

Effects of emotion on pain reports, tolerance and physiology

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The effects of specific emotional states on a laboratory pain task were tested by examining the behavioural, verbal and psychophysiological responses of 80 student volunteers (50% female). Participants were assigned to one of four Velten-style emotion-induction conditions (ie, anxiety, depression, elation or neutral). The sexes of experimenters were counterbalanced. Overt escape behaviour (ie, pain tolerance), pain threshold and severity ratings, verbal reports of emotion and physiological measures (ie, electrocardiogram, corrugator and trapezium electromyogram) were recorded. A pressure pain task was given before and after the emotion induction. As predicted, those who participated in the anxiety or depression condition showed reduced pain tolerance after induction of these negative emotions; pain severity ratings became most pronounced in the depression condition. Emotion induction did not have a discernable effect on pain tolerance or severity ratings in the elation condition. A pattern of participant and experimenter sex effects, as well as trials effects, was seen in the physiological data. The influence of negative affective states (ie, anxiety and depression) on acute pain are discussed along with the unique contributions

of behavioural, verbal and physiological response systems in understanding the interactions of pain and emotions.

Key Words: Anxiety; Emotion; Fear; Pain; Pain tolerance; Psychophysiology

Effets des émotions sur la perception douloureuse, la tolérance à la douleur et la physiologie de la douleur

RÉSUMÉ : Les effets d'états émotionnels spécifiques sur l'évaluation de la douleur en laboratoire ont été mesurés par l'analyse de réactions comportementales, verbales et psychophysologiques d'un groupe de 80 étudiants volontaires (à 50 % composé de femmes). Les participants ont été assignés à l'un ou l'autre des quatre états inducteurs d'émotions du système Velten (c.-à-d., anxiété, dépression, euphorie ou état neutre). Le sexe des expérimentateurs a été contrebalancé. Des comportements manifestes d'évitement (c.-à-d. tolérance à la douleur), le seuil de la douleur et l'évaluation de sa gravité, l'expression verbale des émotions et les mesures

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physiologiques (telles électrocardiogramme et électromyogramme du muscle sourcilier et du trapèze) ont été consignés. Un test de douleur par pression a été administré avant et après l'induction de l'émotion. Comme prévu, ceux qui ont été soumis à l'anxiété et à la dépression ont montré une tolérance moindre à la douleur après l'induction de ces émotions négatives. Les évaluations de l'intensité de la douleur sont devenues plus prononcées en présence de signes de dépression. L'induction de l'émotion n'a pas exercé d'effets discernables sur la tolérance à la douleur ou sur les

Pain is a major reason for people to seek medical treatment (1). Emotions, particularly negative ones, have been recognized as important factors in pain perception and response (2-4). In recent years, there has been a growing focus on the relation that anxiety and fear have with pain, particularly in the area of avoidance behaviour (5), including extensive theoretical development (6-9), work relating to a basic anxiety proneness, anxiety sensitivity (10,11), programmatic research on attention (12,13), study of acceptance as a treatment strategy (14), empirical investigations in applied settings (15), experiments designed to tease apart subtleties between emotions (16) and the development of measurement strategies (17,18). Moreover, the field has matured to the extent that comprehensive reviews have been necessary (19,9).

Clarifying the relative effects of anxiety, fear and other emotions on the experience of pain, however, has proved to be extremely difficult. The research literature on this topic is quite convoluted, and no theory has been able to capture adequately the complex relation between a broad range of emotions and pain (20). Some researchers have suggested that the study of pain and emotions (eg, anxiety and depression) is empirically confounded due to methodological difficulties (21,22). Despite these impediments, researchers continue to investigate the extent to which anxiety (and fear), depression and happiness affect the pain experience, although these states reflect only a subset of all possible emotional responses. Each of these emotional states, however, is considered in turn.

Anxiety (as well as fear) and pain share a complex relationship in both clinically acute (23) and chronic (24,25) pain populations. Severe pain and fear of pain often produce anxiety so compelling that patients avoid previously desirable activities in the hope of preventing another pain episode (26,27). Unless the need is sufficiently great to seek help (eg, emergency dental care), many patients endure their pain and fail to obtain pain treatment (28), often until their condition has progressed to a point of serious health risk, including death in some cases (29). Such avoidance behaviour can worsen patients' physical problems and needlessly leave them in agonizing situations.

