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Cognitive and Psychophysiological Investigation of Chronic Pain

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By

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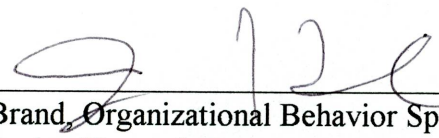
Each person whose signature appears below certifies that this thesis in their opinion is adequate, in scope and quality, as a thesis for the degree Master of Arts.



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Abstract

Using Bower's (1981) associative network model of mood and memory, and Klinger's theory of current concerns, it was hypothesized that the experience of chronic pain may be functionally similar to a mood state and that the chronicity of the condition may maintain it as a current concern. Specifically, it was hypothesized that chronic pain patients would not show any differences in reaction time and accuracy when making lexical decisions about pain-related, neutral, and nonwords. However, it was anticipated that chronic pain patients would show differences in physiological responding (particularly, increased skin conductance responses) when compared to controls. Results confirmed that there were no differences between chronic pain patients and control subjects on reaction time and accuracy. Physiological indices, on the other hand, showed that chronic pain patients exhibited diminished skin conductance response magnitudes overall when compared with controls. Moreover, unlike controls, chronic pain patients failed to show an acceleratory heart rate response at the end of the trials. Word type was not observed to produce differences in psychophysiological responding. These results are interpreted as suggesting the possibility of diminished attentional resource allocation in those individuals suffering from chronic pain

Cognitive and Psychophysiological Investigation of Chronic Pain

Does experiencing chronic pain alter the way an individual processes information from the environment, and if so, how? Assuming an affirmative answer, the associative network theory of mood and memory may offer a theoretical explanation of the changes in information processing in chronic pain patients. Bower (1981) developed the associative network theory of mood and memory from the previous work of Collins and Loftus (1975) and suggested that emotional states are represented as nodes within a semantic network. Each node is connected to particular events which individuals rely upon to recall events. Events are represented in terms of descriptive propositions, and new associations are characterized in terms of the concepts used when the event is described. Activation spreads from one concept to another via associative connections, as well as occurring when a related stimulus is presented or when a similar thought had been previously activated. Emotional states prime or activate particular categories or words related to those states. Learning is defined as the establishment of associations and the subsequent strengthening of the links.

The associative network model of mood and memory has been the impetus for numerous studies (Caballero & Moreno, 1992; Challis & Krane, 1988; Clark, Teasdale, Broadbent, & Martin, 1983; Halberstadt, Niedenthal, & Kushner, 1995; Hill & Kemp-Wheeler, 1989; MacLeod & Mathews, 1991; Mathews & Milroy, 1994; Mathews, Richards, & Eysenck, 1989; and Niedenthal & Setterlund, 1994). This theoretical approach has been tested by manipulating mood experimentally and by examining the

behavior of subjects suffering disorders of mood using a number of tasks, including lexical decision and word recall. For example, Halberstadt, et al. (1995) found that when subjects were asked to write down the meanings they associated with ambiguous word cues, responses corresponded with their induced mood state. Sad subjects were more likely to record sad meanings relative to the neutral list of words they were presented. These findings were also consistent with those of Mathews, et al. (1989) where clinically anxious subjects were presented with homophones, each having the same sound but different spellings. The two spellings were either neutral (e.g., d-y-e; p-a-n-e) or threat-related (e.g., d-i-e; p-a-i-n). Subjects were presented the words and instructed to write down the word they heard. Results showed that anxious subjects interpreted the homophones in a threatening context rather than a nonthreatening context, using the threat-related spelling (e.g., d-i-e instead of d-y-e).

Similar mood congruency effects were found by Niedenthal and Setterlund (1994) where subjects in induced happy and induced sad mood states were studied. Subjects in a happy mood had faster lexical decision times for happy words than for sad words, while subjects in a sad mood had faster lexical decision times for sad words than happy words. MacLeod and Mathews (1991) found similar findings as well. When subjects were presented two letter strings (which were some combination of neutral words, anxious words, and nonwords) lexical decision times of anxious subjects were faster when negative words were presented than when neutral words were presented.

However, not all evidence has been supportive of the associative network model. In one study, Clark, et al. (1983) examined whether induced elation or depression would

affect lexical decision time and word recall. Lexical decision times were not significantly faster for mood congruent words than for neutral words or mood incongruent words. Also contrary to the associative network hypothesis was the finding that words not congruent with the mood state were recalled faster than those words which were congruent with the mood state.

Failure to find a mood congruency effect with induced mood using the lexical decision paradigm was also seen in the work of Challis and Krane (1988). Results demonstrated that subjects in an elated mood responded significantly faster to positive words than negative words or neutral words. Despite similar responses found in the neutral word group (responses faster for positive and negative words than for neutral words), depressed subjects were found to respond faster to both positive and negative words than neutral words.

One possible reason for these results not being well accounted for by the associative network model is that experimentally inducing mood may not always yield a strong effect, and the induced mood may not be as powerful as when an individual is 'naturally' experiencing a mood state. In order to avoid this potential confound, Caballero and Moreno (1992) investigated the relationship between perception and mood in subjects diagnosed with a mood disorder. They hypothesized that lexical decision time to mood congruent words would be faster than reaction time to incongruent words, as well as expecting a higher probability of word recall for congruent as compared with incongruent items. Of the four groups (mildly depressed, non-depressed, induced depression, and induced elation), the non-depressed and elated groups responded faster to

positive words than to negative words. Responding to negative words was not significantly faster than responding to positive words in either the mildly depressed or depression induced groups, and probability of word recall was not significantly different for any of the four groups.

