormedic miniature electrodes (Sensormedic, Yorba Linda, CA), using the placement recommended by Fridlund and Cacioppo (1986). The raw EMG signals were amplified by 30,000, and frequencies below 90 Hz and above 1,000 Hz were filtered with a Coulbourn S75-01 bioamplifier. The raw signals were rectified and integrated using a Coulbourn S76-01 contour-following integrator, with a nominal time constant of 500 ms.

Skin conductance electrodes were placed adjacently on the hypothenar eminence of the left palmar surface, using Sensormedic standard electrodes filled with the recommended 0.05-m NaCl Unibase paste. The signal was acquired with a Coulbourn S71-22 skin conductance coupler (Coulbourn Instruments, Allentown, PA) and calibrated before each session to detect activity in the range of 0–40 μS.

The electrocardiogram was recorded from the left and right forearms, using large Sensormedic electrodes filled with electrolyte paste. The signal was filtered with a Coulbourn S75-01 bioamplifier, and a trigger interrupted the computer each time it detected a cardiac R-wave. Interbeat intervals were recorded to the nearest millisecond and reduced off-line by using VPM software (Cook, 1997) into heart rate in beats per minute, in half-second bins. The eyeblink component of the startle response was measured by recording EMG activity over the orbicularis oculi muscle of the left eye. The raw EMG signal was amplified (×30,000), and frequencies below 90 Hz and above 250 Hz were filtered with a Coulbourn S75-01 bioamplifier. The raw signal was rectified and integrated with a Coulbourn S76-01 contour-following integrator, with an actual time constant of 123 ms. Activity in the orbicularis oculi muscle was sampled at 20 Hz during baseline and picture viewing, with an increase in sampling rate to 1,000 Hz for 50 ms before the onset of the startle probe and for 250 ms after probe onset.

Pleasure, arousal, and dominance ratings were obtained by using SAM (Bradley & Lang, 1994; Lang, 1980), an animated, interactive computer display that is part of the VPM software package (Cook, Atkinson, & Lang, 1987). The SAM monitor was positioned directly below the picture presentation monitor.

Procedure

The participant sat in a recliner in a small, dimly lit room. After filling out a consent form and several questionnaires, the sensors were placed on the participant. Each participant was then familiarized with the SAM rating procedure, which involves ratings of pleasure, arousal, and dominance, using a computer manikin that dynamically illustrates changes separately along each affective dimension (1–20 scale). For instance, SAM varies from a smiling figure to a frowning figure when indexing the pleasure dimen-

[3] Because half of the trials did not present a startle probe, we were able to assess whether the presentation of a startle probe affects the relationship between picture valence and physiological responses. These analyses included picture valence (pleasant, neutral, unpleasant) and trial type (probed or nonprobed) as repeated measures. Effects of picture valence were essentially the same regardless of whether a startle probe was presented during picture viewing for most measures. Exceptions were obtained for (a) arousal ratings, in which a main effect of trial type, $F(1, 93) = 8.41$, $p < .001$, indicated slightly higher ratings of arousal for all pictures on probed trials, (b) dominance ratings, in which an interaction of valence and trial type, $F(2, 92) = 4.46$, $p = .014$, indicated that dominance ratings were slightly lower for neutral pictures when a startle probe was presented ($\mu = 12.9$) compared with when it was not ($\mu = 13.7$), and (c) orbicularis oculi electromyographic change, in which the main effect, $F(1, 94) = 21.9$, $p < .001$, is expected as the startle probe elicits activity in this muscle.

sion. The participant was instructed to select a figure anywhere along each scale with a joystick, consistent with their reaction to the previously presented picture. All three ratings (e.g., pleasure, arousal, dominance) were made for each picture; the order in which the ratings were presented was randomly determined on each trial.

The participant was then instructed that a series of pictures would be displayed and that each picture should be viewed the entire time that it was on the screen. After picture offset, the SAM ratings were made and were followed by an intertrial interval that varied between 12 and 22 s. Finally, the participant was instructed that brief noises heard over the headphones could be ignored.

In a postexperimental questionnaire, participants were asked to estimate how many "loud sounds" (e.g., startle probes)[4] were presented over the course of the study and to rate their confidence in their estimates by using a 5-point Likert scale, where 1 = *just guessing* and 5 = *extremely confident.* We subsequently debriefed, paid credit, and thanked the participant.

Data Reduction and Analysis

Reactions in corrugator, zygomatic, and orbicularis oculi EMG, skin conductance, and heart rate were determined by subtracting activity in the 1 s before picture presentation from that occurring at each half-second after picture onset. For facial EMG activity, the average change over the 6-s picture period was used to estimate reactivity. For skin conductance, the maximum change occurring between 1 and 4 s after picture onset was scored, and a log transformation (log [SCR + 1]) was performed to normalize the data.

Heart rate waveform scores were computed by determining, for each participant and each trial, the maximum deceleration from baseline in the first 3 s of picture viewing and the maximum acceleration from baseline in the last 3 s of picture viewing (c.f. Hodes, Cook, & Lang, 1985). The blink data were reduced off-line by using a program that scored each trial for magnitude in analog-to-digital units and for onset latency in milliseconds, using an algorithm devised by Globisch, Hamm, Schneider, and Vaitl (1993).

Separate analyses were conducted to assess effects of picture valence (pleasant, neutral, and unpleasant) and effects of the specific picture content within each valence category for each measure. In the first set of analyses, effects of emotional content were assessed for pleasant, neutral, and unpleasant pictures by averaging responses over the different stimulus contents in each set; reactions to same-sex erotica were omitted from these analyses, because, although they were rated neutral, reactions were more consistent with affectively arousing stimulus. Thus, analyses of same-sex erotica are reported separately. A between-subjects variable of presentation mode (color, grayscale) was included in this mixed-model analysis of variance (ANOVA). In a second set of analyses, effects of specific stimulus content within each valence category were assessed by conducting mixed-model analyses (with presentation mode as a between-subjects factor and stimulus content as a repeated measure) separately for seven pleasant contents (i.e., excluding pictures of same-sex erotica), two neutral contents, and eight unpleasant contents.

For all analyses that involved repeated measures variables, the multivariate test statistic (Wilks's lambda) is reported to avoid potential sphericity issues (Vasey & Thayer, 1987).

Results

Color Versus Grayscale

Affective responses—both self-reported emotion and physiological reactions—were essentially the same regardless of whether pictures were presented in color or grayscale. The mode of picture presentation (color or grayscale) did not result in any significant main effects or interactions involving picture content (pleasant, neutral, unpleasant) in analyses of any dependent measure. Similarly, for analyses conducted on specific content within each valence condition, there were no main effects or interactions involving mode of presentation for any dependent measure.[5]

[4] Startle probes were presented on 38 trials (36 picture + 2 pre-experimental startle probes) in this study. When estimating the frequency of startle presentations postexperimentally, participants greatly underestimated the number of probes presented. The average estimate of number of probe presentations was 17.6 (approximately half of the actual number). Level of confidence in these reports was not high, however, with a mean confidence rating of 2.4 on a scale of 1 to 5, where 1 = (*just guessing*) and 5 = (*extremely confident*). These data suggest that participants are not very aware of the frequency with which startle probes occur, despite their somewhat loud and intruding nature.