Adding to the complex interaction between anxiety and pain, many contend that anxiety can reduce one's pain threshold, essentially increasing the pain experience for that individual (30). Further, as Al Absi and Rokke (31) demonstrated, increasing pain-relevant levels of anxiety are associated with increased pain reports. There also is oppos-

évaluations de l'intensité de la douleur chez les sujets soumis à une expérience euphorisante. Pour ce qui est des données physiologiques, on a pu observer un mode de présentation des effets lié au sexe des participants et des expérimentateurs, de même que des effets sur les essais. L'influence des états affectifs négatifs (telle anxiété et dépression) sur la douleur aiguë est présentée, de même que les contributions particulières des systèmes de réactions comportementales, verbales et physiologiques dans la compréhension des interactions entre la douleur et les émotions.

ing evidence, however, that suggests that pain-irrelevant anxiety decreases the pain experience (12,31-33), perhaps through distraction. Arntz and colleagues (33) suggested that other factors (eg, attentional and attributional processes) may be more important to the pain experience than anxiety. For example, spider-phobic participants reported less electric stimulation pain when they were simultaneously exposed to spiders than when they were not (33). This discrepancy among research findings illustrates the current need for research to address exactly how, and under what particular circumstances, anxiety will increase or decrease pain responses.

Depression also has received considerable attention in the clinical pain literature (25,34); a significant relation between chronic pain and depression has been indicated (35). Turk and Holzman (36) suggested that at least 50% of patients with chronic pain are clinically depressed. Cognitive distortions commonly seen in depressed patients also have been noted in patients with chronic pain (37,38). In both chronic pain (39,40) and cardiac pain (41) populations, depression has been associated with reports of significantly more frequent and more severe pain (42). Moreover, antidepressant medication is often prescribed to pain patients and is known to alleviate chronic pain in some individuals (43). Results from depression and pain studies suggest that there is a complex interaction between these variables that is only beginning to be understood.

Traditionally, clinical observations of positive emotions such as happiness have been infrequently reported in the pain literature. Recently, however, increased attention has focused on the potential benefits of positive emotions (eg, happiness), optimism in the general healing process and longevity (44). Periods of laughter have been reported to decrease pain and other somatic complaints (45), reduce 'discomfort sensitivity' (46) and enhance immune system functioning (47). In a review, Salovey (48) identified several factors that may be affected by positive emotions, including immune system function, engagement in health-promoting behaviours and seeking social support.

GOALS AND HYPOTHESES

The primary goals of the present study were to evaluate and understand further the relation between emotions and experimentally induced acute pain and, specifically, to elucidate the effects of certain emotional states (ie, depression, anxiety and elation) on the response to pain. A paradigm developed by Zelman et al (49) was extended to include an

anxiety condition and physiologically dependent measures. A variety of improvements based on the current literature were also added, including greater control for ceiling effects in pain tolerance, providing for an equal number of male and female participants, and control for and assessment of experimenter sex effects. The latter two issues, both sex-related, were addressed because of the sex differences observed, particularly in experimental pressure pain (50), and evidence of differential pain reports to male and female experimenters (51).

The differential response to experimentally induced acute pain was hypothesized to be a function of different emotion-induction conditions. Specifically, laboratory-induced depression and anxiety were expected to increase reports of distress, pain intensity ratings and physiological response, and to decrease pain tolerance compared with the neutral and elation conditions. Elation was predicted to result in decreased distress reports, pain intensity ratings and physiological response, and in increased pain tolerance compared with the other three conditions. Sex was also expected to influence all measures. Male subjects were anticipated to report less distress, display less escape behaviour and be less physiologically responsive, while female subjects were predicted to report more distress, display more escape behaviour and be more physiologically responsive to pressure pain.

SUBJECTS AND METHODS

Participants

Participants comprised 80 undergraduate students (40 female) who were enrolled in psychology classes at Oklahoma State University, Stillwater, and had volunteered for extra course credit or a monetary payment of \$5.00. The average age of the participants was 20.4 years (SD 3.4 years; range 18 to 39 years). The ethnic distribution of participants was as follows: one black, four asian, 67 white, one hispanic and seven Native American.

Participants were screened and excluded from the study if they reported that they were currently pregnant, were receiving treatment for a psychological disorder, had health problems that would interfere with the safe application of pressure pain to the nondominant hand (eg, fractured finger) or would compromise physiological recording (eg, history of cardiac dysfunction), or if they reported that they currently experienced significant acute or chronic pain. Also, participants who had scores on the Beck Depression Inventory (BDI) (52) or trait version of the State-Trait Anxiety Inventory Form-Y (STAI) (53) that suggested a significant level of depression (ie, scores of 19 or greater on the BDI, consistent with at least moderate-severe depression [52]) or anxiety (ie, scores on the STAI in the 95th percentile or higher), were excluded from the study. Participants were also excluded if they escaped the pain task within the first 10 s, because insufficient physiological data would be available for statistical analysis. Additionally, data from participants who did not escape at all from the pain task were not included because of their tendency to demonstrate a response set of nonavoidance (49).

Based in part on these criteria, data from 32 participants were replaced. Of these participants, 13 did not escape either pain task, eight scored above the depression or anxiety cutoffs, one escaped a pain task before 10 s had elapsed and one was excluded due to noncompliance with procedural instructions. Data for the remaining nine participants were unavailable due to experimenter error or equipment malfunction. There were 122 persons enrolled in the study; minus those excluded, the final number of 80 participants was achieved.