Mathews and Milroy (1994) also conducted a series of three experiments designed to investigate the processing of emotional meaning using clinically anxious subjects instead of mood-induced subjects. The first study examined lexical decision time by anxious subjects and control subjects. Both groups tended to make slower judgments of words with a negative valence than words with a positive valence. The anxiety group did not demonstrate increased proficiency in the emotional processing of words. The second experiment involved subjects making an affective judgment, comparing stimuli which had or had not been primed. Priming did not appear to facilitate subjects' ability to discriminate the affective valence of events, even for mood-congruent words. Finally, the third study revealed that anxiety-prone subjects did not demonstrate faster accessing of negative meaning when threatening words were presented. Though these studies intended to show selective encoding of words by anxious subjects, this was not demonstrated.

Finally, Hill and Kemp-Wheeler (1989) investigated whether anxiety influenced lexical decision times when threatening (anxiety-inducing) and non-threatening words were presented to non-pathological subjects, divided into high anxiety and low anxiety groups. Results again indicated that along with simple reaction time, lexical decision time was not influenced by anxiety. High anxiety subjects did not respond significantly

faster than low anxiety subjects when a threatening, anxiety-inducing word was presented. It was suggested that a sufficient amount of time allowed for semantic processing was not available, and therefore the subjects, regardless of anxiety level, would not identify threatening words more quickly than non-threatening words.

Despite the discrepancies in the findings of the aforementioned studies, the associative network model should not necessarily be discounted as an explanation for the processing of emotionally salient environmental information. As indicated above, mood congruency effects in lexical decision and word generation have been reported. The question then becomes, why are mood congruency effects found in some cases and not in others?

One possibility may be the type of mood state. Many of the studies which failed to support the associative network model used mood induction procedures which may or may not result in the same kinds of processing changes that occur in chronic motivational states. Moreover, the 'natural' mood states used have typically been trait anxiety or depression, both of which may include changes in information processing in addition to those predicted by the associative network model. These additional changes could produce interference with negative or anxiety-related stimuli such that the effects of activation of emotional nodes may not, in turn, produce speeding of lexical decision times. As a result, inconsistent observations may be reported, as indicated above.

Since the present study will utilize subjects in chronic pain, there is assurance of a natural, chronic motivational state. Furthermore, chronic pain might be thought of as including a chronic motivational state such that pain-related stimuli in the environment

would be processed as motivationally relevant, and therefore of current concern. The construct of current concerns (or personal relevance) developed by Klinger (cited in Nikula, Klinger, & Larson-Gutman, 1993) refers to an underlying internal state of an individual, one which continues from the beginning of the pursuit of a goal(s) until the end. The goal(s) for individuals are quite diverse, ranging from finishing a book to working out a relationship. The effect of cognitive activity and current concerns was investigated by Boc0k and Klinger (1986); results indicated that words relevant to personal concern and those considered emotionally arousing were recalled faster than irrelevant and non-arousing words. In addition, current concerns appear to affect physiological indices, specifically electrodermal activity. Nikula, et al. (1993) investigated the effect of current concerns and electrodermal reactivity, and found that there appears to be an influence on skin conductance. In response to personally relevant material of personal concern to the subject, skin conductance increased in magnitude, whereas responses decreased when items were not of current concern. Nonspecific skin responses were also more likely to occur in the presence of cognitions related to negative emotions, experienced arousal, current concern, and inner speech.

If chronic pain can be regarded as a motivational state which may affect the connections between nodes in a semantic network (Pearce, Isherwood, Hrouda, Richardson, Erskine, & Skinner, 1990), and chronic pain may be regarded as a point of current concern/personal relevance for those who suffer it, then it seems reasonable to expect that chronic pain patients may demonstrate changes in processing pain-related information in comparison to individuals without chronic pain.

Indeed, there have been reports indicating changes in information processing among chronic pain patients. Some of these changes could be relevant to the extent that they underlie the accessing and processing of current concern/personally relevant information. For example, the processing of semantic information has been investigated by Pincus, Pearce, McClelland, Farley, and Vogel (1994). Their work focused on semantic processing of ambiguous words by chronic pain patients. Pain patients were presented an ambiguous word cue and asked to respond with an association. Chronic pain patients produced pain-related words in association with the stimuli, whereas control subjects responded with neutral words. However, Asmundson, Kuperos, and Norton (1997) failed to find selective attention to pain-related information by chronic pain patients. Using a modified Stroop paradigm, chronic pain patients showed slower detection latencies than controls (irrespective of word type), yet failed to show any attentional bias towards pain-related cues.

Consistent with Pincus, et al. (1994), word recall by chronic pain patients has demonstrated a bias towards the recall of pain-related words. Pearce, et al. (1990) compared word recall of pain patients and controls when presented with a list containing pain-related words, negative words, and neutral words. Results showed that pain patients were more likely to recall pain-related words when compared to neutral words. Further, when a 5-minute interference task was presented (i.e., reading a newspaper) with word recall following the delay, pain patients again recalled more pain-related words than neutral or negative words in comparison to controls.

In addition to semantic information processing, general information processing ability has also been studied in chronic pain patients. Grigsby, Rosenberg, and Busenbark (1995) retrospectively analyzed information processing in chronic pain patients. The investigators reasoned that the chronic experience of pain may impair information processing, and pain may affect the brain's active state and therefore may account for cognitive impairment. Retrospective data of chronic pain patients were compared to a group of mild to moderate head trauma patients. Though impairment in processing might reasonably be expected in the head trauma patients, pain patients were not anticipated to show significant differences in impairment. Subjects had been measured on several tasks, including motor speed (finger tapping), motor coordination (touching finger to nose), visual short-term memory (recall of visuospatial pattern of lights and visual numerical memory), and processing speed. Processing speed was assessed by subjects moving their right or left hand from a 'home' location to a switch in front of a light. The task began with one specific target, but increased in difficulty as the number of targets increased. Upon analysis, chronic pain patients and head trauma patients did not differ significantly, indicating that both groups demonstrated impairment in processing (compared to the processing ability expected from healthy individuals). In fact, pain patients performance was inferior (albeit nonsignificantly) to head trauma patients on central processing speed. Because of the methodological limitations of their study (e.g., lack of control subjects, retrospective analysis) the findings suggestive of altered information processing in chronic pain patients seem questionable, and further investigation into this area is necessary.

