Pain and Emotion: Effects of Affective Picture Modulation
MARY W. MEAGHER, PHD, RANDOLPH C. ARNAU, MS, AND JAMIE L. RHUDY, MS

Objective and Methods: Two experiments examined the impact of viewing unpleasant, pleasant, and neutral photographic slides on cold-pain perception in healthy men and women. In each experiment, participants viewed one of three slide shows (experiment 1 = fear, disgust, or neutral; experiment 2 = erotic, nurturant, or neutral) immediately before a cold-pressor task. Skin conductance and heart rate were recorded during the slide shows, whereas visual analog scale ratings of pain intensity and unpleasantness thresholds and pain tolerance were recorded during the cold-pressor task. Results: Viewing fear and disgust slides decreased pain intensity and unpleasantness thresholds, but only the fear slides decreased pain tolerance. In contrast, viewing erotic, but not nurturant, slides increased pain intensity and unpleasantness threshold ratings on the visual analog scale in men, whereas neither nurturant nor erotic slides altered pain tolerance. Conclusions: These results are consistent with a motivational priming model that predicts that unpleasant affective states should enhance pain and that pleasant affective states should attenuate it. Key words: emotion induction, cold pressor, pain modulation, pain tolerance, pain threshold, affect.

ANOVA = analysis of variance; ER-SCR = event-related skin conductance response; HR = heart rate; IAPS = international affective picture system; M-VAS = mechanical visual analog scale; PAG = periaqueductal gray; SAM = self-assessment manikin; SCR = skin conductance response; VAS = visual analog scale.

INTRODUCTION

It is generally believed that unpleasant emotional states augment the experience of pain (1–9) whereas pleasant emotional states diminish it (9–17). Although this view is widely accepted, relatively little research has been done to clarify how emotional states modulate pain. Indeed, several theoretical and empirical accounts predict the reverse relationship, that unpleasant emotional states such as fear and anxiety may attenuate pain (17–32).

The relationship between unpleasant emotional states and pain has been described by several theories (4, 18, 21, 28, 30–36); however, none of these models provide a fully integrated account that includes a range of emotional states (eg, pleasant). Furthermore, these theories fail to explain how the affective dimensions of valence (pleasentness) and arousal interact to alter pain perception. To develop a more comprehensive model of pain modulation, it may be useful to consider a recent theory of motivational priming (37). Building on the work of Konorski (39) and others (39–41), Lang (37) proposes that emotions can be viewed as action dispositions that are governed by two opponent motivational systems. One system is appetitive (eg, sexual, nurturant) and engenders approach behaviors, and the other system is aversive (protective, defensive) and promotes avoidance behaviors (38). Considerable evidence indicates that prior activation of these systems modulates defensive behaviors (38, 43–52). Supporting this, defensive behaviors, such as the startle reflex, increase in magnitude when the aversive system is primed by viewing unpleasant images, anticipation of shock, or shock exposure (50–52). Conversely, this defensive response is inhibited when the appetitive system is primed by viewing pleasant images (52). Moreover, the opponent effects of affective valence on defensive behavior become even more pronounced with highly arousing pleasant and unpleasant pictures (38), suggesting that arousal modulates the level of activation of both the appetitive and aversive systems.

Although motivational systems are thought to modulate a range of defensive behaviors, Lang has focused on the startle reflex because the neural basis of this defensive response has been extensively studied (38, 49–51). Interestingly, the same neural circuit that mediates affective modulation of the startle reflex has been implicated in pain modulation. Neuroanatomical studies have shown that the amygdala and PAG are critical components of the aversive circuit that modulates both startle (43, 44) and pain (45–49, 53, 54). For example, animal studies have shown that prior exposure to conditioned and unconditioned aversive stimuli alters startle and pain reactivity and that amygdala and PAG lesions block these modulatory effects (45–49). Given this common neural substrate, we examined whether activation of the aversive and appetitive motivational systems influences pain perception in humans. Our application of motivational priming theory predicts that exposure to unpleasant images should activate the aversive system and amplify pain (hyper-
algesia), whereas pleasant images should activate the appetitive system and inhibit pain (analgesia).

The impact of emotional states on pain perception were investigated in two experiments. To manipulate the subject's emotional state, we presented graphic photographic slides from the IAPS (55) that evoke both unpleasant (ie, fear and disgust) and pleasant (ie, nurturant and erotic) emotions that vary along the affective dimensions of valence and arousal. Prior validation studies indicate that these stimuli provide an effective method for evoking emotional reactions (38, 56). Although viewing slides is a relatively subtle manipulation, physiological reactivity has been shown to vary as a function of rated valence and arousal. To verify that the slide shows evoked emotional states comparable to prior norms (56), subjects rated the degree of pleasantness (valence), arousal, and the specific emotions elicited by the slide shows. Physiological reactivity was also assessed by recording HR and skin conductance during the slide show. Immediately after subjects finished viewing the slides, they were exposed to a cold-pressor task. Three measures of pain were assessed: (1) pain intensity threshold ratings, (2) pain unpleasantness threshold ratings, and (3) pain tolerance. Pain intensity ratings are thought to reflect the sensory-discriminative dimension of pain, whereas pain unpleasantness ratings and tolerance are believed to reflect the affective-motivational dimension of pain (9, 57). In experiment 1, subjects viewed either fear, disgust, or neutral slide shows. In experiment 2, subjects viewed either erotic, nurturant, or neutral slide shows. Pain sensitivity was tested after the slide presentation to minimize the effects of distraction.1