[5] Separate t tests assessing the effect of mode of presentation for each stimulus content (18) and dependent measure (8) resulted in only one significant difference, in ratings of arousal for mutilation pictures. When presented in color, each stimulus content and dependent measure were given slightly higher arousal ratings (M = 15.8) than when pre-

Taken together, whether a picture was presented in color or grayscale had no observable impact on the pattern of affective reactions to IAPS pictures measured here, and the data reported below are averaged over participants viewing the pictures in color or grayscale.

Hedonic Valence

Consistent with previous findings, hedonic valence of the pictures significantly affected most dependent measures (see Table 1). It is not surprising that pleasant, neutral, and unpleasant pictures were each rated as differing in pleasure, and pleasant and unpleasant pictures were rated as more arousing than neutral pictures. Unpleasant pictures, averaged over specific contents, were also rated as slightly more arousing than pleasant pictures in this picture set.

As Table 1 indicates, measures of heart rate and skin conductance change varied with picture valence, with significantly greater initial cardiac deceleration and larger electrodermal reactions when viewing unpleasant or pleasant, compared with neutral, pictures. Moreover, when averaged over specific content, unpleasant pictures prompted somewhat more initial deceleration than did pleasant pictures, and pleasant pictures prompted significantly greater peak acceleration, compared with unpleasant pictures.

The shape of the heart rate waveform was clearly different when viewing pleasant or unpleasant pictures, as Figure 3 (left panel) illustrates. In both cases, the waveform was defined by an initial deceleration that was then sustained when viewing unpleasant pictures but that changed to relative acceleration when viewing pleasant pictures. Confirming this impression, the best-fitting function was cubic when viewing pleasant pictures ($r^2 = .93$) and quadratic when viewing unpleasant pictures ($r^2 = .98$). For neutral pictures, although the quartic function was the best fitting ($r^2 = .91$), heart rate changes across the viewing interval were small, and the function remained fairly flat.

As expected, the blink reflex was affected by picture valence (see Table 1). When averaged across specific contents, larger blinks were elicited when viewing unpleasant, compared with pleasant, pictures, and smaller blinks were elicited when viewing pleasant, compared with neutral, pictures. Replicating previous studies, facial EMG activity measured over the corrugator and zygomatic muscles varied with picture valence (see Table 1), with greater corrugator activity when viewing unpleasant, compared with pleasant, pictures, and greater zygomatic activity when viewing pleasant, compared with unpleasant, pictures.

Defensive Activation

To assess defensive reactivity as it varies with specific picture content, analyses were conducted by using picture content as a variable (eight contents: human attack, animal attack, mutilation, accidents, contamination, illness, loss, and pollution). Significant main effects of picture content were obtained in ratings of pleasure, arousal, and dominance, $F(7, 86) = 18.22$, $p < .001$; $F(7, 86) = 44.55$, $p < .001$; $F(7, 86) = 19.44$, $p < .001$, respectively. In general, all of these unpleasant contents were rated as similarly low in pleasure, as illustrated in Figure 4 (top panel). Slight differences indicated that pictures of mutilations were rated as most unpleasant, followed by scenes of human attack, accidents, loss, and illness, which did not differ from one another; pictures of contamination were rated as more unpleasant than pollution, which did not differ from pictures involving animal attack (see Table 2). Dominance ratings were also quite low and similar, with slight differences indicating that human attack, mutilations, and accidents were rated as lowest in dominance, and contamination and pollution as highest in dominance.

Unlike pleasure and dominance ratings, however, arousal ratings varied more dramatically across specific unpleasant contents, as illustrated in Figure 4 (middle panel). As Table 2 indicates, pictures of threat—either human or animal attack—and mutilation were rated as highest in arousal, followed by scenes depicting accidents. Less arousing contexts, including scenes of contamination and illness, followed scenes of illness, loss, and pollution.

Consistent with arousal ratings, a main effect of picture content was obtained for skin conductance change, $F(7, 85) = 5.34$, $p < .001$, with the largest skin conductance changes associated with viewing pictures involving animal attack and mutilations, followed by pictures of human attack, which were the three unpleasant picture contents rated as highest in arousal (see Table 2). Pictures of mutilation and animal attack also prompted significantly larger skin conductance responses than those evoked when view-

sented in black and white ($M = 13.9$), $t(92) = 2.24$, $p < .03$. In the absence of a significant Mode × Content interaction for unpleasant pictures, however, these t tests are not really warranted, and when a Bonferroni correction is used to control for error rate, even this single difference does not reach standard criterion for significance.

Table 1
Mean Reports of Rated Pleasure, Arousal, and Dominance and Physiological Reactions When Viewing Pleasant, Neutral, and Unpleasant Pictures, Averaged Across Specific Content

	Pleasant		Neutral		Unpleasant		
Dependent measure	*M*	*SD*	*M*	*SD*	*M*	*SD*	Valence main effect
Pleasure ratings (1–20)	15.6	2.2	10.3	1.6	4.9	2.8	$F(2, 91) = 281.0, p < .001$[abc]
Arousal ratings (1–20)	12.0	2.5	5.1	3.5	13.0	2.9	$F(2, 91) = 195.0, p < .001$[abc]
Dominance ratings (1–20)	13.5	2.8	13.3	3.8	7.0	3.2	$F(2, 91) = 132.0, p < .001$[bc]
Skin conductance Δ (log μS + 1)	.03	.04	.02	.03	.03	.03	$F(2, 92) = 5.5, p = .005$[ac]
Initial deceleration (bpm)	−4.2	1.9	−3.5	2.2	−4.9	2.0	$F(2, 91) = 21.7, p < .001$[abc]
Peak acceleration (bpm)	2.8	2.4	3.6	3.5	1.6	2.7	$F(2, 91) = 24.5, p < .001$[bc]
Blink magnitude (T score)	49.3	2.1	50.9	5.2	50.9	2.0	$F(2, 83) = -8.7, p < .001$[ab]
Corrugator EMG Δ (μV)	.42	1.00	.70	1.10	1.00	1.40	$F(2, 92) = 24.7, p < .001$[abc]
Zygomatic EMG Δ (μV)	.36	.69	.19	.75	.13	.46	$F(2, 92) = 7.7, p < .001$[b]
Orbicularis oculi EMG Δ (μV)	.81	.82	.50	.76	.63	.66	*ns*

Note. bpm = beats per minute; EMG = electromyographic.
[a] Comparison of pleasant versus neutral conditions is significant at $p < .05$. [b] Comparison of pleasant versus unpleasant conditions is significant at $p < .05$. [c] Comparison of unpleasant versus neutral conditions is significant at $p < .05$.

ing pictures of accidents, contamination, illness, loss, or pollution. As Figure 5 illustrates, only the most arousing picture contents elicited skin conductance changes that were larger than the moderate response elicited when viewing neutral pictures, mutilation versus neutral, $F(1, 94) = 26.92, p < .001$; animal attack versus neutral, $F(1, 94) = 17.42, p < .001$; human attack versus neutral, $F(1, 94) = 3.53, p = .06$.