The work of Grigsby, et al. (1995) showing general processing changes taken together with the tendency to interpret ambiguous items as pain-related, and the work pertaining to current concerns suggest that changes in performance by chronic pain patients in a lexical decision task may be expected. Such a task using personally relevant material (i.e., pain-related words), might be expected to show modulation of lexical decisions and word recall, as well as producing psychophysiological changes. This considered, the aim of this study is threefold: (1) to assess whether the performance of chronic pain patients is significantly different from controls on a lexical decision task (measured in terms of reaction time and accuracy); (2) to assess whether recall of pain-related items used in the lexical decision task is significantly different between chronic pain patients and controls; and (3) to compare psychophysiological indices (specifically skin conductance response and heart rate) recorded during the lexical decision task between chronic pain patients and controls. Though based on the inconsistent results in previous lexical decision work, it is not anticipated that there will be differences in reaction time and accuracy between groups. However, it is hypothesized that word recall will be different for the two groups, with the pain group recalling more pain-related words than the control group. In addition, the work with current concerns and physiology suggests the hypothesis that skin conductance response (SCR) and heart rate (HR) will differ (i.e., chronic pain patients exhibiting larger SCR and greater HR responses) from controls when viewing items of personal relevance (i.e., pain-related words), indirectly indicating cognitive processing differences.

Method

Subjects

Thirty-six participants (18 controls, 18 pain patients) were recruited from the Loma Linda University community and from the physical therapy clinic located at the University via advertisement. Advertisements were posted on the walls in the reception area of the clinic, as well as in the University's employee newsletter. Subjects were paid $10 as compensation for their time.

The chronic pain group consisted of individuals who had experienced continuous pain for at least six months. The six-month criterion was chosen as the cutoff for the 'chronic' condition because there appears to be some convergence on this length of time as a minimum time for pain to be considered chronic (instead of acute or sub-acute) across the literature including those studies focused on depression (e.g., Haythornthwaite, Sieber, & Kerns, 1991; Rudy, Kerns, & Turk, 1988; Smith, O'Keeffe, & Christensen, 1994; Turner & Romano, 1984) and social support (e.g., King & Snow, 1989; Kleinke, 1994; Paulsen & Altmaier, 1995; Romano et al., 1992). In addition, the International Association for the Study of Pain has set forth guidelines concerning the classification of chronic pain, finding that in differentiating between acute and chronic pain, three months is a convenient point of division (though more often, it is pain persisting for six months that is classified as chronic) (IASP, 1986). Given the choice between three and six months, the six-month minimum was felt to be the most conservative length of time to use. The chronic pain group did not include individuals with cancer or other terminal

conditions because of the possible confounding effects of the strong drug treatments often used in these conditions.

Because subjects were not randomly assigned to groups (due to the preexisting nature of chronic pain), an effort was made to match subjects in both groups on the potentially confounding variables of gender, age, and education level. The groups were not statistically different (gender and education level, χ^2's > 1.88, p's > .05; age, t (34) = 0.71, $p > .05$) when compared on these variables (see Table 1).

Materials and Apparatus

All stimuli for the lexical decision task was presented via a color monitor controlled by a Pentium-based PC. Subjects responded using their preferred hand to press buttons labeled 'word' and 'nonword' on a response box. MEL computer software (v 2.0, Schneider, 1995) was used to program and generate the lexical decision task and to record the response times in the lexical decision task. Eighteen pain-related words were selected from the adjectives appearing in the short form of the McGill Pain Questionnaire (Melzack, 1975). Neutral words were chosen from those items appearing in the in the corpus used by Francis & Kucera (1982) and matched to the pain-related words on frequency, number of syllables, and length (as closely as possible). Nonwords were created by making an anagram from each word in the pain-related and neutral word categories. With 18 pain words, 18 neutral words and 36 nonwords each presented once, the lexical decision task consisted of 72 total trials. These items are listed in Appendix A.

Each trial began with a fixation cross ('+') at the center of the screen. After 1000 ms the fixation cross was replaced by the stimulus: a pain-related word, nonword, or neutral word. Words and nonword stimuli were presented in random order in white letters on a black background. Stimuli were presented for 350 ms and were immediately masked. The mask remained on the screen until the subject made a response. At the viewing distance of .5m, typical for all subjects, the words subtended a horizontal visual angle ranging from 1.15° to 4.35°; the stimuli were .7° in height.

Skin conductance responses were recorded using a Contact Precision Instruments (CPI) constant voltage system (CPI SC4 module, SN 9121, 0.6V) and SensorMedic Ag/AgCl electrodes (9mm inner diameter) filled with Synapse ™ electrode paste. Skin conductance data were digitized and sampled at 20 Hz throughout the experiment. The magnitude of responses were scored as the largest increase (in μSiemens) observed with a response onset occurring between one and four seconds after the stimulus onset. A square root transformation was applied to the data before analysis (Dawson, Schell, & Filion, 1990).

Heart rate output were recorded via a Contact Precision Instruments (CPI) photoplethysmograph (CPI-FPA coupler, SN 9127) which was attached to the middle finger of the nonpreferred hand. Output was directed through a timer (CPI, SN 9151) that returned the interval between successive pulse waves at the finger, which were digitized and sampled at 20 Hz throughout the experiment. The interpulse interval data were averaged within .5s epochs beginning one second before the stimulus and

continuing for a total of eight seconds (16 epochs) using the algorithm of Graham (1978). After converting the interpulse interval scores to heart rate (bpm), change scores were calculated with reference to the second epoch (i.e., the half-second interval before the onset of the stimulus). The heart rate change scores were used in the analyses.

Procedure

After obtaining informed consent, subjects were asked to wash their hands with warm water and soap in order to remove any dirt, oils, or lotions from their skin which might potentially corrupt the skin conductance recording. Upon the subjects' return, electrodes were placed on the thenar and hypothenar eminence of the subject's nonpreferred hand for measurement of the skin conductance response. Subjects were then taken into a small, well-lit room where a photoplethysmographic device was attached to one finger to record their heart rate.