METHODS

Subjects

Male and female students participated for research credit in an Introductory Psychology class. Experiment 1 included 50 subjects tested during late fall and early winter (mean age = 19.4 years). Sixty-two percent of the subjects were female, and 38% were male. Ethnicity was primarily white (70%), followed by Hispanic (14%), other (10%), and African American (6%). Experiment 2 included 70 students tested during the late spring and summer (mean age = 19.4 years). The sample consisted of about equal percentages of male (51%) and female (49%) subjects, and ethnicity was primarily white (73%), followed by Hispanic (15%), other (9%), and African American (3%). Because ambient room temperature was generally warmer during the summer months and because baseline pain sensitivity scores vary with room temperature (subjects generally exhibit increased cold pain sensitivity when tested in a warm room; see Ref. 58), the results from experiments 1 and 2 could not be combined. Subjects with any of the following conditions were excluded: circulatory, cardiovascular, or neurological disorders; current analgesic, antidepressant, anti-anxiety, or tobacco use; chronic pain; diabetes; and snake or spider phobias. To evaluate gender differences, the male/female ratio was held constant for each condition.

Stimulus Materials

The IAPS (55, 56) is a collection of photographic images classified into affective categories using average ratings of affective valence (pleasantness) and arousal (56). Normative ratings on these dimensions were used to classify each slide as either pleasant, unpleasant, or neutral. These ratings have good stability and covary with emotional behaviors and physiological events such as HR and SCR (38, 56, 59). In terms of valence, the groups can be further subdivided (38, 60). For example, the pleasant group includes erotic and nurturant categories, whereas the unpleasant group includes disgust and fear categories. The IAPS slide numbers for each affective condition are as follows: fear (1040, 1050, 1070, 1120, 1200, 1300, 6230, 6530, 6540, 6560); disgust (3000, 3010, 3030, 3060, 3100, 3110, 3120, 3130, 3140, 3150); erotic (4650, 4660, 4670, 4680, 4611, 4652, 4653, 4659, 4690, 4810); nurturant (1440, 1460, 1710, 1750, 2040, 2050, 2070, 2080, 2160, 2300); and neutral (2210, 5510, 7000, 7010, 7030, 7040, 7050, 7080, 7090, 7150). To control for the effects of arousal, we selected erotic, fear, and disgust slides with similar arousal ratings (mean arousal: erotic = 6.36, fear = 6.71, and disgust = 6.62; response scale = 0–9) but markedly different valence ratings (mean valence: erotic = 6.86, fear = 3.13, disgust = 1.75). In contrast, we selected nurturant slides with high valence ratings (mean = 8.15) but intermediate arousal ratings (mean = 4.75), and neutral slides with intermediate valence (mean = 4.93) and low arousal (mean = 2.01) ratings. In each experiment, subjects viewed slide shows consisting of 10 slides; each slide was presented for 9 seconds. The order of presentation of slides within each show was randomized to control for order effects. The subject was seated 6 feet from the projected image, which was 1'5" high × 2'4" wide.

Apparatus and Response Measurement

Collection of physiological, pain threshold, and pain tolerance data as well as the presentation of the slides were computer automated using a 486 PC and an AT-MIO 16-2L data acquisition card (National Instruments) running LabVIEW. Physiological signals were amplified by a Grass Instruments model 7E polygraph equipped with low-level DC preamplifiers and model 7DA driver amplifiers. A Kodak 4600 projector was used to present the slides.

Cold Pressor

The cold-pressor apparatus consisted of an insulated cooler filled with circulating 2°C ice water. A screen separated the subject's hand from the crushed ice and pump. Subjects immersed their hand and forearm by lowering an arm cradle into the water. A mercury switch attached to the cradle sent a signal to the computer, which timed the duration of hand immersion. A 4-minute cutoff was used to minimize stress.
Mechanical VASs

During the cold-pressor test, subjects rated the sensation of the pain using an M-VAS (57). The M-VAS is a physical instrumentation analog of a pencil-and-paper visual analog scale. Two such scales were used to measure two dimensions of pain, intensity and unpleasantness. Both scales consisted of a 100-mm line. The intensity scale was anchored with “no pain at all” at the zero end and “the most intense pain imaginable” at the 100-mm end. The unpleasantness scale was anchored with “not at all unpleasant” at the zero end and “the most unpleasant pain imaginable” at the 100-mm end. Subjects moved a sliding lever along the line to indicate their pain ratings. This sent a proportional voltage to the computer that allowed for continuous “real-time” pain ratings (58–62).