Heart rate response did not significantly differ as a function of stimulus content across different unpleasant contents, with no reliable differences in the magnitude of either initial deceleration or peak acceleration (see Table 3). This is also apparent in Figure 2 (right bottom), in which the heart rate waveforms for unpleasant pictures are strikingly similar in shape and magnitude when viewing all unpleasant picture contents, with a large initial deceleration that is sustained across the viewing period.

Startle reflex magnitude varied as a function of specific unpleasant content, $F(7, 77) = 3.92, p = .001$. Pairwise analyses (see Table 2) indicated that pictures of animal attack, human attack, and contamination elicited equivalent, large blink reflexes. Pictures of mutilation also elicited relatively large blink reflexes and were not significantly different from those elicited either during animal attack or contamination but were slightly smaller than those elicited when viewing human attack. As Figure 6 illustrates, when unpleasant picture contents are ordered by mean arousal ratings, a linear relationship is obtained, which is supported by a significant linear trend, $F(1, 83) = 22.62, p < .001$. Compared with blinks elicited when viewing neutral pictures, unpleasant pictures rated lowest in arousal (i.e., pollution and loss) resulted in reflexes that were inhibited, $F(1, 84) = 4.68, p = .03$.

Appetitive Activation

Across the different pleasant picture contents, main effects of stimulus content were obtained in ratings of pleasure, arousal, and dominance, $F(6, 87) = 10.87, p < .001$; $F(6, 87) = 7.97, p < .001$; $F(6, 87) = 3.32, p < .01$, respectively. In general, all stimulus contents were rated similarly high in pleasantness, as illustrated in Figure 4 (top panel). Nonetheless, small but significant differences indicated that pictures of families were rated highest in pleasantness and that pictures of erotic couples and food were rated lowest in pleasantness (see Table 2). Dominance ratings were also fairly similar across pleasant contents, with scenes of families and nature rated as eliciting the highest dominance and pictures of adventure rated as eliciting the lowest dominance (see Table 2).

Like unpleasant pictures, however, pleasant pictures varied widely in rated arousal (Figure 4, middle panel), with erotic couples and opposite-sex erotica rated as most arousing, followed by pictures of adventure. Pictures of sports and food were rated as lower in arousal than adventure scenes but as more arousing than pictures depicting families, which, in turn, were rated as more arousing than nature scenes (see Table 2).

Again, similar to the case with unpleasant pictures, skin conductance changes paralleled arousal ratings, $F(6, 88) = 8.89, p < .01$, with erotic couples and opposite-sex erotica—the contents reported as highest

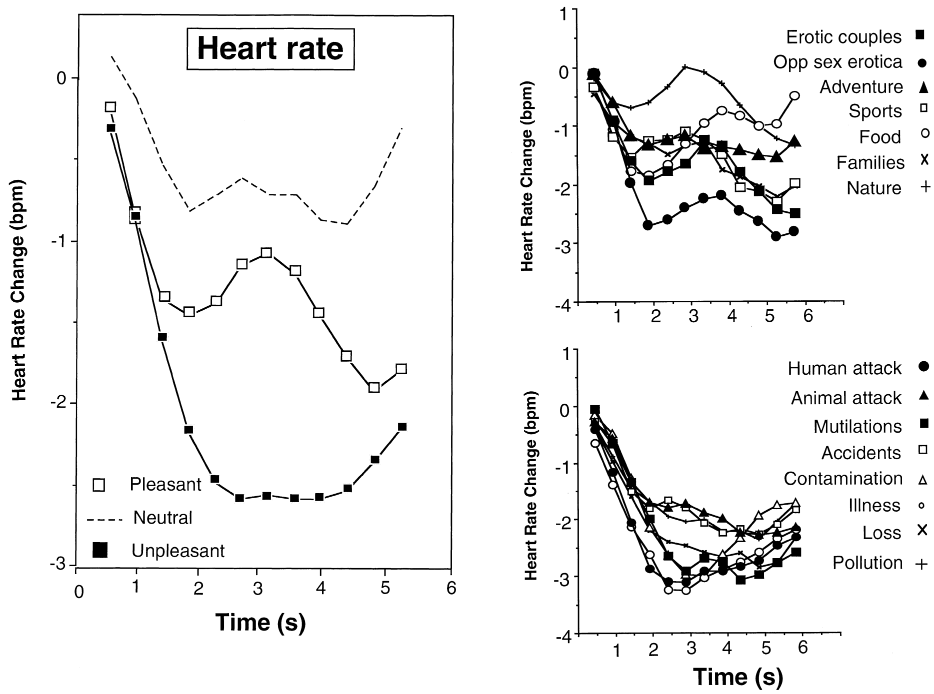

Figure 3. Averaged waveforms for heart rate change when viewing pleasant, neutral, and unpleasant pictures (left panel) indicate a sustained deceleratory response for unpleasant pictures but a triphasic (deceleratory, acceleratory, deceleratory) response when viewing pleasant pictures. Separate cardiac waveform plots when viewing specific pleasant (top right) and unpleasant (bottom right) picture contents indicate that sustained deceleration is obtained for all unpleasant contents, whereas the triphasic waveform predominates for pleasant contents. Opp = opposite.

in arousal—eliciting the largest changes in skin conductance (see Table 2). All other pleasant contents prompted moderate changes that did not significantly differ from one another. Again, as Figure 5 illustrates, only the most arousing contents elicited an increase in skin conductance activity over the moderate responses elicited by neutral pictures; erotic couples versus neutral, $F(1, 94) = 39.62$, $p < .001$; opposite-sex erotica, $F(1, 94) = 23.52$, $p < .001$.

As Figure 3 (top right) illustrates, the triphasic waveform associated with pleasant-picture viewing was similar for each of the pleasant contents. Unlike unpleasant pictures, however, stimulus content did affect the magnitude of both initial deceleration, $F(6, 87) = 2.34$, $p = .038$, and peak acceleration, $F(6, 87) = 3.12$, $p = .008$. Pictures of erotic couples resulted in the greatest initial deceleration and the least peak acceleration, and pictures of nature scenes resulted in the least initial deceleration and the greatest peak acceleration (see Table 3).

The main effect of specific picture content for pleasant pictures was marginal in analyses of the startle reflex, $F(6, 78) = 1.98$, $p = .08$, but the linear trend when contents were ordered by arousal ratings was strong, $F(1, 84) = 8.47$, $p = .005$, as Figure 6 illustrates. Pairwise comparisons indicated that erotica (couples and opposite sex) elicited the smallest blink reflexes, and pictures of sports and families, the largest (see Table 2).

Facial EMG Activity

For pleasant pictures, effects of stimulus content were significant for all of the facial EMG measures, including corrugator EMG, $F(6, 88) = 3.96$, $p = .001$; zygomatic EMG, $F(6, 88) = 3.43$, $p = .004$; and orbicularis oculi EMG, $F(6, 88) = 5.08$, $p = .000$. Figure 7 illustrates these data. For zygomatic and orbicularis oculi EMG activity, pictures of families elicited the most activity, with equivalent zygomatic activity elicited when viewing pictures of food (see Table 4). The least activity in zygomatic and orbicularis oculi EMG was obtained when viewing erotic couples, which also elicited the highest corrugator EMG changes, along with opposite-sex erotica and pictures of adventure.