Apparatus and materials

Experimentally induced acute pain was activated using an algometer pressure pain simulator similar to that introduced by Forgione and Barber (54). Modifications were made to the algometer based on experimentation by Dougher et al (55) and were extensively diagrammed by Rainwater and McNeil (56). The algometer is a device that allows the placement of a dull lucite blade on the second phalanx of individual fingers of the hand, using weights of different mass. From a vertical slide position, the algometer produces a slowly building, aching, acute pain. The index and middle fingers of the nondominant hand were used in the first and second pain conditions, respectively.

For each participant, the total duration of pain stimulation was no longer than 5 min; however, it could be terminated by the participant at any time. Pain tolerance was monitored and recorded using a hand-held stopwatch.

Physiological data were collected using Coulbourn Instruments (USA) modules controlled by an IBM PC/XT microcomputer (IBM, USA) equipped with a Labmaster interface board (Scientific Solutions, USA) and specialized software (ie, virtual processing machine [VPM] [57]). This equipment was used to time the procedures, to control a precision signal generator (F81-06, Coulbourn Instruments), an audio mixer-amplifier (S82-24, Coulbourn Instruments) and a selectable envelope shaped rise/fall gate (S84-04, Coulbourn Instruments), and to collect three channels of physiological signals. Two channels of analog electromyogram (EMG) data were recorded using bioamplifiers (S75-01, Coulbourn Instruments) and contour-following integrators (S76-01, Coulbourn Instruments) to evaluate muscle tension during all experimental conditions, with the exception of the emotion-induction condition. Recording electrodes were attached to the corrugator supercilia (ie, 'knits' of the eyebrows) and the trapezius (ie, shoulder) muscles. For the corrugator data, two 4 mm electrodes (Beckman Instruments, USA) fixed with electrode collars and filled with electrode electrolyte gel (TECA #650454, TECA Corporation, USA) were used. The trapezius recordings were made using three 8 mm disposable electrodes (#DS-02, Bio-Medical Instruments, USA), which were also filled with gel. EMG data falling between the cutoff values of 90 and 1000 Hz were collected; the contour-following integrators were set at a 0.1 s time constant with a sampling rate of 10 Hz. Electrode impedance was kept below 10 k Ω as measured by an electrode impedance

meter (#EZM5, Grass Instruments, Astro-Med, USA). For consistency in EMG research, the guidelines provided by the Society for Psychophysiological Research (58) were followed. In addition, electrocardiographic (ECG) data were collected with a high gain bioamplifier/coupler (S75-01, Coulbourn Instruments) and a Schmitt trigger device (Bipolar Comparator [S21-06] and Retriggerable One Shot [S52-12], Coulbourn Instruments), which were used to filter, amplify and digitize the ECG signal. To collect ECG data, silver-silver chloride (Medi-Trace, USA) pregelled disposable foam electrodes (#GC-11) were attached to the participant's skin surface to the right and left of the sternum just below the clavicle and on the left side of the chest at the last palpable rib. The VPM software recorded the time interval between cardiac R-waves.

Verbal report instruments

Two 'trait' self-report instruments were administered to each participant at the beginning of the experiment. The BDI (52) is a 21-item questionnaire that measures the presence and severity of the affective, motivational, cognitive and psychomotor aspects of depression. Each item is rated on a four-point Likert-type scale (0 to 3) with a total score range of 0 to 63; higher scores are indicative of more severe depressive symptoms. The trait version of the STAI (53), which consists of 20 items designed to assess chronic (trait) anxiety level, was also used. Items are rated on a four-point Likert-type scale (1 to 4), with a total range of 20 to 80; higher scores indicate more anxiety.

'State' emotion and pain reports were measured with two instruments. The emotion assessment scale (EAS) (59) is a 24-item questionnaire in which specific emotional states are rated along separate visual analogue scales. This questionnaire provides subscales for eight emotions: anger, anxiety, disgust, fear, guilt, happiness, sadness and surprise. To maintain the integrity of the questionnaire, the entire EAS was administered to each participant during each trial of the study, although only the anxiety, fear, happiness and sadness subscales were used for data analysis. Pain severity ratings were collected using an 'open transformed' scaling procedure (60) to avoid ceiling effects in pain severity ratings. Participants put a tally mark on a sheet of paper when they perceived pain and another mark at each 'just noticeable' increase in their pain, until tolerance was reached. The timing of these ratings was algebraically transformed to produce scores of 1 to 10 across the time intervals. This rating method appears to be more natural for participants and shows promising test-retest reliability (60). The VPM software was configured to record the cumulative time between each key stroke made by the computer operator corresponding to the participant's rating marks during the pain task.