Manipulation Checks

To verify that the slides elicited the targeted emotional states, subjects rated their subjective emotional reaction to the slide show using the SAM (63, 64) and an emotion scale. The SAM consists of two sets of five cartoon pictographs depicting different levels of affective valence and arousal. For each dimension, subjects were instructed to place an “X” on or between the figures that best described their experience during the slide show. This yielded ratings ranging from 0 to 9 for each dimension. This was the same rating system used to generate IAPS norms, but it was used as a manipulation check in this study. The emotion scale consists of a list of eight emotion adjectives (angry, disgusted, fearful, happy, sexually aroused, sad, surprised, and neutral). Subjects rated the degree to which they experienced each emotion during the slide show using a five-point scale ranging from 1 (“not at all”) to 5 (“strongly”). Both measures were obtained after the cold-pressor test rather than after the slide show to minimize possible demand or expectation effects (9, 63).

Procedure

Subjects were randomly assigned to one of three conditions (experiment 1 = fear, disgust, or neutral; experiment 2 = erotic, nurturant, or neutral) and individually tested in a single 1-hour session. After the subject read the informed consent sheet, the experimenter summarized each aspect of the consent and procedures. Subjects were told that HR and skin conductance would be monitored during exposure to the cold-pressor test and to slides that may or may not contain images of nude, mutilated bodies, or violent scenes. They were informed that no known risks were associated with these procedures but that they might experience temporary discomfort during skin preparation for the physiological sensors (skin abrasion) and during the cold-pressor test. The experimenter told the subject, “You will be asked to place your hand in cold water and keep it there for as long as you can tolerate it,” but also emphasized that the discomfort would be temporary and under their control because they could remove their hand at any time. Additionally, the subjects were told that they could withdraw from the study at any time without penalty.

After providing consent, subjects were acclimated to the experimental context for 15-minutes while they completed two questionnaires (about demographics and health status) and while HR and skin conductance sensors were attached to the index and middle finger of the hand opposite that to be used for the cold-pressor test (randomly determined). While physiological sensors were being attached and signals were being checked, subjects were provided with a detailed description of the physiological measures to disguise our primary interest in pain. Next, the SAM and the M-VAS ratings were explained, and then subjects practiced using these scales by rating hypothetical stimuli. To equalize hand temperature, the subject’s hand was immersed in a 26°C water bath for 3 minutes.

Subjects were informed that they would view a series of slides, during which they would need to keep their eyes focused on the screen and allow themselves to experience the emotions evoked by the slides. The cold-pressor test was then explained, and subjects were told that they would be instructed to immerse their hand in the cold water after the slide show and that they were to keep their hand and forearm in the water until the pain became intolerable. Subjects were instructed to adjust the sliding scales of the M-VAS during the cold-pressor test whenever they noticed a change in their pain. After explaining the procedures, the experimenter monitored the subjects by video camera from a separate room and communicated with them through headphones.

Statistical Analyses

Differences across slide show groups and genders were analyzed using an ANOVA. Subsequent group-mean comparison tests were conducted using Duncan’s New Multiple-Range Test and group-mean contrasts. Figures depict the data by gender when there were significant main effects of gender or significant interactions between gender and slide show group; otherwise data were collapsed across genders.

RESULTS

Experiment 1

The first experiment examined the influence of unpleasant emotional states on pain perception by comparing the effects of the fear, disgust, and neutral slide shows. The fear slides depicted snakes and violent assault scenes, and the disgust slides depicted mutilated bodies. Prior work indicated that both the fear and disgust slides receive low pleasantness ratings (valence) and high arousal ratings, thereby activating the aversive motivational system (56). In addition, the disgust slides have been shown to evoke feelings of pity, which promote an approach disposition to help others (38). According to Lang (38), the simultaneous activation of the aversive-withdrawal and appetitive-approach motivational states by the disgust slides may summate and therefore have less impact on defensive behaviors than the fear slides. Thus, we hypothesized that subjects viewing the fear or disgust slide shows would experience enhanced pain relative to those viewing neutral slides but that the disgust slides would be less effective. It was also hypothesized that the fear and disgust slides would receive higher arousal ratings, lower affective valence ratings, and higher ratings of negative emotions than the neutral slides.

HR and skin conductance provided measures of sympathetic arousal during the slide show. Prior research suggests that HR tends to covary with the slide’s reported valence (unpleasant slides produce more heart rate deceleration), whereas skin conductance
tends to covary with reports of arousal independent of reported valence (38). Thus, we anticipated that the fear and disgust slides would decrease HR and increase skin conductance.

Pain measures. The following three indices were used as measures of pain sensitivity: (1) pain intensity threshold, (2) pain unpleasantness threshold, and (3) cold-pressor tolerance (all measured in seconds).

Pain thresholds. Pain threshold was defined as the time between immersion of the hand in the cold-water bath and the first detection of pain, as indicated by the first movement of the M-VAS. Subjects rated two dimensions of pain on the M-VAS, sensory-intensity and affective-unpleasantness, yielding two pain thresholds, pain intensity and pain unpleasantness thresholds. Figure 1 presents the mean pain intensity threshold as a function of treatment condition. An ANOVA revealed a significant difference in intensity threshold across the slide show groups ($F(2,39) = 4.02, p < .05$). Mean comparisons indicated that intensity thresholds for both the fear and disgust groups were significantly lower than the neutral group ($p < .05$) but not different from one another. No other differences were significant.