For unpleasant pictures, main effects of stimulus content were found for corrugator EMG change, $F(7, 87) = 5.22$, $p < .001$, and orbicularis oculi EMG change, $F(7, 87) = 5.36$, $p < .001$, with pictures of mutilation eliciting the largest changes over the corrugator muscle (see Table 4), followed by pictures of contamination, and pictures of both mutilations and contamination eliciting large changes over the orbicularis oculi muscle, as Figure 7 illustrates. For corrugator EMG changes, all other picture contents prompted relatively smaller changes in corrugator EMG activity, with the least activity associated with pictures of animal attack. For orbicularis oculi EMG, the changes were somewhat more varied.

As the data in Figure 7 suggest, the configuration of EMG changes across the three sites measured here—corrugator, zygomatic, and orbicularis oculi—appears to differ as a function of specific picture content. To explore this, we conducted a cluster analysis that used the average change scores for each of the facial EMG measures for each of the 18 picture categories. A four-cluster solution summarized the data. A first cluster involved reactions to pictures of mutilation, contamination, and same-sex erotica, and involved large changes in corrugator EMG activity (mean change = 1.3 μV) and orbicularis oculi EMG activity (.76 μV), with little zygomatic EMG activity (mean change = .24 μV). A second cluster involved a similar pattern of changes, but of smaller magnitude, and included all of the remaining unpleasant stimulus contents (mean change = .85 μV, .37 μV, and .10 μV for corrugator, orbicularis oculi, and zygomatic EMG change, respectively). A third cluster was characterized by high zygomatic EMG activity (mean change = .76 μV) and orbicularis oculi EMG activity (mean = 1.08 μV) and included pictures of families and, to some extent, food. The fourth cluster consisted of small, equivalent changes at all three facial EMG sites (.45 μV, .51 μV, and .33 μV for corrugator, orbicularis oculi, and zygomatic EMG change, respectively) and included neutral pictures and all of the remaining pleasant contents.

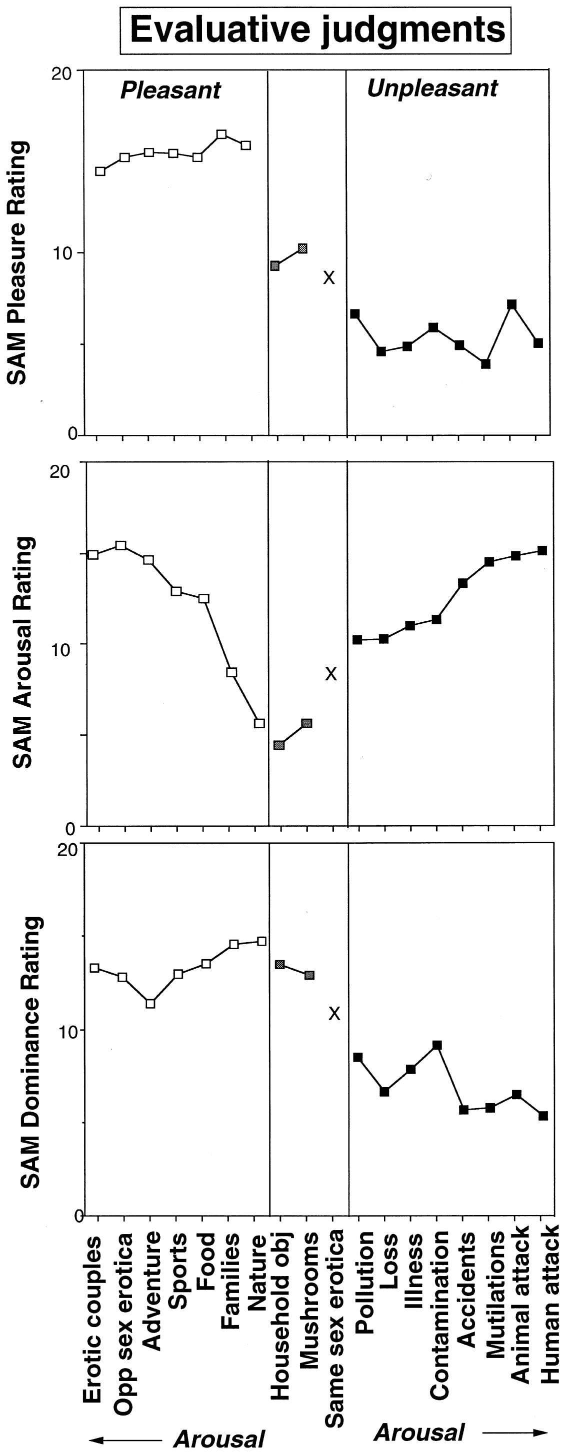

Figure 4. Evaluative judgments of pleasure (top), arousal (middle), and dominance (bottom) for the specific pleasant, neutral, and unpleasant picture contents investigated here. Specific stimulus contents are ordered by rated arousal within the pleasant (left to right: high to low arousal) and unpleasant (right to left: low to high arousal) picture sets. SAM = self-assessment manikin; Opp = opposite; obj = objects; open symbols represent pleasant picture contents; shaded symbols represent neutral picture contents; solid symbols represent unpleasant picture contents; x represents same-sex erotica.

Table 2
Results of Separate Pairwise Analyses Between Specific Picture Contents Within Unpleasant or Pleasant Pictures, Separately for Ratings of Pleasure, Arousal, and Dominance, Peak Skin Conductance Magnitude, and Startle Reflex Magnitude

	Dependent measures				
Content	Valence	Arousal	Dominance	SCR	Startle reflex
Unpleasant picture contents					
Human attack	b	a	a	b	a
Animal attack	d	a b	b c	a b	a b
Mutilations	a	b	a b	a	b c d
Accidents	b	c	a	b c	c d e
Contamination	c	d	e	b c	a b c
Illness	b	d f	d	b c	b c d
Loss	b	e	c	c	e
Pollution	d	e f	d e	b c	d e
Pleasant picture contents					
Erotic couples	c	a	b	a	a
Opposite sex	b	a b	b	a	a b
Sports	b	c	b	b	c
Adventure	b	b	c	b	b c
Food	b c	c	b	b	b c
Families	a	d	a	b	c
Nature	b	e	a	b	b c

Note. Within each of the separate dependent measures, letter sets are used to indicate the results of pairwise comparisons. Contents that share at least one letter do not significantly differ. SCR = skin conductance responses.

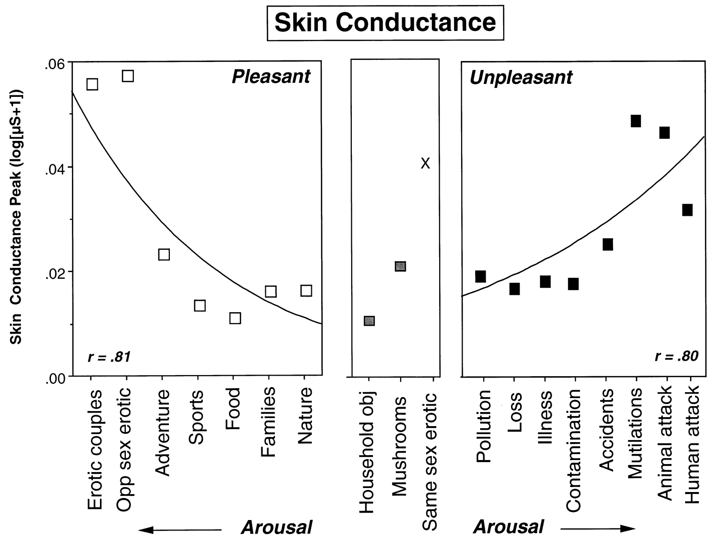

Figure 5. Mean skin conductance changes when viewing specific pleasant, neutral, and unpleasant picture contents are illustrated. Specific stimulus contents are ordered by rated arousal within the pleasant (left to right: high to low arousal) and unpleasant (right to left: low to high arousal) picture sets. Open symbols represent pleasant picture contents; shaded symbols represent neutral picture contents; solid symbols represent unpleasant picture contents; x represents same-sex erotica. Opp = opposite; obj = objects.