Emotion induction

Laboratory-induced emotions were produced using a style of emotion-induction technique described by Velten (61). A different group of 50 statements, ranked in previous research and ordered from least to most emotion-provok-

ing, was used for each of the four emotion conditions: anxiety (eg, "I'm really feeling upset and nervous, this worries me"; "I feel all jittery; I want to run away; This is really getting to me." [62]), depression (eg, "I can remember times when everybody but me seemed full of energy"; "Just to stand up would take a big effort" [49]), elation (eg, "I feel enthusiastic and confident now"; "I'm feeling amazingly good today" [49]) and neutral (eg, "Oklahoma City is the largest city in the world in area, with 631.166 square miles"; "Slang is a constantly changing part of the language" [49]). The anxiety induction was successfully used in previous research (62), and all other conditions were previously used in the study by Zelman et al (49).

A shortened version of the elation statements (ie, every odd numbered statement) was viewed at the end of the study by participants assigned to the anxiety and depression conditions. A similar short positive emotion induction was found to be effective in countering the after-effects of negative emotion-induction conditions (63).

PROCEDURE

Teams of two experimenters conducted the study. One experimenter operated the computer from a control/equipment room, and the other instructed and assisted the study participant.

After informed consent was obtained and exclusionary criteria were evaluated, participants were randomly assigned to one of the four emotion-induction conditions, with the restriction that sex of the experimenter in direct contact with the participant was counterbalanced across participant sex and condition. Participants then completed the BDI and STAI-Trait, followed by instruction in the use of the EAS.

Participants were then instructed to relax with their eyes closed. During this 5 min interval, baseline heart rate and muscle tension data were recorded. Participants were seated throughout the procedure.

Participants then listened, via audiotape, to instructions regarding the experimental session. These instructions were patterned after the 'low demand' instructions developed by Miller and Bernstein (64). Participants were instructed to say 'stop' when they became fairly uncomfortable, at which time the algometer pressure was discontinued. This procedure allowed the measurement of pain tolerance (ie, overt escape behaviour), using time as a naturalistic variable. After the instructions were given, the index finger of the participant's nondominant hand was placed in the algometer. Pain tolerance time was defined as the time from initial pressure stimulation to discontinuation of the task or until the 5 min time limit was reached. Pain ratings were obtained from the participant throughout the pain task in the method described previously. EAS ratings were obtained following discontinuation of the pain induction. Heart rate and muscle tension data were collected continuously during the pain task.

During the emotion-induction portion of the experiment, participants were exposed to one of four emotion-

induction conditions, (ie, anxiety, depression, elation or neutral). Condition-specific, audio-taped instructions asked participants to “read each statement, think about it carefully, and try to experience the emotion suggested by the statement” (49). Following the instructions, each of the 50 statements was shown for 15 s on a 51 cm video screen. Following the completion of this procedure, participants were again asked to give EAS ratings based on how they felt following the emotion induction. No physiological measures (ie, heart rate, EMG) were obtained during the emotion induction phase.

After completion of the emotion induction, a pain task, identical to the pain task previously outlined in terms of instructions and procedures, was repeated. Added to this pain task, however, were instructions for the participant to continue feeling the way suggested by the Velten statements. The middle finger of the participant’s nondominant hand was placed in the algometer, and pain intensity ratings were recorded as before. Following discontinuation of the task or the end of 5 min, EAS ratings were obtained, again based on how the individual felt just before the end of the trial.

After the second pain task, participants were again asked, via audiotape, to relax with their eyes closed for 5 min while heart rate and muscle tension data were collected. At the end of this period, EAS ratings were obtained based on how the participant felt at the end of the rest period.

For individuals assigned to the depression or anxiety conditions, a short (ie, 6 min) positive mood induction followed the final physiological recording period. Audiotaped instructions informed the participants that the pain tasks were completed and encouraged them to read the statements listed on the video screen to assist in overcoming any negative after-effects of the previous procedures. Following this procedure, all participants were debriefed regarding the purposes of the experiment.

RESULTS

Design and statistical approach

Analyses followed a basic design of 4 (emotion induction condition: anxiety, depression, elation, neutral) \times 2 (participant sex) \times 2 (experimenter sex), for the between-subjects factors. Trial was a repeated measure. The number of trials analyzed differed depending on the dependent variable and the type of analysis used. For the overt behaviour dimension, pain tolerance time was the only dependent variable. For this measure, two trials were analyzed (pain tasks 1 and 2). For the verbal report dimension, five trials were analyzed (preinduction baseline, pain task 1, emotion induction, pain task 2 and postinduction baseline). All three dependent variables used in the physiological dimension (heart rate, corrugator and trapezius muscle tension) included four trials each (preinduction baseline, pain task 1, pain task 2 and postinduction baseline). Finally, separate repeated measures ANOVAs were used to test each dependent variable within each system of data (ie, overt behaviour, verbal report and physiology) across trials. For significant