Subjects were seated in a comfortable chair and the response box was moved to a comfortable, convenient position, in which the subjects were able to rest their hand and quickly respond using the buttons on the box. The experimenter then briefly described the lexical decision task and instructed the subjects to read the computer-generated instructions. Following this, subjects completed 10 practice trials. All words in the practice trials were of neutral valence and none of them were used during the actual experiment. If there were any remaining questions, the experimenter answered them to ensure that the subjects completely understood the task. The subjects then began the experimental trials.

At the conclusion of the 72 experimental trials (each trial consisting of the presentation of one word), electrodes were removed, subjects were provided with paper and pencil, and they were told that their next task would be to write down as many of the real words that they had seen during the experiment as they could recall. Subjects were told that they would have up to five minutes to complete the task. The experimenter also explained to the subjects that they had purposefully not been told that a recall task was part of the experiment because it was important to focus on the lexical decision task during the preceding trials rather than on memorizing the words.

Following the recall test, subjects completed the short form of the McGill Pain Questionnaire (Melzack, 1975). Subjects were instructed to complete the form with reference to how they were feeling at that moment in time. Subjects in the control group were asked to complete the form in order to verify that they were not experiencing chronic pain. Although six of the 18 control subjects reported the experience of current pain, it was later verified that the pain was not due to a chronic condition, and that the complaint had recently developed (e.g., a headache, stiff neck from sitting at work, etc.). Moreover, statistical analyses indicated that the control subjects in acute pain differed from those not in pain only in that they recalled more words, specifically pain-related words, following the lexical decision task (means = 5.5, 3.1 words, respectively, $\underline{F}(1, 15) = 6.45$, $\underline{p} = .02$). Upon completion of the questionnaire, subjects were debriefed and compensated for their time.

Design and Analysis

The experiment employed a 2 (Group: pain vs. control) x 3 (Word Type: pain-related vs. neutral vs. nonword) mixed factorial design. Separate analyses of variance (ANOVAs) were calculated on the following dependent variables: reaction time, accuracy, skin conductance response, and heart rate. Because the word-type factor consisted of more than two levels, Greenhause-Geisser corrections of degrees of freedom were employed to guard against possible violations of the sphericity assumption. Uncorrected degrees of freedom and the epsilon correction factors are reported where indicated.

Results

Reaction Time

The means for the lexical decision task are presented in Table 2. A significant main effect for Word Type was demonstrated $F(2,68) = 10.77$, $\varepsilon = .61$, $p = .001$, in which all subjects demonstrated faster reaction time for pain and neutral words than for nonwords (t's > 2.6, p's $< .01$). A significant main effect of Group was not found. However, there was a nonsignificant trend ($p = .21$) for pain patients to be slower than controls in reaction time across all word types. Moreover, pain patients were faster in responding to pain words than to neutral or nonwords, however, there was not a significant Group x Word Type interaction.

Accuracy

Despite the fact that pain patients had slower reaction times to all words than the controls, their performance was not more accurate than that of the controls. The statistical analysis revealed no significant main effects or interactions.

Word Recall

There were no significant differences between groups on total number of words recalled or number of intrusions (t's > .71, p's > .05). Control subjects did recall fewer words (mean = 3.9) and reported more intrusions (mean = 2.1) than pain patients (means = 4.5, 1.5, respectively). When the control subjects in acute pain were excluded from the analysis, the effect remained insignificant. As indicated above, six of the control subjects reported experiencing acute pain at the time of the experiment and recalled more pain-related words when compared to control subjects not in acute pain.

Heart Rate (HR)

The ANOVA of the heart rate change scores across epochs revealed a significant main effect for Epoch, $F(15, 510) = 61.78$, $\varepsilon = .18$, $p < .001$. These results reflect the deceleration-recovery pattern of heart rate commonly observed in warned, speeded-response studies such as this (see Figure 1). In addition to the significant main effect for Epoch, there were significant linear, cubic, quadratic, and quartic trends, F's $(1,34) > 8.75$, p's $< .005$.

Visual inspection of the heart rate change scores suggested that at Epochs 13 to 16, heart rate responses of the two groups diverged, with the control group continuing to

show an acceleratory response beyond the pre-stimulus baseline, while the pain group's response stabilized at baseline without the additional acceleration. This pattern was also suggested in the statistical analysis by a marginally significant interaction effect between Epoch and Group, $F(15, 510) = 7.608$, $p = .078$. Because of the graphic representation and the marginally significant interaction, additional exploratory analyses were performed in order to ascertain whether or not there existed a significant difference between the pain group and the control group at Epochs 13 to 16.

For this analysis, the 16 Epochs were divided into three sets (Epochs 1 to 7, Epochs 8 to 12, and Epochs 13 to 16) and separate ANOVAs were performed for each category of Epochs. For Epochs 1 to 7 and Epochs 8 to 12, there were no significant group differences. However, for Epochs 13 to 16, a significant main effect of Group, $F(1, 34) = 7.83$, $p = .008$, was observed, providing confirmation of the difference in heart rate response patterns between control subjects and pain patients across these Epochs.

None of the effects or interactions involving the Word Type factor were significant.

Skin Conductance Response (SCR)

There was a significant main effect for Group, $F(1,34) = 4.85$, $p < .05$. The magnitude of the skin conductance responses (SCRs) of control subjects was greater than the SCR magnitude recorded in pain patients (see Figure 2). Furthermore, there was a significant interaction effect between Group and Word Type in the analysis of SCR magnitude, $F(2,68) = 4.18$, $\varepsilon = .99$, $p = .019$. Pain patients showed little change in

response magnitude across the three word types, while control subjects showed larger magnitude SCRs when presented with pain-related words and nonwords than when neutral words were presented. One-way ANOVAs performed separately for each group revealed a significant quadratic trend for control subjects, $\underline{F}(1,17) = 6.10$, $\underline{p} < .05$; however, for the pain patients only the linear trend approached significance ($\underline{F} = 4.19$, $\underline{p} = .056$). These trends appear to better explain the significant interaction between the quadratic trend across Word Type and Group (as previously reported).