Neutral Picture Contents

Overall, there were few significant differences between the two neutral picture contents. Household objects were rated as somewhat less pleasant, $F(1, 92) = 4.69$, $p = .03$, and less arousing, $F(1, 92) = 13.3$, $p < .001$, than mushrooms.

Same-Sex Erotica

Pictures of same-sex erotica were rated as slightly unpleasant and moderately arousing (see Figure 3) and differed significantly from all other stimulus contents in terms of both rated pleasure and arousal. Despite moderate ratings of arousal, however, skin conductance changes when viewing attractively posed same-sex nudes were large (see Figure 5) and did not differ significantly from those evoked when viewing other picture contents rated as highly arousing, including erotic couples, human or animal attack, and mutilations. Corrugator EMG changes (see Figure 7) when viewing same-sex erotica were most similar in magnitude to those evoked when pictures of mutilation and contamination were viewed—contents that elicited the largest changes when viewing unpleasant pictures. Changes in orbicularis oculi or zygomatic EMG activity, however, did not significantly differ from those elicited when viewing neutral pictures.

Heart rate response to same-sex erotica was similar in both initial deceleration and peak acceleration to that obtained when viewing other erotic pictures and in fact, did not differ significantly in magnitude from the deceleratory and acceleratory heart rate responses to that elicited when viewing either erotic couples or opposite-sex erotica (see Table 3).

As Figure 6 illustrates, startle blink magnitude was quite small when people viewed pictures of same-sex erotica, and in fact, blinks elicited when viewing these pictures did not differ significantly from those elicited when viewing pictures of opposite-sex erotica or erotic couples. Blinks were significantly smaller when viewing pictures involving same-sex erotica compared with when viewing all other pleasant contents, including nature, babies, food, adventure, and sports.

Discussion

The data are consistent with a motivational view of emotional organization, which holds that affective reports and behavior are determined in significant part by the activation of appetitive and defensive motive systems (Lang et al., 1997; see also Cacioppo et al., 1999; Davidson, Jackson, & Kalin, 2000). As proposed by several theorists (e.g., Konorski, 1967; Rolls, 2000), these motive systems are founded on

Table 3
Measures of Heart Rate Reactivity When Viewing Specific Unpleasant, Neutral, and Pleasant Picture Contents

Content	Initial deceleration (Seconds 1–3)	Peak acceleration (Seconds 4–6)	IAPS no.
	Unpleasant pictures[a]		
Human attack	–5.46	1.06	3530, 6260, 6350, 6510
Animal attack	–4.45	2.09	1050, 1120, 1300, 1930
Mutilation	–4.85	1.23	3060, 3080, 3110, 3130
Accident	–4.47	1.98	9050, 9600, 9910, 9920
Contamination	–4.88	1.73	7360, 7380, 9300, 9320
Illness	–5.46	1.47	2710, 3180, 3230, 3330
Loss	–4.89	1.45	2205, 2900, 9220, 9421
Pollution	–4.66	2.10	9110, 9120, 9330, 9830
	Neutral pictures		
Household object	–3.34	3.79	7010, 7030, 7040, 7080
Mushroom	–3.70	3.48	5500, 5510, 5520, 5530
	Pleasant pictures		
Nature	-3.50_{c}	3.89_{d}	5000, 5760, 5780, 5891
Families	-4.21_{ab}	2.43_{abc}	2070, 2080, 2340, 2360
Food	-4.50_{ab}	3.51_{ad}	7330, 7350, 7400, 7470
Sports	-4.34_{ab}	2.77_{ab}	8190, 8200, 8210, 8470
Adventure	-3.95_{bc}	3.12_{ad}	8170, 8180, 8370, 8490
Erotic couples	-4.83_{a}	1.67_{c}	4650, 4660, 4680, 4690
Opposite-sex erotica	-4.33_{ab}	2.04_{bc}	4210, 4220, 4250, 4290[b]
			4470, 4490, 4510, 4520[c]
Same-sex erotica	–4.68	1.32	4470, 4490, 4510, 4520[b]
			4210, 4220, 4250, 4290[c]

Note. All values are mean changes in beats per minute from a 1-s baseline preceding picture onset. Stimulus contents that share any subscript letters do not significantly differ. IAPS = International Affective Picture System.
[a] Specific pairwise comparisons were conducted only on each dependent measure (i.e., initial deceleration, peak acceleration) for pleasant pictures, as the main effect of stimulus content was only significant for pleasant pictures. [b]Data for men. [c]Data for women.

simple reflexive responses to primary reinforcers that evolved to facilitate the survival of individuals and species. In this view, unpleasant affects in humans are associated with defense system activation, and pleasant affects with activation of the appetitive system. Recent neuroscience research has defined neural circuits in the mammalian brain that prompt specific somatic and autonomic responses associated with motivated behavior. In the present research, we observed similar reflex reactions in humans viewing pleasant and unpleasant picture stimuli.

The experiment focused on evocative picture contents that were held to more or less strongly engage either appetite or defense. In general, responses associated with activation and metabolic arousal were augmented when participants viewed material with high motivational significance, regardless of motivational direction. Furthermore, these effects were not different, for any measure, whether pictures were presented in color or grayscale. This finding is consistent with neural imaging research showing that the functional changes in the brain evoked by affective pictures are specific to the semantic content and are not secondary to formal pictorial features such as brightness, complexity, or color (Bradley et al., 2001; Junghoefer, Bradley, Elbert, & Lang, 2001).

As anticipated, not all measures discriminate defensive from appetitive motive dispositions, and not all measures vary monotonically with motive intensity. It is presumed that functional reflexes appeared at different times in evolutionary history, adapted to specific environmental demands—threats or appetites—and that they are organized differently in response to unique input. Depending on the context, defensive and appetitive systems support orienting to relevant input, information gathering, functional inhibition (e.g., freezing), and metabolic and motor mobilization, as well as a range of overt survival actions.