Pain unpleasantness thresholds across groups were also examined by ANOVA (Figure 2). Although the difference in unpleasantness thresholds across slide show groups did not reach significance ($F(2,39) = 3.02, p = .06$), a significant gender-by-slide-show interaction was observed ($F(2,39) = 3.41, p < .05$). Post hoc mean comparisons revealed lower unpleasantness pain thresholds in men viewing the fear or disgust slide show compared with the neutral slide show (all $F$ values $> 11.63, p < .001$). No other differences were significant.

Tolerance. Pain threshold was defined as the latency to remove the hand from the cold-water. Figure 3 depicts the mean cold-pressor tolerance for each slide show group. ANOVA revealed significant differences in tolerance across slide show groups ($F(2,44) = 3.19, p < .05$). Mean comparisons indicated lower tolerance in the fear group compared with the neutral group ($p < .05$). No other differences were significant.

Manipulation checks. Table 1 shows the mean responses for SAM valence, SAM arousal, specific emotion category ratings, SCR, and HR for each slide show. Overall, these measures suggest that the slide shows induced the targeted emotional states.

SAM valence and arousal ratings. An ANOVA performed on SAM valence (pleasantness) and SAM arousal scores revealed significant differences across slide show groups ($F(2,44) = 29.65, p < .0001$ and $F(2,47) = 23.89, p < .0001$, respectively). Mean comparisons indicated that the neutral slides induced the highest (most pleasant) valence, followed by the fear and the disgust slides, whereas greater arousal was
reported in response to the disgust and fear slides relative to the neutral slides (all p values < .05). No other differences were significant.

Emotion ratings. Table 1 also depicts mean ratings for the eight emotional descriptors across slide show groups. A series of ANOVAs found significant differences across slide show groups for the following emotions: neutrality, happiness, surprise, fear, disgust, anger, and sadness (F(2, 47) = 13.6, 3.7, 38.8, 11.9, 36.3, 6.09, and 30.9, respectively; all p values < .005). Mean comparisons revealed that the neutral slides elicited higher ratings of neutrality and happiness than the disgust or fear slides (all p values < .05). For ratings of disgust, surprise, and sadness, all groups were different from one another and all followed the same pattern, with the highest ratings elicited by the disgust slides, followed by the fear and neutral slides (all p values < .05). For ratings of fear and anger, the disgust and fear slides were greater than the neutral slides (all p values < .05). Main effects for gender were found for ratings of fear, sadness, and happiness (F(1, 44) = 8.33, 6.47, and 3.94, respectively; all p values < .05), with men reporting slightly lower levels of these emotions than women. However, gender and slide show did not interact (F values < 2.28, all p values > .05). A significant interaction between gender and slide show for ratings of anger was observed (F(2, 44) = 3.89, p < .05); female anger ratings were higher in response to the disgust slides and lower in response to the fear slides, whereas the reverse was true for men (all p values < .05).

Physiological reactivity. HR and ER-SCR were used to quantify differences in physiological arousal across slide shows and gender. Because the slide shows lasted 90 seconds, physiological data were divided into 10 epochs of 9 seconds each and transformed into beats per minute. Because of a programming error, baseline HR data were not collected. Using ANOVA, no significant differences emerged in HR across the slide show groups or gender (all F values < 0.69, p > .05). The lack of an effect on HR may be due to our inability to conduct a change from baseline analysis or to methodological differences in how we analyzed our HR signal.

ER-SCRs elicited by the slides were quantified using the procedure outlined by Dawson et al. (64). Briefly, this procedure calculates the difference between skin conductance level (µS) just before presentation of a slide and the highest skin conductance level just after presentation of the slide. Two independent raters scored responses using a computer program, and their scores were then averaged. For analyses, the overall ER-SCR averaged across all 10 slides was used. The average ER-SCR was entered into an ANOVA as the dependent variable, with gender and slide show as independent variables. This analysis revealed a significant difference in average ER-SCR across slide shows (F(2, 39) = 4.63, p < .05). Neither the main effect for