Responders vs. Nonresponders

Because of the difference in magnitude of skin conductance response of pain patients as compared with controls, subjects were classified according to total number of responses throughout the experiment in order to explore any possible differences which may have been related to skin conductance responding. Specifically, it might be suggested that the main effect of Group was due to a large number of subjects in the pain group who did not produce SCRs at all. Even if the pain patients who did produce SCRs responded similarly to the control subjects, the nonresponders might have produced the significant statistical effect. Therefore, those subjects with five or fewer skin conductance responses across all 72 experimental trials were classified as 'nonresponders', while those subjects with six or more responses were classified as 'responders'. A chi-square analysis suggested that this classification produced three valid groups, $\chi^2 =$: Pain Responders ($\underline{n} = 9$), Pain Nonresponders ($\underline{n} = 9$), and Control

Responders (n = 17). Because 17 of the 18 control subjects were Responders, the one Control Nonresponder was omitted.

Skin Conductance Response. Inspection of Figure 3 suggests that even when nonresponding pain patients are excluded, pain patients still produce smaller skin conductance responses than control subjects. The statistical comparison made between Pain Responders and Control Responders did not reveal statistically significant main effects for either Group or Word Type (p's > .05), suggesting that the significant effect of Group in the original analysis was produced by the inclusion of the Nonresponders in the patient group. However, this conclusion is qualified by a marginally significant Group x Word Type interaction, $F(2,48) = 3.08$, $\varepsilon = .99$, $p = .055$, and a significant quadratic trend across Word Type x Group interaction, $F(1,24) = 4.36$, $p < .05$. In order to investigate interactions, an analysis examining only the SCR's to lexical stimuli was conducted. This analysis revealed a significant Word Type x Group interaction, $F(1,24) = 6.55$, $p = .017$, suggesting that pain patients who produced SCR's nevertheless produced smaller responses to pain words than to neutral words in contrast to the responding control subjects, whose responses to pain-word stimuli were greater than to neutral-word stimuli (see Figure 3).

Heart Rate. The expected significant main effect of Epoch was observed, $F(15, 480) = 9.62$, $\varepsilon = .18$, $p < .001$. Visual inspection of the heart rate change scores (see Figure 4) suggested that as in the previous heart rate analysis, the heart rate responses of the three groups diverged at Epochs 12 to 16, with the Control Responders continuing to

show an acceleratory response beyond the pre-stimulus baseline, while the responses of both pain groups stabilized at baseline without the additional acceleration. Analyses including only Control Responders and Pain Responders demonstrated a significant main effect for group, $F(1,24) = 7.72$, $p = .01$, as well as Epoch, $F(4,96) = 6.82$, $p = .02$. However, no other pair-wise comparisons (Pain Responders vs. Pain Nonresponders; Control Responders vs. Pain Nonresponders) revealed any significant differences between groups. Because of the acceleration pattern of Pain Nonresponders and deceleration pattern of Control Responders at the end of the trial (Epochs 14 to 16), pair-wise analyses were performed using only Epochs 12 and 13. These analyses revealed a significant difference in heart rate between Control Responders and Pain Nonresponders at Epoch 13, $F(1,24) = 5.72$, $p < .025$, and a marginally reliable difference at Epoch 12, $p = .14$, indicating that the acceleration pattern in heart rate produced by Control Responders was greater than that of both pain subject subgroups.

Reaction Time. Analyses revealed a significant main effect for Word Type, $F(2, 64) = 13.02$, $\varepsilon = .62$, $p < .001$, reflecting the advantage of words over nonwords as reported above. Of the three groups, the Pain Responders showed the slowest average reaction time to pain words and neutral words when compared to Pain Nonresponders and Control Responders. However, when examining reaction times to nonwords it was the Pain Nonresponders who showed the slowest responding. This crossover in reaction times resulted in a significant Word Type x Group interaction effect, $F(4,64) = 3.00$, $\varepsilon = .62$, $p = .05$.

Accuracy and Recall. No significant differences between type of responder or word type were observed in the analyses of accuracy, word recall, and prevalence of intrusions.

Discussion

As was anticipated, there were no significant differences in reaction time by group, indicating that pain patients did not respond differently to pain words than control subjects. Despite the fact that pain patients tended to demonstrate slower reaction times overall, their performance was not more accurate than that of controls. These results are in harmony with previous work in which no differences were observed between control and motivation/emotion groups when presented with only a single stimulus (Matthews & MacLeod, 1994; Hill & Kemp-Wheeler, 1989; Challis & Krane, 1988; and Clark et al., 1983).

The physiological indices produced the most interesting findings. Analysis of heart rate change scores revealed the deceleration-recovery pattern of heart rate often observed in warned, speeded-response studies (Bohlin & Kjellberg, 1978). Though pain patients were hypothesized to show different responding to pain words than controls, no significant word type effects were observed. However, the two groups did diverge toward the end of the trial, with pain patients' heart rate responses stabilizing at baseline and control subjects' responses exhibited additional acceleration. This statistically significant late acceleration occurred during the seconds after the subject had produced their lexical decision and did not vary across word types. A phasic heart rate acceleration may be caused either by the withdrawal of parasympathetic tone or an increase of

sympathetic activity (Papillo & Shapiro, 1990). Of these alternatives, the possibility that this late acceleration may be sympathetically generated is suggested by the skin conductance results.

It was hypothesized that pain words would be motivationally salient to pain patients and, when presented as target items in a lexical decision task, would result in larger SCRs in those experiencing chronic pain as compared with the control group. This hypothesis was not supported by the data. Rather, pain patients demonstrated smaller SCR magnitudes overall when compared to controls. Moreover, the difference persisted even when the half of the pain patients classified as Nonresponders were removed from the analysis. Skin conductance responses are sympathetically generated (Dawson et al., 1990) and, as scored in this experiment, occurred during the five seconds after presentation of the lexical decision stimulus; therefore, control subjects were producing larger SCRs than pain patients at about the same time their heart rate was accelerating above the baseline.

