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Acupuncture Analgesia and Radiant-heat Pain:

A Signal-detection Analysis

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Responses to radiant-heat stimulation to the back of the hand were obtained during baseline conditions and during acupuncture sessions. Signal-detection methodology and analysis were used to determine whether acupuncture affects d' (changes physiologic processes) relative to pain report. A binary rather than a rating-scale procedure was used to obtain more accurate measures of sensitivity. Results indicated that acupuncture decreased sensitivity only at intensity levels that were never described as painful. (Key words: Acupuncture; Pain, experimental, sensory decision theory; Measurement techniques, sensory decision theory.)

SINCE 1954, Chinese medical practitioners have claimed that acupuncture is an effective analgesic method. Reports consisting mainly of case histories in which acupuncture has been used as the major analgesic procedure suggest that acupuncture is effective in the control of surgical pain,[1,2] dental pain,[3-5] and chronic pain.[6]

However, under controlled conditions using experimentally induced pain, results concerning analgesic effects of acupuncture have been more conflicting. Anderson and associates[7] found that acupuncture significantly lowered ratings of cold pressor pain. Man and Barager[8] reported that acupuncture lessened pain responses to pin pricks. Berlin *et al.*[9] found that acupuncture significantly delayed onset of the pain-terminating response when radiant heat was used as the noxious stimulus. On the other hand, Brennon and co-workers[10] found no significant effect of acupuncture on dental pain, and Lee *et al.*[11] found that only 18 per cent of 979 patients with chronic pain reported significant relief after acupuncture.

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Two studies have been conducted using signal detection[12] to analyze "analgesic" effects of acupuncture on experimentally induced pain.[13,14]

Signal-detection theory (SDT) is useful in analgesia research because with it one can separate detection responses, which are presumably a function of physiologic variables (sensitivity), from decision responses, which reflect the subject's tendency to report that a given stimulus has occurred (response criterion, likelihood, or bias). In other words, with SDT, it is possible to determine whether "analgesic" effects following the administration of various drugs, or other procedures such as acupuncture, are caused by 1) procedurally induced physiologic changes in sensitivity, or 2) biasing factors of the experimental situation that might affect a subject's predisposition to respond. Briefly, SDT analysis allows one to separate more precisely the sources of variance in pain report.

The two acupuncture studies in which SDT has been used have yielded conflicting results. Clark and Yang[14] presented 24 radiant-heat stimuli in a rating-scale experiment. Measures were taken before, during, and after acupuncture. There was no significant change in sensitivity (d') during or after acupuncture; however, changes in response bias indicated that subjects were less predisposed to admit that pain occurred during acupuncture treatment, even though acupuncture did not have a physiologic effect.

In contrast to the above results, Chapman and associates[13] found a decrease in pain sensitivity during acupuncture compared with controls. Four levels of electrical stimulation were applied to tooth pulps of 45 subjects in a rating-scale experiment before and during acupuncture. Both sensitivity and response bias decreased significantly during acupuncture.

The discrepancy in results concerning sensitivity between the above two studies is important to the field of analgesia because re-

duced sensitivity indicates that acupuncture has an authentic physiologic analgesic effect, whereas a change in response bias only indicates that acupuncture has only a suggestive or psychologic effect and no physiologic basis.

The present study was conducted to determine whether acupuncture does, in fact, affect physiologic processes by using a more precise measure of sensitivity. Two studies[15,16] have indicated that when thermal stimuli are used in a signal-detection paradigm, rating scale procedures yield values of d' that are less precise than values obtained with a binary procedure. During a binary procedure subjects have only two alternatives from which to choose their response; during a rating scale procedure, on the other hand, subjects can have as many as 12 alternatives from which to choose their response.

In the present study, thermal intensities were used in a binary procedure (subjects had to report which of two stimuli presented consecutively was more intense or higher). Each stimulus was presented 50 times, and a zero stimulus was used to assure that signal detection standards were closely adhered to.[17,18] It was hypothesized that the failure to find reduced sensitivity in the Clark and Yang study[14] resulted from the use of less precise measures of sensitivity. If so, then acupuncture treatment should lead to reduced values of sensitivity when a binary procedure is used.

Methods

Subjects

Subjects were members of an undergraduate abnormal psychology course who volunteered for points towards their final grade. There were eight subjects (five male and three female).

Apparatus

A modified version of the Hardy-Wolff-Goodell dolorimeter was used to present radient-heat stimuli. Light from a 300-watt projection lamp passed through a condenser lens which focused the light on a small circle (approximately .5 cm diameter) of a band blackened with India ink on the back of each subject's hand. The amount of radiant heat presented was controlled by a variable autotransformer (Superior Electric Co.). Each stimulus was presented for 2 seconds; the time of stimulus presentation was determined by the opening and closing of a shutter (Ralph Gerbrands, Model G1166) controlled by a timer (Hunter, Model 111-C). Four stimulus intensities were used: S_0, a zero stimulus; S_1, a stimulus never defined as painful by three pilot subjects; S_2, a stimulus defined as painful approximately 50 per cent of the time by the pilot subjects; and S_3, a stimulus defined as painful approximately 75 per cent of the time by the pilot subjects.

Procedure

Before any measure was taken, each subject read an information sheet explaining the purpose of the experiment, the definition of faint pain, and the basic procedure followed by the experimenter and the acupuncturist. Subjects were free to ask questions. The back of each subject's right hand was then coated with a band of India ink approximately 6 cm wide and 7.5 cm long. Subjects reclined and closed their eyes, after which they received one presentation of a S_3 stimulus to determine whether the stimulus was painful for them. All subjects reported that the stimulus was painful, indicating that they were sensitive to the thermal stimuli presented.