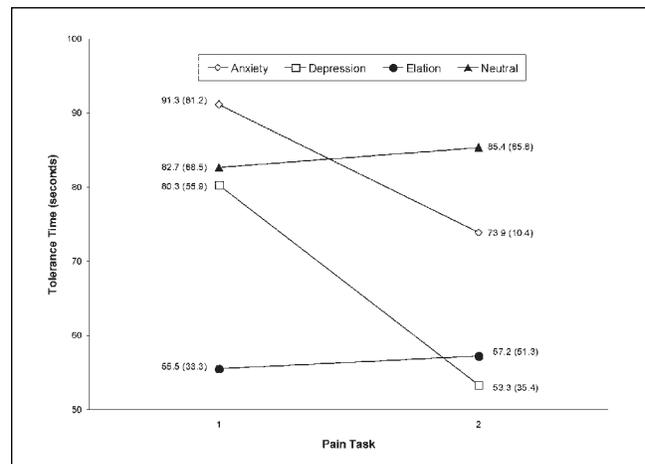


Figure 1) Pain tolerance times by pain trial for each emotion induction condition. (Standard deviations in parentheses.) 1 First pain trial; 2 Second pain trial

ANOVAs, Tukey’s method of testing honestly significant differences (HSD) ($P < 0.05$) was used for follow-up analyses.

Overt behaviour

The nonparametric Lilliefors Test for Normality (65) showed that the pain tolerance data were not normally distributed ($T = 0.12$, $P < 0.01$) as was found by Zelman et al (49). Pain tolerance data were, therefore, transformed into ranks, and a nonparametric ANOVA was performed on the ranks (ie, Kruskal-Wallis test). A 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 2 (trial: pain task 1 versus pain task 2) Kruskal-Wallis test was completed on these ranked data as well. These calculations revealed a condition by trials interaction ($H[3] = 2.84$, $P < 0.05$) as well as main effects of participant sex ($H[1] = 13.64$, $P < 0.0005$) and experimenter sex ($H[1] = 4.19$, $P < 0.05$). No other results were significant. The Kruskal-Wallis multiple comparison procedure at the 0.05 level was used as a follow-up for conditions within each trial; the Wilcoxon matched-pairs signed-ranks test at the 0.05 level was used for comparing the two trials of each condition. Figure 1 presents the unconverted mean avoidance/escape time for each group during the first and second pain tasks. Pain tolerance in both the anxiety and depression conditions decreased significantly following the emotion induction (Figure 1). Furthermore, pain tolerance for the depression condition was significantly lower during the second pain trial than that during the neutral or anxiety conditions. Those in the elation condition group had lower pain tolerance in the first trial than those in any other group. In terms of main effects, women escaped the pain task more than men; there was more escape with male experimenters than with female experimenters.

Verbal reports

Pain severity ratings: The rating system recommended by Fernandez et al (66) produced cumulative times starting at pain threshold and continuing in a naturalistic fashion

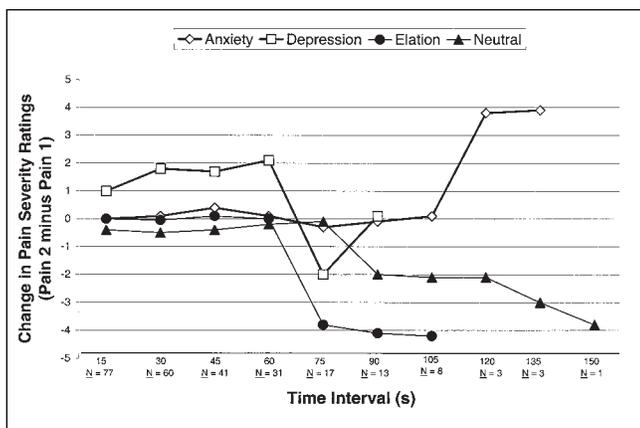


Figure 2) Pain rating change scores across 15 s intervals of pain tasks for each emotion-induction group

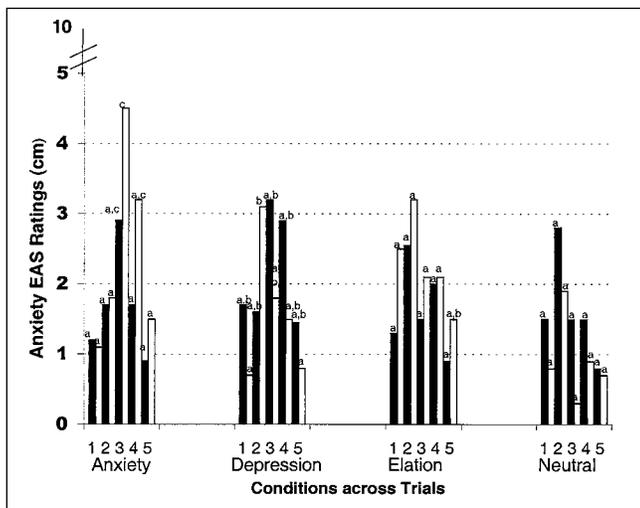


Figure 3) Emotion assessment scale (EAS) anxiety ratings across trials for each condition. Bars that do not share common superscripts are significantly different at or beyond $P < 0.05$. Filled bars correspond to male participants and open bars to female participants. 1 Prebaseline trial; 2 First pain task; 3 Emotion induction; 4 Second pain task; 5 Postbaseline