One possible explanation for the different physiological responding observed in pain and control subjects may lie in the fact that with chronic pain there is constant stress on the body and therefore the allocation of resources may be different for chronic pain patients than for control subjects. For example, pain may result in smaller amounts of attentional resources available for allocation when presented with an environmental demand, and, in turn, smaller physiological responses.

Another explanation may relate to the function of the sympathetic nervous system in chronic pain. This argument essentially involves the Law of Initial Values. The

sympathetic nervous system responds to pain and the system has been reported to be tonically aroused in chronic pain patients (Cailliet, 1993). When other stimuli are presented which might induce sympathetic activation, such as the arousing pain words in the current lexical decision task, there may be a restricted range for further increases in sympathetic activation, and thus, smaller SCRs and lack of heart rate acceleration would be observed in chronic pain patients.

It is currently not possible to decide between these two options. To begin with, pain patients showed slower reaction times overall (to all word types) when compared to control subjects as would be expected if sympathetic activation compromised attentional responding, yet statistical comparison revealed that these differences were nonsignificant. Moreover, pain patients were not less accurate than controls in lexical decision performance as would be predicted if attentional resources were compromised. In contrast, visual inspection of the heart rate suggests that there were no differences between average heart rate of chronic pain patients and controls. If one were to consider increased sympathetic activation as an explanation of the physiological differences between the two groups, this would not be supported by the heart rate. More direct evidence would be obtained if in future experiments an adaptation period was added to the experimental procedure in an effort to measure resting heart rate and nonspecific skin conductance responses.

A logical next step to help differentiate the alternatives in the function of patients with chronic pain would be to increase the difficulty of the information processing task, for example masking the lexical decision stimuli earlier in the trial, employing the Stroop

paradigm or the Rapid Serial Visual Presentation (RSVP) paradigm. For example, Asmundson, et al. (1997) found significant response latency differences between chronic pain subjects and controls when utilizing a modified Stroop task. Moreover, additional physiological responding needs to be recorded, perhaps including other indices such as EMG of the blink response. Flor, Knost, and Birbaumer (1997) reported that pain-related words elicited a higher startle eyeblink amplitudes when compared with neutral words (Flor et al., 1997).

It also was hypothesized that pain patients would recall more words, specifically more pain words, when compared to controls. This result was not observed; pain patients did not recall more words (pain or neutral) than controls. However, it was found that those control subjects reporting pain (acute pain at the time of the experimental session, such as a headache, a sore neck from sitting at work, etc.) did recall more pain-related words than controls. An explanation for this finding may be that with acute pain, pain-related words may be more salient for those individuals who are not used to experiencing pain. For chronic pain patients, on the other hand, the pain-related words may not be salient because they have habituated to their pain state, and therefore any words relating to pain are not pertinent to them. Nevertheless, this result points to possible differences in the mechanisms of pain, specifically distinctions between acute and chronic pain, and the impact it may have on information processing and physiological responding. This considered, further work in the area of acute versus chronic pain could be usefully pursued, specifically the combined examination of information processing ability along with physiological responding. Such an investigation may provide better distinctions

between these different pain states, and may elucidate characteristics specific both to chronic pain and acute pain.

Another important consideration relates to the associative network theory of mood and memory. This experiment was conducted under the assumption that chronic pain can be considered equivalent to mood, and subsequently, results should coincide with the previous work focusing on mood dependent/congruent memory. This considered, the results of this study did not support the associative network model of mood and memory. Chronic pain may therefore not be equivalent to a mood state (moods not being a permanent or chronic state as in the case of chronic pain); rather, acute pain may serve as a better comparison because it is not a permanent state, and, like moods, waxes and wanes over a period of hours to a day or two. Furthermore, chronic pain may not be perceived as a current concern and of personal relevance. This may be because, counter-intuitively, individuals with chronic pain eventually habituate to the pain state, thus the pain is not perceived as a current concern. For acute pain suffers, pain may be a more salient current concern, and the personal relevance may be a factor in information processing and physiological responding. Further research incorporating the distinctions between chronic and acute pain should aid in a better understanding of the cognitive and physiological underpinnings of pain.

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Table 1

Demographic Information of Pain Patients and Control Subjects

Variable	Statistic	p-value
Mean Age	$t = 0.71$	0.48
Pain = 42.3 years		
Control = 39.7 years		
Education	$\chi^2 = 1.87$	0.17