<table>
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<tr>
<th>Slide Show Category</th>
<th>Valence (0-9)</th>
<th>Arousal (0-9)</th>
<th>Angry (1-5)</th>
<th>Disgusted (1-5)</th>
<th>Fearful (1-5)</th>
<th>Happy (1-5)</th>
<th>Sexual (1-5)</th>
<th>Sad (1-5)</th>
<th>Surprised (1-5)</th>
<th>Neutral (1-5)</th>
<th>SCR (log µS)</th>
<th>HR (beats/min)</th>
</tr>
</thead>
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<td>5.00A</td>
<td>1.75A</td>
<td>1.06A</td>
<td>1.06A</td>
<td>1.31A</td>
<td>1.93A</td>
<td>1.00A</td>
<td>1.06A</td>
<td>1.33A</td>
<td>4.19A</td>
<td>0.277A</td>
<td>75.66A</td>
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<tr>
<td>Disgust</td>
<td>2.12B</td>
<td>4.82B</td>
<td>2.24B</td>
<td>3.65B</td>
<td>2.70B</td>
<td>1.06B</td>
<td>1.00A</td>
<td>3.41B</td>
<td>3.77B</td>
<td>2.12B</td>
<td>0.234A</td>
<td>74.64A</td>
</tr>
<tr>
<td>Fear</td>
<td>3.77C</td>
<td>5.24B</td>
<td>1.88B</td>
<td>2.35C</td>
<td>2.59B</td>
<td>1.41B</td>
<td>1.05A</td>
<td>2.47C</td>
<td>2.88C</td>
<td>3.00C</td>
<td>0.772B</td>
<td>76.44A</td>
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* Means in the same column followed by different letters are significantly different (p < .05).
gender nor the interaction between gender and slide show was significant (both F values < 2.19, p > .05). Mean comparisons showed that the average ER-SCR amplitude induced by the fear slides was greater than that induced by the disgust slides and the neutral slides (p values < .05). The greater SCRs observed in subjects viewing the fear slides suggests that these images evoked a sympathetic arousal response indicative of fright. The lack of an effect of the disgust slides was unexpected because prior studies reported increased skin conductance in response to these slides (59, 60). However, this may simply indicate that these are relatively subtle manipulations.

Discussion. Prior exposure to both the fear and disgust slides reduced pain intensity and unpleasantness thresholds, but only the fear slides reduced pain tolerance. Although our manipulation checks verified that the slides evoked the targeted emotional states, only the fear slides evoked heightened physiological arousal. Together these results suggest that unpleasant and physiologically arousing emotional states increase pain sensitivity. It is important to note that our measures of pain sensitivity were conducted after the slide show to minimize the effects of distraction. If the slides had been presented during the cold-pressor test and pain was decreased, one could argue that the slides distracted the subjects from the pain. Because the slides were presented before the cold-pressor test, and pain reactivity was increased, our effects cannot be attributed to simple distraction. This does not, however, preclude a role of attentional mechanisms. Changes in affective state may be accompanied by shifts in attentional focus, which influence perceptual processing. For example, negative affect may enhance processing of threatening external or internal stimuli, which in turn could amplify the perceived intensity of noxious stimuli (4, 29). The decreased tolerance observed after fear slides may reflect central changes in pain processing and/or autonomic arousal-induced changes in vasoconstriction and/or blood pressure (65–67).

Experiment 2

Prior studies have shown that pleasant affect elicited by imagining scenes, listening to audiotapecs, viewing slides or videotapes, or genital stimulation decreases pain sensitivity (9–17, 31, 68). However, these studies have frequently confounded pleasant affect with other stimulus characteristics (eg, arousal and distraction) and/or have failed to characterize the emotional state evoked by these stimuli. Thus, it is unclear which properties of these “pleasant” stimuli altered pain. Although it is generally assumed that the pleasurable and calming nature of these stimuli play a crucial role, researchers have not systematically manipulated the dimensions of valence and arousal. This is problematic because the valence dimension may interact with arousal, such that highly arousing pleasant stimuli produce greater activation of the appetitive motivational system and consequently greater pain inhibition. Supporting this, Lang (38) observed stronger startle reflex modulation when highly arousing stimuli were used.

In this experiment we examined the contribution of arousal and valence by comparing the effects of erotic, nurturant, and neutral slide shows. The erotic slides depicted sexually explicit images, whereas the nurturant slides included pictures of infants and puppies. Both the erotic and nurturant slides elicited high pleasantness ratings compared with the neutral slides, whereas only the erotic slides elicited high arousal (56). Motivational priming theory predicts that viewing pleasant and highly arousing slides will lead to greater suppression of pain than pleasant and calming slides (38). Because men and women respond differently to erotic and nurturant slides (56, 59, 60), we anticipated that men would react more to erotic slides and that women would react more to nurturant slides.

Pain measures.

Pain thresholds. Figure 4 presents the mean pain intensity threshold as a function of treatment condition and gender. An ANOVA indicated a significant

![Fig. 4. Mean pain intensity thresholds for groups that viewed neutral, nurturant, or erotic slide shows immediately before the cold-pressor test. Error bars indicate SEM.](image-url)
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main effect for slide show ($F(2,57) = 4.97, p < .01$) and gender ($F(1,57) = 3.94, p < .05$) as well as a significant gender-by-slide-show interaction ($F(2,57) = 6.40, p < .03$). Mean comparisons showed that the intensity threshold for the erotic group of slides was higher than that for the nurturant group ($p < .05$), but this effect depended on gender. Although intensity thresholds for women were low across all three slide shows, intensity thresholds for men viewing erotic slides were higher than those viewing neutral and nurturant slides ($p < .005$). A similar pattern was observed for pain unpleasantness thresholds (Figure 5). An ANOVA revealed a significant main effect for slide show ($F(2,61) = 4.20, p < .05$). However, the effect of gender and its interaction with slide show were not significant (both $F$ values $< 1.67, p > .05$). Mean comparisons indicated that unpleasantness thresholds for the erotic group were higher than those of the nurturant ($p < .01$) or neutral ($p < .05$) groups.