until pain tolerance was reached. These cumulative times were transformed into pain ratings using an algorithm that was developed from interpolation formulas. This process produced values that estimated each participant's pain ratings on a scale of 0 to 10, as if ratings had been given every 15 s. On this scale, 0 was assumed to equal no pain, 1 was equivalent to pain threshold and 10 was assumed to be the participant's 'quit point' or pain tolerance.

These converted ratings were used to calculate change scores (pain trial 2 minus pain trial 1) for every 15 s interval that the participant continued the task. This method is consistent with that of Zelman et al (49). Because of the need to allow escape from the pain task as an overt behavioural measure of pain tolerance, the number of pain ratings decreased considerably over time. This design choice necessarily reduced the statistical power for the pain severity rat-

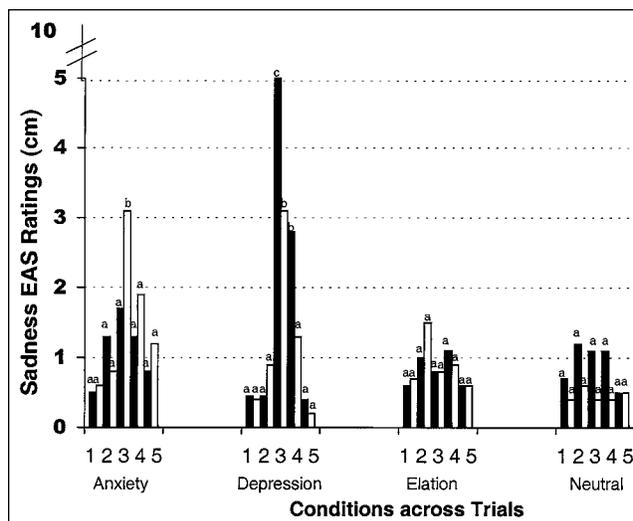


Figure 4) Emotion assessment scale (EAS) sadness ratings across trials for each condition. Bars that do not share common superscripts are significantly different at or beyond $P < 0.05$. Filled bars correspond to male participants and open bars to female participants. 1 Prebaseline; 2 First pain task; 3 Emotion induction; 4 Second pain task; 5 Postbaseline

ing variable. Figure 2 shows the pain rating change scores across 15 s intervals of pain tasks for each group and illustrates the decreasing number of participant ratings over time.

Separate 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) ANOVAs were used to analyze the change in pain severity ratings across time intervals. There were condition main effects at the 15 s mark ($n=77$; $F[3,61]=4.20$; $P < 0.01$) and at the 30 s mark ($n=60$; $F[3,44]=3.49$; $P < 0.05$). ANOVAs for later time intervals in the pain task (45 s, $n=41$; 60 s, $n=31$) showed no significant main effects or interactions.

For both the 15 s and 30 s intervals, participants in the depression condition reported more pain during the second pain task (ie, after the emotion induction) than participants in the neutral condition. After the number of participants remaining in the pain task dropped below 75%, this pattern was no longer present.

EAS: The 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 5 (trial) ANOVAs on the anxiety, happiness and sadness subscales revealed a variety of interactions.

Anxiety: A condition by participant sex by trial interaction was found involving the anxiety subscale ($F[12,256]=2.17$; $P < 0.05$). Consistent with expectations, women in the anxiety condition reported more anxiety following the emotion induction than women in the depression condition and participants of both sexes in the elation and neutral conditions (Figure 3). Only women in the anxiety condition reported significant increases in anxiety from either baseline. No other differences were found among conditions or trials.

Sadness: For the sadness subscale, a significant condition by participant sex by trial interaction was found ($F[12,256]=1.94$; $P < 0.05$). Specifically, this interaction indicated that participants of both sexes in the depression condition, and women in the anxiety condition, reported

more sadness following the emotion induction than participants in other conditions (Figure 4). Furthermore, men in the depression condition reported more sadness than participants in any other condition. These men also expressed significantly more sadness following the emotion induction than following either baseline or pain tasks. Women in the depression and anxiety conditions reported more sadness after the emotion induction than participants in the other two conditions. These women showed significant increases in sadness following the emotion induction compared with either baseline. No other differences in the sadness subscale were found.