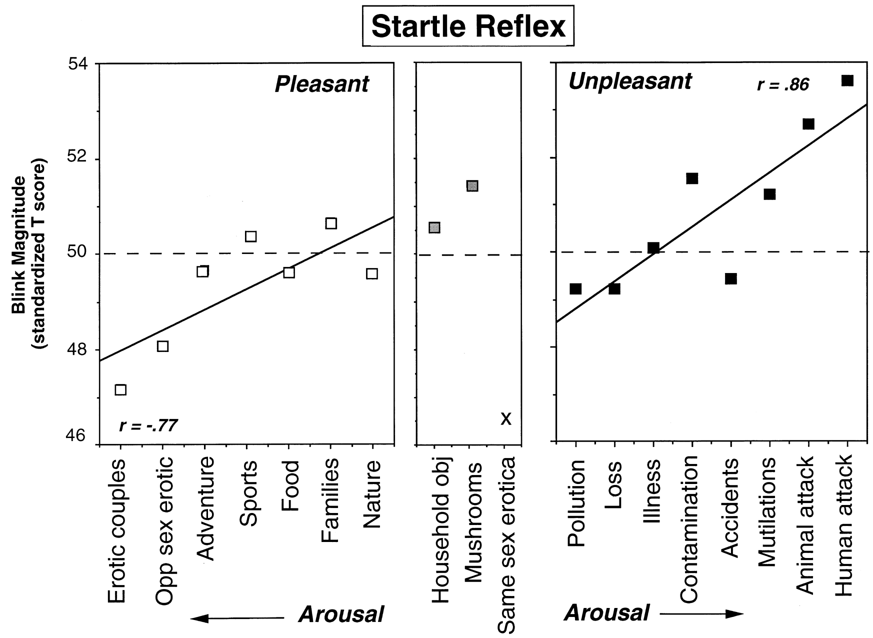

Figure 6. Mean startle blink magnitude when viewing specific pleasant, neutral, and unpleasant picture contents are illustrated. Specific stimulus contents are ordered by rated arousal within the pleasant (left to right: high to low arousal) and unpleasant (right to left: low to high arousal) picture sets. Open symbols represent pleasant picture contents; shaded symbols represent neutral picture contents; solid symbols represent unpleasant picture contents; x represents same-sex erotica. Opp = opposite; obj = objects.

In humans, furthermore, affects are imbedded in a complex cultural context and may be in part inhibited or used instrumentally in the context of social communication. The present data show that in general, reports of affective arousal are closely related to the degree of motive system engagement, as defined by autonomic and somatic reflex responses. These findings also highlight unique differences in affective patterns, determined by specific stimulus content.

Defensive Motivation

The defense cascade model (Lang et al., 1997) posits that defense is a staged response that proceeds from oriented attention (e.g., distant threat) to defensive action (e.g., imminent attack), with the intensity of motivational activation related to the nature of the stimulus context. We predicted that pictures representing attack—either human or animal—and pictures of mutilated bodies would prompt the greatest evidence of defensive activation, as these stimulus contents are the most threatening from a survival perspective. The data were consistent with this view. These contents were rated as the most arousing, elicited the largest skin conductance responses, and evoked the greatest startle reflex potentiation.

Modest skin conductance responses were elicited for most other unpleasant picture contents, consistent with the notion that electrodermal activity is a component of the orienting response (Maltzman & Boyd, 1984) that occurs in response to any novel stimulus. More substantial increases in the magnitude of the skin conductance responses were only obtained for the most highly arousing unpleasant pictures, including attack and mutilation, suggesting that an increment over obligatory orienting relies on reaching a certain threshold of defensive activation.

Heart rate during aversive-picture viewing was characterized by a large initial deceleration, sustained for most of the interval, similar for all aversive contents. Cardiac deceleration in the context of aversive-picture viewing is, in fact, a prototypical finding in psychophysiological investigations (e.g., Klorman et al., 1977; Hare, Wood, Britain, & Shadman, 1970) and could be considered at odds with the notion that defensive responding is associated with cardiac acceleration (Graham, 1979). In fact, sustained cardiac deceleration is the most common initial reaction to a threat stimulus—fear bradycardia—elicited in most animals, for example, when first confronting a predator at a distance (Campbell, Wood, & McBride, 1997).

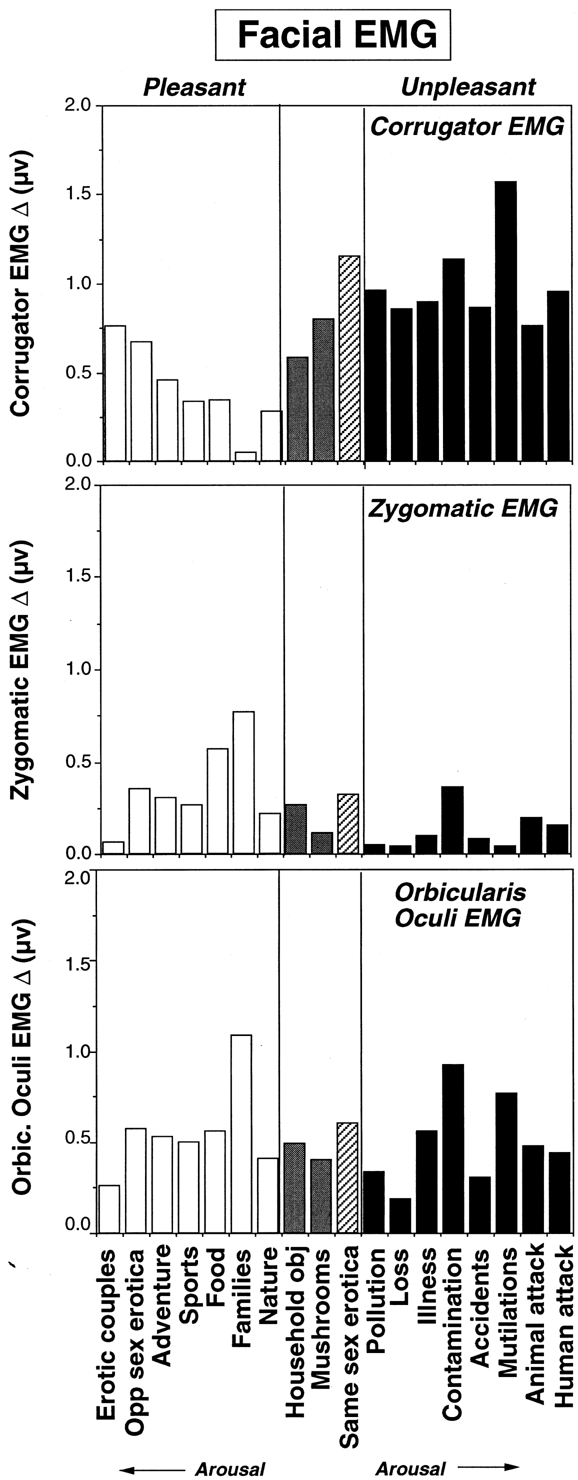

Figure 7. Mean changes in corrugator electromyographic (EMG) activity (top), zygomatic EMG activity (middle), and orbicularis oculi EMG activity (bottom) when viewing specific picture contents are illustrated. Specific stimulus contents are ordered by rated arousal within the pleasant (left to right: high to low arousal) and unpleasant (right to left: low to high arousal) picture sets. Open bars represent pleasant picture contents; shaded bars represent neutral picture contents; hatched bars represent same-sex erotica; solid bars represent unpleasant picture contents. Orbic. = orbicularis; Opp = opposite; obj = objects.