Tolerance. Figure 6 depicts the mean tolerance for men and women as a function of slide show. Although no differences across slide show groups were found ($F(2,68) = 0.25, p > .05$), there was a marginally significant difference in tolerance between men and women ($F(1,68) = 3.73, p < .06$), with men having a higher tolerance. Prior studies indicate that women tend to have lower pain tolerance than men (71), but results obtained using the cold-pressor procedure have been inconsistent across studies (31, 72).

**Manipulation checks.** Table 2 shows the mean responses for SAM valence, SAM arousal, specific emotion ratings, SCR, and HR for each slide show group.

SAM valence and arousal ratings. An ANOVA performed on SAM valence ratings revealed a significant effect for slide show group ($F(2,68) = 11.76, p < .0001$). Although the main effect for gender was not significant ($F(1,68) = 0.33, p > .05$), the interaction between gender and slide show was significant ($F(2,68) = 3.64, p < .05$). Women gave the nurturant slides higher pleasantness ratings than did the men whereas men gave the erotic slides higher pleasantness ratings than women did. Mean comparisons indicated that erotic and nurturant slides did not differ in valence ratings, but both received higher ratings than the neutral slides (all $p$ values $< .05$). Similarly, an ANOVA conducted on the SAM arousal ratings indicated that the slide show groups differed ($F(2,68) = 8.28, p < .001$). Mean comparisons showed that the erotic slides were rated as more arousing than either the nurturant and the neutral slides ($p$ values $< .05$).

Emotion ratings. A series of ANOVAs found significant differences across slide show groups for the following emotions: neutrality, surprise, fear, and happiness ($F(2,70) = 12.76, 33.87, 7.24$, and $10.73$, respectively; $p$ values $< .01$) as well as disgust and sexual arousal ($F(2,67) = 8.88$ and $65.30$, respectively; $p$ values $< .001$). For ratings of disgust, there was a

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**Fig. 5.** Mean pain unpleasantness thresholds for groups that viewed neutral, nurturant, or erotic slide shows immediately before the cold-pressor test. Error bars indicate SEM.

**Fig. 6.** Mean cold-pressor pain tolerances for groups that viewed neutral, nurturant, or erotic slide shows immediately before the cold-pressor test. Error bars indicate SEM.
main effect of gender \((F(1,67) = 5.50, p < .05)\) as well as an interaction between gender and slide show \((F(2,67) = 9.55, p < .001)\). Although the erotic slides elicited higher disgust ratings than the other slide shows, this was largely due to the gender-by-slide-show interaction, with women rating the erotic slides as eliciting more disgust than the other slides \((p < .05)\). Additional mean comparisons revealed that ratings of sexual arousal and surprise were higher for the erotic slides than for either neutral or nurturant slides \((p < .05)\). For happiness, nurturant slides received higher ratings than did neutral or erotic slides \((p < .05)\). Ratings of neutrality and fear were higher for the neutral slides than for nurturant or erotic slides \((p < .05)\); however, the neutral slides received very low fear ratings \((mean = 1.35)\).

**Physiological reactivity.** Unexpectedly, no statistically significant differences emerged in SCR across the slide show groups or gender \((all F values < 1.25, p > .05)\). There were, however, significant differences in HR \((F(2,70) = 5.16, p < .01)\). There was also a main effect of gender \((F(1,70) = 15.63, p < .001)\) as well as an interaction between gender and slide show \((F(2,70) = 3.79, p < .05)\). Mean comparisons showed that HR during both the erotic and nurturant slide shows were lower for men \((mean = 73.47, SD = 8.27)\) and mean = 85.20, SD = 10.73, respectively) than for women \((mean = 89.94, SD = 9.67)\) and mean = 97.00, SD = 10.67, respectively; \(p < .01)\). For men, HR was lower during the erotic slides \((mean = 73.47, SD = 8.27)\) than during the neutral \((mean = 89.93, SD = 10.87)\) or nurturant \((mean = 85.20, SD = 10.73)\) slides. For women, HR was higher during the nurturant slides \((mean = 97.00, SD = 10.67)\) than during the neutral \((mean = 88.31, SD = 11.33)\) or erotic \((mean = 89.94, SD = 9.67)\) slides. The significant deceleration responses to the erotic slides is consistent with results of prior work suggesting that orienting responses and attention are associated with HR deceleration \((59, 69, 70)\).

**Discussion.** We found that viewing erotic slides increased pain intensity threshold ratings in men and pain unpleasantness threshold ratings in both men and women but had no effect on pain tolerance. Despite high valence ratings, the nurturant slides had no impact on pain reactivity, an effect that may be linked to their lower impact on arousal. Together these results suggest that pleasant emotional states that are highly arousing diminish pain sensitivity. Just as the induction of a negative affective state may enhance attention to pain-eliciting stimuli, positive affective states and/or processes may decrease attention to such stimuli.