	High School Only	College +
Pain Patients	5	13
Controls	9	9

Gender	$\chi^2 = 2.22$	0.14

	Male	Female
Pain Patients	5	13
Controls	9	9

Table 2

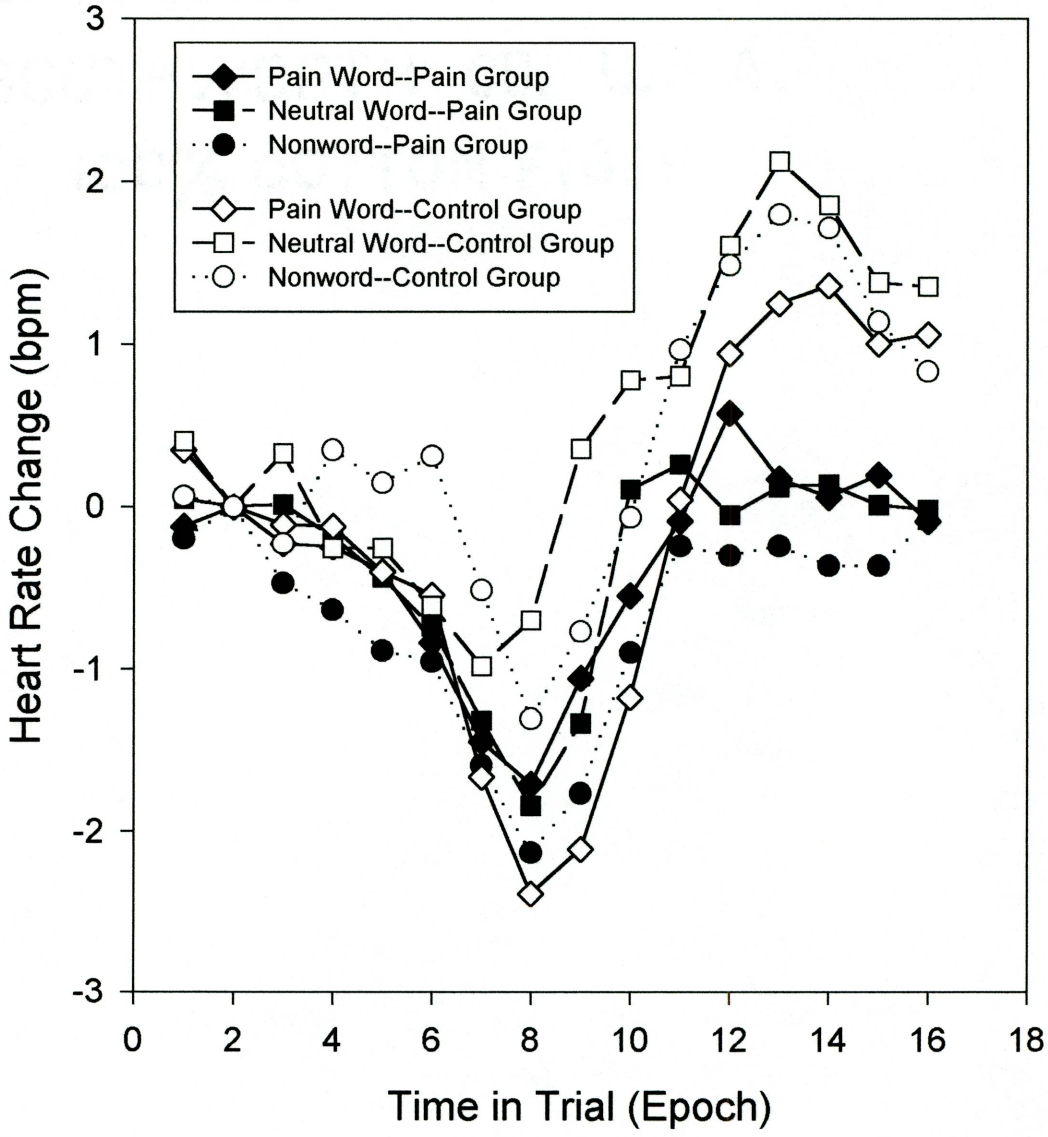
Reaction Time (ms) of Pain Patients and Controls to Pain Words, Neutral Words, and Nonwords

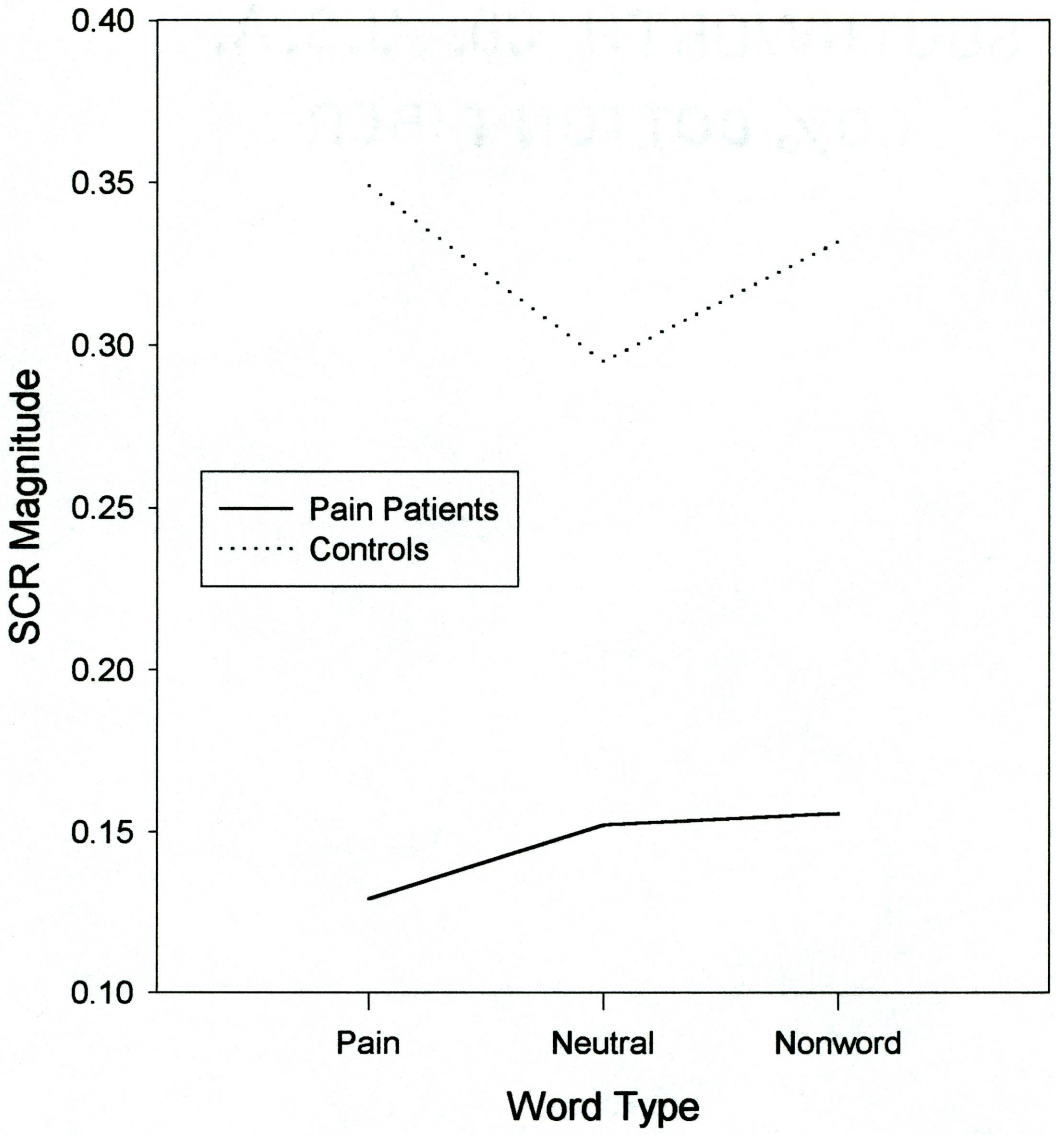
	Word Type		
Group	Pain	Neutral	Nonword
Pain	569	584	628
Control	544	548	567