According to the defense cascade model, sustained cardiac deceleration is indicative of continued attention to an aversive stimulus and occurs when the defensive system is moderately activated but action is not imminent. In picture viewing, a shift to cardiac acceleration when viewing threatening pictures would indicate an unusually high level of defensive activation (rare for symbolic stimuli). It has generally been observed only when pictures have an unusually high personal threat value, for instance, as when phobic individuals view pictures of the phobic object (Hamm et al., 1997). Interestingly, the degree of both early and late deceleration in picture viewing was equivalent across different aversive contents (and greater than for neutral contents), suggesting that even at low threat levels, defensive activation prompts heightened orienting and information intake.

Fear bradycardia is attenuated by the administration of pharmacological agents that block cholinergic activity, indicating that the cardiac deceleration associated with defensive activation is parasympathetically mediated (Campbell et al., 1997). Recently, researchers have suggested that palmar skin conductance may also be, in part, parasympathetically determined (Guyton & Hall, 1996), which may be the mechanism for the modest orienting responses found when viewing less arousing, unpleasant contents. As defensive activation increases, however, autonomic balance shifts, adding a stronger sympathetic component that appears to drive substantial conductance increases. Pictures of attack and mutilation illustrate this higher level of activation in the current study. The fact that, unlike the conductance response, cardiac deceleration remains relatively constant for all aversive contents indicates autonomic coactivation in aversion and illustrates the basic tenet of the defense cascade model: Different reflex systems change at different levels of motivational engagement. The increase in sympathetic involvement, prompted here uniquely by the attack and mutilation stimuli, prompts an abruptly

Table 4
Results of Pairwise Analyses Between Specific Picture Contents Within Unpleasant and Pleasant Pictures, Separately for Each Facial EMG Measure

Content	Corrugator EMG	Zygomatic EMG	Orbicularis EMG
Unpleasant picture contents[a]			
Human attack	b c		c e
Animal attack	c		c d
Mutilations	a		a b
Accidents	b c		d f
Contamination	b		a
Illness	b c		b c
Loss	b c		f
Pollution	b c		d e f
Pleasant picture contents			
Erotic couples	a	d	c
Opposite sex	a	b c	b
Sports	b	c d	b
Adventure	a b	b c d	b
Food	b	a b	b
Babies	c	a	a
Nature	b c	c d	b c

Note. For each dependent measure, letter sets are used to indicate the results of all pairwise comparisons. Contents that share at least one letter do not significantly differ. EMG = electromyographic.
[a] Pairwise analyses were not conducted for zygomatic EMG activity when participants viewed unpleasant pictures, as the main effect of stimulus content was not significant.

heightened electrodermal response. This occurs, however, while the participant is still clearly in a predominantly attentional phase, as indicated by the bradycardia. A shift to cardiac acceleration would require yet greater motivational activation, with clear motor mobilization (i.e., the phobic individual might actually pull off the electrodes and leave the laboratory).

The defense cascade model holds that the startle reflex also varies with the level of defensive activation. When specific aversive contents were ordered by rated arousal, a strong linear relationship was obtained between judged affective intensity and startle magnitude, with the blink reflex increasingly potentiated as reported arousal increased (see also Cuthbert et al., 1998). In the present view, probe startle magnitude is determined by the extent to which the motor system is either inhibited in the service of attention and information gathering or primed for defensive action. Thus, relative to neutral stimuli, moderately arousing, unpleasant contents (e.g., pollution, loss) primarily prompt a passive, highly attentive posture. Sensory intake is primary and motor behavior in general inhibited (Obrist, 1981), which is reflected in a reduced probe startle reflex.

As stimuli become more threatening, however, the system begins to tilt toward preparation for action, including priming of defensive reflexes, indicated by increasing startle potentiation. Thus, startle magnitude is a summation of reciprocal processes determined by the level of defense system engagement, that is, the extent to which passive attention or defensive action dominates (Lang et al., 1997). As with skin conductance, the largest startle responses observed here were for attack pictures. Unlike conductance reactivity, however, increased startle did not abruptly increase only for the most threatening contents, but rather, reflex potentiation increased progressively as motive strength (indexed by arousal ratings) increased for unpleasant picture contents.

Contamination pictures (spoiled food, feces, and other "disgusting" objects) elicited startle potentiation that was not significantly different in magnitude from that elicited when viewing threatening stimuli or mutilated bodies. From a motivational perspective, both mutilation and contamination contents are likely to be threatening to an organism, as they are potential vehicles for disease, possibly deadly if ingested. However, both arousal reports and the conductance data suggest that mutilation stimuli engage more intense defense activation. As noted, blink magnitude is modulated by two presumably independent processes: (a) an inhibitory process associated with increased attention and (b) a facilitory process related to the intensity of defensive activation. Scenes of mutilation may prompt smaller relative blink magnitude because of a larger contribution of the inhibitory attentional process.

Other data are consistent with the notion of greater attention to mutilation pictures. For instance, the P3 component of the event-related potential to a probe stimulus is often reduced when attention is directed away from an eliciting stimulus. During picture viewing, the startle probe P3 is significantly smaller when viewing mutilations, compared with other unpleasant picture contents (Schupp, Cuthbert, Bradley, Birbaumer, & Lang, 1997), and this is true throughout the viewing interval (Codispoti, Bradley, Cuthbert, Montebarocci, & Lang, 1998). Greater attention to mutilation pictures recalls the gaper phenomenon, in which traffic slows and attention is captured by a roadside accident that might involve mutilation or death. In fact, relatively inhibited reflexes were also obtained in the current study when accident scenes were viewed, consistent with an interpretation of heightened interest for these contents. However, such a gaper's effect is not part of the folklore for scenes of contamination (e.g., vomit, feces); rather, speedy withdrawal or avoidance is the more characteristic response. Taken together, the data are consistent with data and theory suggesting that heightened attention can reduce the magnitude of blink potentiation to highly arousing, unpleasant contexts.

Appetitive Motivation

We contrasted pictures representing strong appetitive motivation—pictures of erotic couples and opposite-sex erotica—with contents judged similarly pleasant, but less arousing or immediately engaging. As with defensive motivation, we expected that the motivationally most intense stimuli would have the greatest impact on somatic and autonomic reflexes. Consistent with this view, pictures involving erotic stimuli prompted the highest arousal ratings, elicited the largest skin conductance changes, and evoked the most inhibited startle reflexes.

Modest skin conductance responses were obtained when viewing pleasant pictures, similar to those observed when viewing less arousing, unpleasant pictures. For pleasant stimuli, an additional increment in conductivity was found only for erotic contents, and even picture contents rated as similarly arousing (e.g., adventure) did not evidence these effects. The data again suggest that a threshold of motivational activation is necessary before greater sympathetic activity, associated with high drive, is initiated. It is reasonable to assume that personally relevant appetitive cues (other than erotic) may also prompt strong sympathetic engagement. For instance, Hillman et al. (2000) found significant evidence of higher electroencephalographic activation in sports fans viewing home-team–relevant compared with home-team–irrelevant pictures. Similar effects may be expected for skin conductance. However, other than erotic stimuli, few positive picture contents reliably evoke high levels of electrodermal responding in unselected participants.