**DISCUSSION.**

In this study we investigated the effects of viewing unpleasant and pleasant slides on cold-pressor-induced pain. Manipulation check data indicated that the targeted emotional states were elicited by the slide shows. Consistent with the motivational priming hypothesis, we found that viewing either fear or disgust slides before a cold-pressor test reduced pain intensity and unpleasantness threshold ratings, suggesting that both the sensory-discriminative and affective-motivational dimensions of pain are amplified by unpleasant emotion. However, only the fear slides reduced pain tolerance. In contrast, erotic, but not nurturant, slides increased pain intensity and unpleasantness threshold ratings in men, whereas neither nurturant nor erotic slides altered pain tolerance in either men or women. This pattern of results provides preliminary support for a motivational priming model of pain modulation, which predicts that unpleasant affective states enhance pain whereas pleasant affective states attenuate it and that high arousal augments both effects \((38)\). Our findings are also consistent with the view that affective states may influence pain by altering attentional processing and/or autonomic function. Specifically, negative affect may decrease pain thresholds by enhancing attention to noxious stimuli, whereas the fear-induced decrease in tolerance may be related to autonomic arousal and its peripheral effects on vasoconstriction and/or blood pressure \((65–67)\).
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It is unclear why the disgust slides, which were rated as more unpleasant than the fear slides, did not affect pain tolerance. One explanation may be the greater level of physiological arousal evoked by the fear slides. Higher levels of arousal may lead to heightened activation of the aversive system, resulting in prolonged sensitization of pain. Alternatively, fear may unambiguously prime the aversive motivational system, whereas disgust may evoke a more complex array of emotions, including pity, which elicits an approach disposition to help others (38). When complex affects elicit dual motives, the behavioral outcome is determined by the relative level of activation of the aversive and appetitive motivational states (38). Supporting this, disgust slides receive high pity ratings and produce less startle potentiation compared with fear slides (38). Although we did not obtain pity ratings, disgust slides received higher sadness ratings than either the fear or neutral slides, suggesting that the disgust slides evoked a more complex emotional state.

Experiment 2 evaluated the influence of pleasant affect by comparing the effects of erotic, nurturant, and neutral slides. Interestingly, only the male subjects showed a consistent increase in pain intensity and unpleasantness thresholds after viewing the erotic slides. Manipulation checks indicated that the nurturant slides received the highest valence ratings, followed by the erotic slides and then the neutral slides, whereas the erotic slides received the highest arousal ratings, followed by the nurturant slides and then the neutral slides. Although both genders rated the erotic slides as sexually arousing, women also rated them as disgusting. The simultaneous activation of appetitive (erotic-approach) and aversive (disgust-withdrawal) motivational states in women may explain the failure to observe an effect on pain intensity threshold (38). Specifically, the pain-attenuating effects of sexual arousal seem to be canceled by the concurrent experience of disgust in women.

Despite the higher valence ratings of the nurturant slides, only the erotic slides altered pain threshold ratings in males. These results are consistent with the priming hypotheses, which predicts that pleasant and highly arousing stimuli should lead to greater pain inhibition than pleasant and calming stimuli. Although the results do not seem to support the view that pleasant and calming emotions reduce pain, the lack of an effect of the nurturant slides may be due to the rapid decay of the affective state. This seems plausible because highly arousing stimuli produce more persistent and vivid emotional memories than less arousing stimuli (62). Indeed, arousal may contribute to the analgesic properties of pleasant stimuli by producing prolonged activation of the appetitive motivational system. Thus, it may be helpful to present pleasant and calming stimuli during the pain to alter pain perception, a common practice in pain management settings.

Changes in pain sensitivity were more often observed for pain threshold than for tolerance. Differential sensitivity across measures may reflect the decay of the emotional state over time: Threshold ratings occurred early in the session when the affective state was greatest, whereas tolerance occurred later after the emotion declined. Thus, the lack of an effect of the erotic slides on tolerance may be attributable to low physiological arousal and the consequent decay of this emotion over time. In contrast, the fear slides induced significant physiological arousal that maintained the activation of the aversive system long enough to influence tolerance. Finally, it could be argued that our cold-pressor instructions ("remove your hand when the pain becomes intolerable") created a negative expectancy that counteracted the effect of the pleasant slides on tolerance.

Relation to Prior Empirical Accounts

Our findings are generally consistent with prior studies examining the influence of emotion on cold pain (9, 15, 17, 31). For example, Zelman et al. (9) reported that pain tolerance, but not pain threshold, was decreased by reading depressive statements and increased by reading pleasant statements. Similarly, we found that unpleasant affect (fear) decreased tolerance but that both pleasant and unpleasant affect altered pain thresholds. Other studies report that viewing erotic (17) and humorous films (15) increase pain thresholds and tolerance, respectively; however, viewing a holocaust or violent film had no effect. Although the increase in pain thresholds observed after the erotic film fits with the results of the present study, the increase in tolerance observed after viewing a humorous film contrasts with the lack of effect of nurturant and erotic slides. This discrepancy may be due to the stronger physiological and subjective arousal induced by films compared with slides (71). Another inconsistency is the lack of an effect of the unpleasant films. One explanation for this inconsistency is that the holocaust and violent films elicited a dual motivational state in which the pain-enhancing effects of fear were canceled by the concurrent experience of pity. To examine this issue, future studies should carefully characterize the emotional state induced by film stimuli rather than assume that pure aversive or appetitive states are elicited (72, 73).
Theoretical Implications