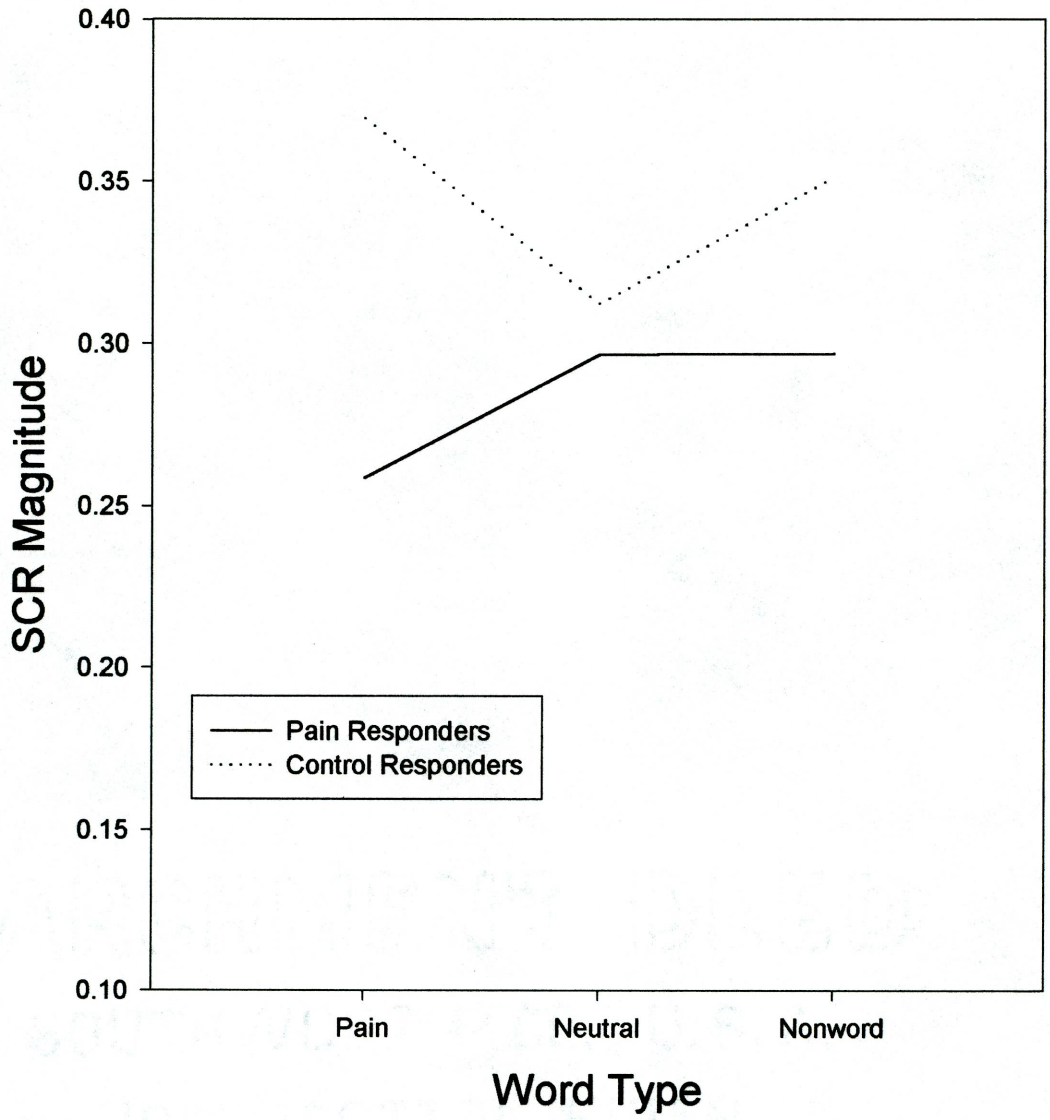
Appendix

Pain Words, Neutral Words, and Nonwords Presented to Subjects

Pain Words	Neutral Words
Throbbing	Snorkel
Shooting	Neither
Stabbing	Golfer
Cramping	Flight
Gnawing	Terrain
Hot	Pillar
Burning	Frame
Aching	Replace
Heavy	Profile
Tender	Kitchen
Splitting	Outfit
Tiring	Bubble
Exhausting	Essay
Sickening	Deputy
Fearful	Magnify
Punishing	Window
Cruel	Jacket
Sharp	Lease


Pain Word--Pain Group
Neutral Word--Pain Group
Nonword--Pain Group
Pain Word--Control Group
Neutral Word--Control Group
Nonword--Control Group
Heart Rate Change (bpm)
Time in Trial (Epoch)
3
2
1
0
-1
-2
-3
0
2
4
6
8
10
12
14
16
18


0.40
0.35
0.30
0.25
0.20
0.15
0.10
SCR Magnitude
Pain Patients
Controls
Pain
Neutral
Nonword
Word Type


0.40
0.35
0.30
0.25
0.20
0.15
0.10
SCR Magnitude
Pain Responders
Control Responders
Pain
Neutral
Nonword
Word Type