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Signal Detection and Threshold Measures for Chronic Back Pain Patients, Chronic Illness Patients, and Cohort Controls to Radiant Heat Stimuli

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Three distinct subject populations consisting of 15 chronic low back pain patients, 11 chronic respiratory patients, and 11 nonpatient controls were studied using a standard radiant heat signal detection methodology. Following determination by ascending limits of each subject's stimulus detection and faint pain thresholds, 26 randomized trials at each of five stimulus levels were administered. Subjects rated each stimulus on a 6-point subjective rating scale ranging from no pain to severe pain. Results indicated that the chronic low back pain patients and chronic respiratory patients had higher radiant heat pain thresholds than the controls, and the chronic low back pain patients had a discrimination deficit for mildly painful stimuli. These results fit the predictions of an adaptation model of pain perception in chronic pain patients as opposed to a hypochondriasis model.

Recent psychological, physiological, and biochemical research has addressed the question of why widely disparate reports of pain and limitation result from a similar amount of tissue damage (for a review see Leibeskind & Paul, 1977). Some of the variables identified as mediators of the response to acute and experimental pain include sociocultural background, experimental setting, neurochemistry, and personality. Despite the fact that altered pain perception is often cited as a major etiologic factor in the development of chronic pain states (Chapman, 1978; Sternbach, 1974), research on chronic pain patients has generally focused on personality variables. There have been virtually no systematic, experimental laboratory studies of chronic pain patients.

Two theoretical positions predict a chronic pain patient's response to nociceptive stimulation. In a recent restatement of the underlying mechanisms of hypochondriasis, Chapman (1978) has emphasized the role of perceptual vigilance in the development of chronic pain. He postulates that chronic pain patients are hypervigilant to "somatic distress signals, in particular pain sensations" (p. 117). As a consequence of this exaggerated focus on painful sensation, the hypothesis predicts that compared to controls, chronic pain patients would have lower pain thresholds to aversive stimuli and an increased bias to label stimulation as painful.

The opposite prediction could be made from an adaptation level model, which emphasizes the context in which a stimulus is judged. It predicts that a subject will evaluate the intensity of a stimulus through comparison with other stimuli similar in type or context (Helson, 1964). Though never directly applied to chronic pain, the adaptation model can be logically extended to predict that chronic pain patients would demonstrate higher pain thresholds and would be less likely to label a pain stimulus as painful because of their greater experience with painful sensations.

To evaluate the predictions of these models, the present study examined the radiant heat pain response of three distinct subject populations: chronic low back pain patients,

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chronic respiratory disease patients, and nonpatient controls. The chronic respiratory disease patients were included to isolate differences due to chronicity of illness and hospital contact from the experience of chronic pain. Traditional threshold and signal detection methods were used to evaluate the subjects' responses to mildly painful radiant heat stimuli. Signal detection analyses have been applied to the psychophysical study of pain in order to separate two perceptual processes, bias for labeling a given stimulus as painful and sensory discrimination ability. The use of these procedures has not been without controversy, although most reviews have concluded that the technique is extremely useful, especially if nonparametric indices are used and the results are interpreted in terms of sensory discrimination and not stimulus detection (see Chapman, 1977; Lloyd & Appel, 1976; Rollman, 1977).

Method

Subjects

Thirty-seven subjects from three distinct populations were used. Fifteen subjects were selected from patients attending a Chronic Low Back Pain Treatment Program at the Sepulveda Veterans Administration (VA) Medical Center. These patients all had histories of either intermittent or continuous chronic back pain (average chronicity of 15 years). Eleven subjects were selected from patients attending the Medical Center's Chronic Respiratory Disease Clinic. The respiratory group consisted of ambulatory outpatients with a modal diagnosis of chronic obstructive lung disease. Eleven healthy nonpatient controls were recruited from local veterans organizations and were similar in age and socioeconomic status to the patient groups. Patients in the low back pain and respiratory groups had no serious ongoing medical problems other than those for which they were selected, and patients in the respiratory and control groups had no history of a chronic pain problem.

Apparatus

Radiant heat stimuli were presented using a specially constructed heat gun. Heat was produced by a 250-W infrared bulb mounted in a foil-lined funnel that narrowed the area of stimulation to a 2-cm diameter circular area of the skin. Voltage to the lamp was regulated by a variable transformer that kept line frequency constant. This system yielded an essentially linear relationship between lamp voltage and centigrade temperature at the area of stimulation ($r = .99$). Following each stimulus presentation, a small fan ventilated the interior of the funnel assembly.

When the subject placed the lamp on his/her forearm, a microswitch at the base of the lamp funnel initiated heat lamp onset. The lamp was interfaced to a PDP-11 computer that controlled the sequence and timing of the trials. After 4 sec of stimulation the computer turned off the lamp, and a tone signaled the subject to withdraw the heat gun. Subjects were instructed to terminate the radiant heat stimulus prior to the 4 sec if the heat became intolerable. During the entire experiment only two trials were prematurely terminated by a subject. Following presentation of the tone, the subject rated each stimulus on a six-category scale by pressing one of six buttons mounted sequentially on a conveniently located panel. The categories available to the subject were *nothing*, *warm*, *hot*, *faint pain*, *moderate pain*, and *severe pain*.