The pattern of affective modulation observed in the present study parallels the results obtained using another defensive behavior, the acoustic startle response. Lang (38) has shown that startle is potentiated by unpleasant affect and inhibited by pleasant affect and that both effects are amplified by high arousal. Our application of Lang's motivational priming theory to pain modulation was based on animal studies indicating that the same neural mechanisms that mediate affective modulation of startle also underlie affective modulation of pain behaviors (43–49). Our laboratory and others have linked distinct startle and pain modulatory effects to the amygdala and PAG (43–49). Considerable evidence indicates that these structures play a critical role in fear, anxiety, and sexual behavior as well as attention (74). The amygdala and PAG modulate pain through descending projections that alter nociceptive transmission in the spinal cord (45–48). In addition, the amygdala and PAG mediate fear-induced increases in sympathetic arousal (eg, blood pressure and vasoconstriction; Refs. 74 and 75) that alter pain (65, 67). Together these studies suggest that affective modulation of startle and pain may share a common neural substrate and that motivational priming theory may have broader significance.

The pain-enhancing effect of fear is theoretically significant because it runs counter to Bolles and Fanselow's (21) model, which predicts that fear inhibits pain. According to this model, exposure to a predator or noxious stimulus triggers the release of endogenous opioids that inhibit pain. Although this model is largely based on animal research, the human studies providing support for this model involved intense fear (eg, electric shock, trauma, and parachute jump; Refs. 23, 28–29, 32). In contrast, our study involved mild fear (50). Thus, this theory may explain how intense fear inhibits pain, whereas priming theory may account for the pain-enhancing effects of mild fear (25, 26, 29).

Several theories suggest that attentional factors mediate the influence of fear on pain in humans (4, 27, 35, 76). Moderate levels of fear seem to increase attention to salient events such as pain, thereby augmenting its perceived intensity. Conversely, high levels of fear may become more salient than pain, in which case fear would attenuate pain. Thus, the moderate level of fear induced by the slides may have increased attention to pain, thereby amplifying its intensity. To further test this model, parametric studies that systematically manipulate fear intensity and measure changes in attentional focus to determine whether the attentional demands of the affective state play a critical role are needed. Such studies may reveal that attentional focus inherently covaries with changes in the emotional states. Indeed, shifts in attention may be viewed as manifestations of emotional state changes that determine perceptual processing priorities.

Attentional accounts have also been used to explain the pain-reducing effects of distraction on clinical pain. These models assume that distraction reduces pain by diverting attention away from pain processing. However, recent research indicates that distraction tasks that demand greater attentional processing do not produce greater reductions in pain (77–79). These findings suggest that other factors, besides attention, determine the effectiveness of a distractor. Because most studies reporting reduced pain have used pleasant distractors (9–17), the pain reduction may be due in part to the pleasant emotional state (15, 78, 79). Unfortunately, stimuli used in prior studies have confounded pleasant affect with other stimulus characteristics, such as degree of arousal and distraction. The present study controlled for these variables by inducing the emotional state before the pain test, which prevented concurrent distraction by the slides, and by manipulating the dimensions of valence and arousal. Because pleasant and unpleasant affective states produced opposite effects on pain, it is difficult to argue that distraction accounts for both effects (1).

Future research should investigate a wider range of affective states. It is possible that arousing emotions (eg, humor and erotic) are more effective inhibitors of pain than calm states of relaxation. Although a few studies have shown that humor (12, 17) and sexual arousal inhibit pain (16, 68), additional studies that systematically vary arousal to determine how this dimension interacts with the dimension of valence and the particular emotional state (eg, humor, fear, etc.) are needed. These dimensions may have opposite effects (eg, negative valence may induce hyperalgesia, whereas arousal may elicit analgesia), or they may interact to produce different outcomes depending on their product (eg, low products yielding hyperalgesia and high products yielding analgesia). Support for the latter perspective comes from research suggesting that differential levels of valence and arousal determine whether an aversive event induces hyperalgesia or analgesia (26, 29, 37, 80). More work is also needed to determine how more intense states of fear that elicit high levels of sympathetic and adrenal-cortical activation alter pain perception. It is possible that the differential effects of fear on pain in normal and phobic individuals may be due to the nonmonotonic effects of arousal on pain modulation. Alternatively, these effects may be mediated by changes in self-efficacy (19), which in turn may influence response bias (81).
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REFERENCES

48. Fields HL, Basbaum A. Central nervous system mechanisms of
73. Weisenberg M. Pain and pain control. Psychol Bull 1977;84:1008–44.
78. Leventhal H. I now distraction works even though it doesn’t! Health Psychol 1992;11:208–9.