The heart rate response to pleasant pictures was characterized by a modest initial deceleration, which was most pronounced for the most arousing contents (i.e., erotic stimuli) and least pronounced for the least arousing contents (i.e., nature, families). As predicted, highly arousing pleasant pictures prompted noteworthy heart rate deceleration, consistent with a hypothesis of interest and orienting that was not apparent for pleasant pictures rated lower in arousal. Furthermore, the cardiac waveform for pleasant stimuli showed a clear midinterval acceleration that was consistent across contents. This acceleratory event was highly reliable, but its interpretation is not completely clear. It is possible that this response indicates success of a recognition–encoding process, as we have found that repeated presentation of the same pictures accentuates this cardiac component (Bradley, Lang, & Cuthbert, 1993) while reducing the initial deceleratory response. In the current study, the greatest midinterval acceleration occurred when viewing pictures of nature and food. These stimulus contents may be more readily perceptually resolved than pictures of families or sports scenes, which portray novel, unique individuals who require more sustained processing.

The magnitude of the startle reflex also varied with the intensity of appetitive motivation, but inversely to that found for the defense system. Erotic stimuli, the most arousing content, elicited the most inhibited probe startle reflexes. Moreover, when specific pleasant contents were ordered by arousal ratings, a strong linear trend was obtained, with the smallest reflexes associated with viewing the most arousing pictures. Blink inhibition during appetitive perception could reflect the reciprocal inhibition between motive systems proposed by some theorists (e.g., Konorski, 1967), in which greater appetitive drive is associated with increasing inhibition of defensive reflexes, such as the startle response (and augmentation of consonant reflexes such as salivation). Alternatively, reflex inhibition during pleasant-picture viewing may also reflect, in part, sustained motivated attention (Bradley, Cuthbert, & Lang, 1993; Lang et al., 1997) in which responses to secondary probes are diminished when attentional resources are allocated elsewhere. If caused by motivated attention, the data suggest that heightened attention persists at higher levels of activation for appetitive, compared with defensive, stimulation, at least in the picture-viewing context.

Same-Sex Erotica

Pictures of members of the same sex in erotic poses were judged somewhat unpleasant and as low in emotional arousal and elicited a facial expression consistent with disgust (e.g., concurrent activity over the corrugator, zygomatic, and orbicularis oculi muscles). Autonomic and reflex indices of emotion, however, were consistent with those evoked by other erotica stimuli (opposite sex and couples)—significant cardiac deceleration, augmented skin conductance responses, and greatly inhibited startle reflexes. Thus, although an aversive reaction was communicated through reports and facial expressions, physiological indices suggest these stimuli strongly activate appetitive motivation. The lack of concordance between evaluative judgments and autonomic reaction for same-sex erotica was, in fact, unique among the picture contents sampled here. This may reflect a social adaptation. Appetitive reactions to erotically portrayed members of the same sex are generally frowned upon in predominantly heterosexual Western culture. The fact that both evaluative judgments and facial expression differed dramatically from autonomic and reflex measures is consistent with the view that the former measures are, to some extent, voluntarily controlled and thus modifiable by sociocultural norms.

Viewing members of the same sex in erotic positions could prompt appetitive activation by intrinsic resemblance to the representations of the participant in erotic contexts or because pictures of erotic members of the same sex cue memory representations dealing with erotic behavior in general. Distinguishing between these alternatives relies on future research in which gender and sexual preferences are carefully assessed. In any event, these data define same-sex erotic pictures as a dramatic instance of response system discordance (Lang, 1971).

Tactics in Emotional Expression: Facial EMG

Whereas autonomic and reflex measures covaried with intensity of motivational activation, the pattern of facial EMG activity more closely related to the specific semantic content of pictures. For example, larger changes in orbicularis oculi and corrugator EMG activity were found when viewing pictures of contamination, mutilations, and same-sex erotica, compared with viewing other pictures rated as unpleasant, which is interpreted as consistent with an expression of disgust. Tassinary et al. (1989), for example, reported that increased corrugator EMG was associated with a "nose wrinkle," which is part of the disgust expression, and IAPS pictures of both contamination and mutilation reliably yield reports of disgust in studies of emotional evaluation (see Bradley, Lang, Codispoti, & Sabatinelli, 2001).

An expression suggestive of smiling involved concurrent activity over the zygomatic and orbicularis oculi sites and occurred mainly for pictures of families and food. These data are consistent with the idea that an authentic Duchenne smile (Ekman, Davidson, & Friesen, 1990), which is thought to involve activity over both the zygomatic and orbicularis oculi muscles, is elicited during picture viewing, but only for specific contents. An expression involving changes only in zygomatic EMG activity, that is, an unfelt smile (Ekman et al., 1990), never occurred during picture viewing. Modest changes in orbicularis oculi EMG activity were obtained for most pleasant picture contexts (excluding erotica), however, suggesting that small changes in this muscle may be indicative of a smile that primarily involves the eyes.

Facial expressions are, of course, highly varied (e.g., smiling, frowning, disgust, anger, etc.) and play a major role in social communication. They are related to threat displays and distress, courtship, and sexual signals deployed by social animals and extensively studied by ethologists. Unlike autonomic and somatic reflexes that reflect degree of motivational engagement, they are tactical responses to the local context and can be intentionally modulated in humans. We have previously distinguished between strategies (engaging a motive system) and tactics (local contextual response) in emotion (Lang, Bradley, & Cuthbert, 1990). At a strategic level, a stimulus activates appetitive or defensive motivation with some degree of intensity. The resulting response is, however, determined in large part by the specific context of activation. Our data suggest that facial expression is predominantly tactical. Thus, although corrugator muscle was activated consistently for unpleasant stimuli, it did not vary systematically with affective arousal. The facial muscles measured here varied explicitly with the specific, local context represented in the picture—unlike, for example, the startle reflex, which covaried reliably with motive intensity. In the context of picture perception, in which gross actions such as fight or flight are constrained, facial expression is a primary tactical response.

Summary and Conclusions

In this study, we assessed evaluative judgments and a variety of physiological responses in a large sample of participants viewing affective pictures. In general, the pattern of psychophysiological reactions was consistent with the hypothesis that emotion is organized motivationally by appetitive or defensive systems that vary in intensity of activation and that involve a transition from attention to action. Because the picture-viewing context encourages a passive, perceptual intake of cues (with little demand for response output aside from affect evaluation), the measured physiology indexed a primarily attentional set (e.g., modest electrodermal responses, initial cardiac deceleration) for all affective contents. Picture contents representing primary reinforcers, however, including threatening or erotic stimuli, were presumed to more strongly activate motive systems and, consistent with this, were reported as more arousing and prompted larger electrodermal responses, as well as significantly greater startle modulation (defensive potentiation or appetitive inhibition). As anticipated, not all responses covaried monotonically, or changed in the same way, with increases in affective arousal judgments (i.e., inferred motivational engagement) of the picture contents. Overall, the findings suggest that affective responses serve different functions—mobilization for action, attention, and social communication—and reflect the motivational system that is engaged (defensive or appetitive), its intensity of activation, as well as the specific emotional context.

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The Publications and Communications Board has opened nominations for the editorships of ***Journal of Experimental Psychology: Animal Behavior Processes, Journal of Personality and Social Psychology: Personality Processes and Individual Differences, Journal of Family Psychology, Psychological Assessment,*** and ***Psychology and Aging*** for the years 2004–2009. Mark E. Bouton, PhD, Ed Diener, PhD, Ross D. Parke, PhD, Stephen N. Haynes, PhD, and Leah L. Light, PhD, respectively, are the incumbent editors.

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