Procedure

The following procedure was used for all subjects. After providing written informed consent, subjects were seated in a comfortable chair in a 2.7 m × 2.1 m room, and the heat gun and rating apparatus were explained and demonstrated. A separate equipment room contained the computer and variable transformer. Five locations on the volar surface of each forearm were marked and the 10 points were used, in a repetitious sequence, as stimulus points throughout the experiment. Subjects were then given three ascending series of radiant heat stimuli to determine stimulus detection threshold (ST) and faint pain threshold (PT). Subjects who varied their ST or PT responses more than 3 °C on the last two series were given a further series to determine consistent thresholds. A maximum temperature of 64 °C at the heat gun mouth was chosen to eliminate skin burning. Four low back pain patients, six respiratory patients, and no controls received this maximum as their pain threshold.

Each subject was then presented 130 stimulus trials consisting of 26 trials at each of five different stimulus intensities. Intensities were computed individually for each subject as follows: 1 = no heat, 2 = ST, 3 = PT − 3 °C, 4 = PT, 5 = PT + 3 °C. Each trial was initiated by the subject placing the heat gun on his/her forearm. Following 4 sec of stimulation (or early withdrawal of the gun by

the subject), the lamp was turned off and the subject was signaled by the onset of a 10-sec tone to remove the gun and rate the stimulus intensity. The offset of the tone signaled the subject to place the heat gun on the next forearm spot and begin the next trial. This sequence of events continued until the subject rated each stimulus intensity 26 times for a total of 130 trials. Intensities were presented randomly with the stipulation that each 5-trial block contained each of the intensities.

Results

Average stimulus detection and faint pain thresholds as well as ages for the three groups are shown in Table 1. One-way analyses of variance (ANOVAs) yielded no significant differences between the groups on stimulus detection thresholds or age, but a significant difference for faint pain thresholds was found, $F(2, 34) = 5.1$, $p < .05$. Newman-Keuls post hoc tests of the faint pain data indicated that the control group had a significantly lower threshold than did either the low-back or respiratory groups. The low back and respiratory groups did not differ from each other.

Nonparametric signal detection indices of discrimination (A′) and response bias (B″) were computed for each subject using the formulas provided by Grier (1971). These indices are based on the geometry of the unit square and do not require any assumptions about the normality of the underlying distributions. Each index was computed for Stimulus Pairs 3 and 4 (PT − 3° and PT), and 4 and 5 (PT, PT + 3°) for each rating category. Only categories with two or more ratings were used. Where multiple categories were used, values were averaged across categories for each stimulus pair, and these averages were the observations used in the between-groups analysis. In a few cases the ratings were such that no category was usable to compute an index for a pair, which left the subject with missing data for that pair. Average A′ and B″ values for the three groups are also shown in Table 1. A one-way ANOVA for the A′ measure indicated a significant difference between the groups at Stimuli 3 and 4, $F(2, 32) = 3.35$, $p < .05$. Post hoc tests revealed significantly poorer discrimination for the low back pain group than for either the respiratory or control subjects. There was no significant difference between the groups at Stimuli 4 and 5, although the means showed that both the respiratory and low back pain groups were somewhat lower than the controls.

Analysis of B″ for the two stimulus pairs indicated no reliable group differences.

Discussion

Two interesting and related findings are evident in the results of this study. First, both the chronic low back pain patients and the chronic respiratory disease patients had substantially higher radiant heat pain thresholds than the controls. Second, chronic back pain patients showed comparatively poorer discrimination at low levels of painful stimuli. These data do not support the hypervigilance model presented by Chapman (1978). The chronic back pain patients, if hypervigilant to pain sensations, should have had decreased thresholds and perhaps lowered response bias to painful stimuli. We found the opposite to be true for our sample

Table 1
Average Stimulus Detection and Faint Pain Thresholds and Nonparametric Signal Detection Indices

Measure	Low back		Respiratory		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age (in years)	49.9	8.6	56.2	5.6	47.3	12.1
Detection threshold (°C)	28.0	4.9	26.6	3.4	26.6	7.2
Faint pain threshold (°C)	60.7	6.5	62.9	1.8	54.2	9.9
Discrimination index (A′)						
Stimuli 3–4	.66[a]	.05	.71	.06	.73	.08
Stimuli 4–5	.67	.07	.63	.06	.71	.10
Response bias index (B″)						
Stimuli 3–4	−.11[b]	.15	−.05	.33	−.06	.26
Stimuli 4–5	−.16	.24	−.03	.13	−.23	.22

[a] Larger A′ values indicate better discrimination.
[b] Larger B″ values indicate less bias to report pain.

of pain patients. The data better fit an adaptation level model such as that outlined originally by Helson (1964) and recently discussed in relation to pain perception by Rollman (1979). An adaptation approach would predict the chronic back pain patients' higher pain thresholds based on their different "pain history" from that of the controls. One explanation for the high thresholds of the respiratory patients is that they were all previously exposed to multiple painful procedures in the hospital and therefore had extensive experience with pain in this context. Since the three groups did not differ in stimulus detection threshold, the data do not seem to indicate that a general attention deficit mediated the higher pain thresholds in the respiratory and chronic pain groups. Further research is needed to elucidate the important variables leading to the pain-specific adaptation seen in these two groups (e.g., contextual, physiological, stimulus properties, etc.).

The finding of a poorer discrimination for the mildly painful stimuli in the chronic back pain patients is not directly predicted by either the adaptation or vigilance models. Clinical observation, however, does indicate that chronic back pain patients often have difficulty altering their behavior in situations that cause low levels of back pain. In fact we frequently see patients continuing to overdo activities until the pain becomes very intense, ignoring small changes in low intensity pain because "that's always there." Whether or not this poor discrimination is the result of adaptation to chronic pain or precedes chronic pain is a matter for further study.

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