Happiness: Condition by trial and participant sex by trial interactions were indicated for the happiness scale of the EAS ($F[12,256]=10.13$; $P<0.0001$ and $F[4,256]=5.61$; $P<0.0005$, respectively). In the condition by trial interaction, participants in all conditions showed significant decreases in reported happiness from the first baseline to the first pain task (Figure 5). Reports of happiness remained low following the emotion induction for all conditions except elation. In the elation condition, participants reported significant increases in feelings of happiness after the emotion induction compared with the first and second pain tasks. For the depression condition, reports of happiness increased significantly following the final baseline. The participant sex by trial interaction indicated that men reported more happiness at baseline than women. All participants showed less happiness during the pain tasks than at baselines.

Psychophysiology

To test for possible baseline differences among conditions, separate one-way (across the four emotion-induction conditions) ANOVAs were completed separately for ECG and both EMG channels. No significant differences were found among conditions for the initial baseline or postbaseline period.

Heart rate: For each condition within the experiment, median heart rate, in beats/min, was calculated in 10 s segments. Consistent with previous research (67,68), cardiac activity was assessed at the time the pain task was stopped, including the 10 s before discontinuation.

The 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 4 (trial) ANOVA calculated on the cardiac data found a significant participant sex main effect ($F[1,64]=8.58$; $P<0.005$). Men were found to have lower heart rates (mean 69.2 beats/min, SD 9.7 beats/min) than women (mean 74.6 beats/min, SD 8.4 beats/min). A trials main effect was also found ($F[3,192]=34.35$, $P<0.0001$), indicating that the postbaseline heart rate was significantly lower than the heart rate in the initial baseline. Consequently, postbaseline heart rate was used as a covariate in an additional covariance analysis that focused on the two pain tasks. A 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 2 (trial: pain task 1 versus pain task 2) ANCOVA revealed only a significant trials main effect ($F[1,64]=9.08$; $P<0.01$). The trials main effect results

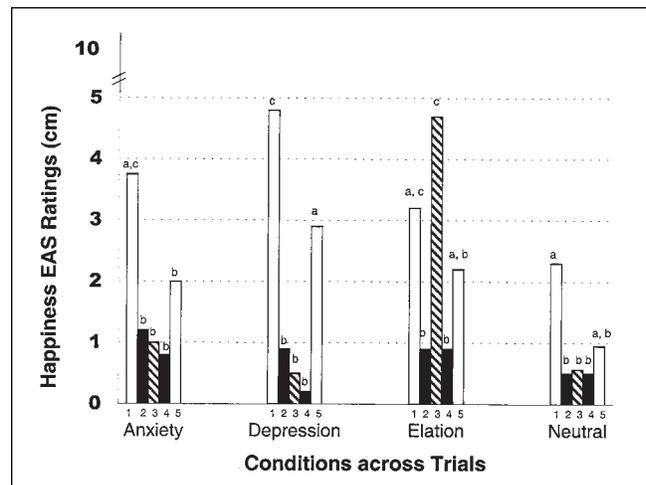


Figure 5) Emotion assessment scale (EAS) happiness ratings across trials for each condition. Bars that do not share common superscripts are significantly different at or beyond $P<0.05$. Open bars refer to baselines, filled bars correspond to pain tasks and the striped bar relates to the emotion induction. 1 Prebaseline; 2 First pain task; 3 Emotion induction; 4 Second pain task; 5 Postbaseline

showed that, when collapsed across conditions, heart rate was higher during the first pain task (mean 74.3 beats/min, SD 9.0 beats/min) than during the second task (mean 72.8 beats/min, SD 8.6 beats/min). No other differences were noted for this ANCOVA.

Muscle tension: To produce comparable information, data reduction procedures for EMG are similar to those outlined for heart rate. The 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 4 (trial) ANOVA for the corrugator supercilia EMG data revealed a significant experimenter sex by trial interaction ($F[3,192]=2.81$; $P<0.05$). No other interactions or main effects were significant. For the experimenter sex by trial interaction, corrugator EMG activity dropped significantly for the participants paired with female experimenters. Corrugator EMG activity during the final baseline, however, was higher for those paired with female experimenters than those paired with male experimenters. There were no other significant differences.

A 4 (condition) \times 2 (participant sex) \times 2 (experimenter sex) \times 4 (trial) ANOVA for the trapezius EMG data showed a trials main effect only ($F[3,192]=21.48$; $P<0.0001$). Follow-up tests revealed that trapezius EMG values increased significantly from the first baseline to the two pain tasks, then decreased during the final baseline. No other differences were found.

DISCUSSION

The present study found that, even in a laboratory setting, acute pain and emotion interact across response systems. Both anxiety and depression had a powerful effect on pain, precipitating greater escape (ie, less pain tolerance). The effects of anxiety and depression on pain have been observed independently (39,40,41,49,69,70) but infrequently together in the same paradigm (15). Verbal reports

of pain were found to be greater only in participants in the depression condition, and only early in the pain induction.

Zelman et al (49) did not find differences in pain severity ratings based on emotion; methodological differences (eg, in the type of painful stimulation) may have prompted the present results relating to self-reports. The relatively weaker effect of anxiety induction on pain ratings may have to do with the relevance of the anxiety to pain. Vlaeyen and Linton (9) noted that 'pain-related fear' may be an essential component to the development of a chronic pain problem. In the present investigation, the anxiety emotion induction may not have had a significant effect on pain ratings because the anxiety was not relevant enough to the painful stimulation. Nevertheless, this same 'relevance' issue holds true for the depression condition as well.

As predicted, sex was found to affect acute pain strongly; statistical differences associated with sex, both participant and experimenter, were noted in a number of systems of data. The finding that men persisted longer in pain tasks and reported less pain than women was expected and is consistent with results of other research (71). Participants demonstrated longer pain tolerance for female experimenters, which is similar to the findings of some research (51) and inconsistent with others (71). Interestingly, none of these influences appeared to interact with the emotion manipulations or to change across trials.

Anticipatory anxiety may have played a role in the present study. Although this sample did not include patients with significant existing acute or chronic pain conditions, most people have either direct or vicarious experience with pain and thus may experience the types of physiological arousal and emotional responsivity seen in the early parts of this study when concerned about possible pain contact. Other research (72) supports the idea that pre-existing anxiety can interfere with treatment for pain disorders and may be more persistent longitudinally than depression.

The lack of findings for pain tolerance in the elation condition in the present study differed from results of other published research. Zelman et al (49) found that elation produced greater pain tolerance. Whipple and Komisaruk (73), and Stevens et al (74) both reported that pain tolerance increased during episodes of happiness or pleasure. It is difficult to explain definitively why the results of the present study do not coincide with that of other research. During the baseline pain trial, participants in the elation condition demonstrated significantly less pain tolerance than the other groups. In spite of randomization, they may have been pre-experimentally unique from the other groups.

The clinical implications of the present study's findings can be forwarded with caution, given the lack of comparable laboratory-based pain research. Depression appears to decrease tolerance to pain as well as increase reports of pain, at least early in pain induction. Therefore, when individuals with pain problems are treated, it is important to assess for concurrent depression. For example, a depressed patient may endure a painful medical procedure with less pain and greater tolerance if a brief intervention is imple-

mented before the procedure aimed at reducing their depression. Regarding anxiety, similar clinical implications apply as those with depression. Patients with increased anxiety are likely to display greater pain behaviours than a patient who is less anxious. Previous research (30) has suggested that it would likely be of benefit to patients and their pain level if they were less focused on anxiety. Providing information or control may help reduce anxiety sufficiently to ameliorate significantly the aversiveness of the pain experience.

There are a number of limitations to the generalizability of the present study's findings. First, baseline differences were present for some variables, despite statistical and methodological attempts to equalize these values. In addition, due to ethical concerns, pain duration was limited and participants could discontinue the pain task whenever they wished, which contributed to the previously discussed limitation of statistical power of some analyses. Given the fundamental differences between highly predictable laboratory pain (ie, duration of 5 mins) and less predictable clinical pain, generalization of laboratory conclusions to clinical settings must be made with caution. The same cautionary statement must be made regarding the generalizability of the mild, transient changes produced by the Velten-style emotion induction to settings outside of the laboratory. Second, the population used in this study may also limit the conclusiveness of the obtained results. These individuals were relatively young, healthy, mostly white, and were not experiencing significant pre-existing acute or chronic pain at the time of the experiment. Therefore, it is possible that a different population (eg, chronic pain patients) may show an alternative pattern of results. Third, this study focused only on experimentally induced acute pain. While the results may well generalize to certain settings (eg, dentistry) and pain conditions (eg, migraine headaches), they are not universally applicable to all situations or types of pain.

The present study extended aspects of experimental pain research into areas where little has been published. Strong conclusions are best drawn from a body of literature and not from a single study. For this reason, additional work is needed. Specifically, theory-driven models are needed to include various types of negative affect, as well as positive emotions. Moreover, additional experimental work that includes a focus on more than one dimension of negative affect is needed (4). The present results are consistent with the literature suggesting the importance of sex and gender effects in the experience and expression of pain (75,76) and further encourage their exploration. Finally, the present experimental design prompts further study of the effects of sequential ordering of pain and emotions in experimental and naturalistic settings.

CONCLUSIONS

Pain and emotions are ubiquitous parts of the human condition that have been studied for centuries. Nevertheless, they are not well understood, either independently or in combination. The variables that affect pain and anxiety or

fear (19) and other emotions (2) are interactive and complex. The irony of pain is that those who experience it persistently and respond to it with intense emotion are compelled to alleviate it at immense personal cost. Yet those who ignore pain or suppress the emotions associated with it may more readily perish. The urgency for answers to help control the suffering involved in pain and negative emotions is tremendous. The solutions to these issues, however, continue to be elusive.

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