One hundred and fifty stimulus pairs were then presented. Two stimuli were presented consecutively, and following termination of the second stimulus, the subjects reported which of the two stimuli had been more intense. The 150 pairs were randomly presented with the condition that each subject receive 25 presentations of each of the following pairs: S_0–S_1, S_1–S_0, S_1–S_2, S_2–S_1, S_2–S_3, S_3–S_2. The stimuli were presented randomly to three general areas of the India ink band with the condition that there be at least a 15-second interval between stimuli applied to the same general area, in order to allow sufficient cooling between consecutive presentations. The rating procedure lasted approximately 45 minutes.

Following baseline measure, acupuncture needles (28-gauge) were inserted approximately one-half inch into the subject's right

forearm and hand (two near the elbow, one on the ventral part of the forearm, two on the dorsal part of the forearm, and two between the thumb and first finger). Six of the needles were stimulated electrically (2 cps adjustable wave) with an acupuncture apparatus (multipurpose therapy apparatus, Model 71-3, People's Republic of China); the stimulation remained in effect for the entire rating session, which lasted 45 minutes.

Results

Values of d' (sensitivity) were calculated for control and accupuncture sessions and compared for increases and decreases for each stimulus pair for each subject. There were three levels at which sensitivity could have increased or decreased; discriminability could have changed between S_0 and S_1, between S_1 and S_2, and/or between S_2 and S_3. Discriminability decreased significantly between S_0 and S_1. Seven of eight subjects were less able to discriminate the lowest intensity stimulus from the zero stimulus during acupuncture treatment ($P = <.05$; given probability of decrease = .5). Changes in sensitivity between S_1 and S_2 were insignificant, as were changes between S_2 and S_3. Approximately 50 per cent of the subjects were less able to discriminate between the higher intensities (table 1).

The present experiment was designed particularly to test for shifts in sensitivity (values of d'). Shifts in response bias with the binary procedure used have less meaning than shifts obtained with other procedures such as the rating scale. In the present experiment, values of β were compared in the same manner as were values of d', and it was determined that response bias shifted downwards significantly (seven of eight subjects) only for the pairs including S_0 and S_1 (S_0–S_1; S_1–S_2). The only conclusion that can be drawn from the downward shift in bias is that during acupuncture, subjects were more predisposed to report that the second stimulus presented was more intense than the first, when the two lowest stimuli were presented.

Acupuncture, then, affected sensitivity and bias only between the two lowest stimuli. Sensitivity decreased (subjects were less able to discriminate between S_0 and S_1), as did response bias (subjects were more predisposed to report the second stimulus presented as painful during acupuncture, when S_0 and S_1 were presented as a pair in either order).

TABLE 1. Number of Subjects Showing Shifts in Sensitivity

Stimulus Pairs	Increases in d'	Decreases in d'	No Change in d'
S_0–S_1	1	7*	0
S_1–S_2	3	4	1
S_2–S_3	4	4	0

* $P < .05$.

Discussion

The results of the present experiment indicate that acupuncture significantly decreases the ability to discriminate between extremely low levels of thermal stimulation; however, they also indicate that acupuncture does not have a significant effect as the pain stimuli become more intense. Although the results at extremely low intensities are impressive, also indicated is the result that acupuncture has no effect at stimulus levels that could be considered anything more than minimally painful. At the more intense pain levels, the results were not consistent, with reports of the subjects not being significantly different from chance.

It is possible that the location of the stimulus application was not one that gives a fair test to the effectiveness of acupuncture. Statements in the literature[16] suggest that pain at the extremities and on the surface of the body is not as readily affected by acupuncture as is pain on the trunk of the body and in more internal locations. However, the hypothesis that acupuncture affects only deeper "clinical" pain does not explain the negative results found with dental pain[10] or with chronic pain.[11]

It is possible that the effects found with the lowest stimulus intensities were not due to acupuncture analgesia but instead to sensory masking or distraction resulting from the ongoing electrical stimulation. Although the subjects were reclining with eyes closed, the pulsation from the electrical current was present throughout the second rating session and could have interfered with the subject's ability to discriminate between the stimuli or

with their concentration during the rating task. At this point it is impossible to determine whether the change in d' was due to acupunctural "analgesia" or to sensory masking or distraction. A third hypothesis is that the change was merely an artifact of design, since there were no controls for order effects.

Criticisms of the previous signal-detection study in which thermal intensities were used[14] were that the experiments did not adhere closely enough to basic signal detection procedure (used too few stimulus presentations) and used a less precise measure of sensitivity. The present study made improvements in both of these aspects and obtained basically the same negative results. It was not possible with the present design to determine whether changes in bias occurred during the acupuncture treatment, nor was it possible, due to time limitations, to obtain follow-up data after discontinuation of the acupuncture treatment to determine whether there was any after-effect of acupuncture on d' or β. A better procedure for future experimentation would be to obtain both binary and rating-scale data concurrently,[14,15] and to obtain follow-up data. However, the results of the present experiment strongly suggest that until more controlled research is carried out, no conclusive statement can be made to the effect that as an analgesic method, acupuncture produces its effects by altering physiologic rather than psychologic processes.

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References

1. Dimond EG: Acupuncture anesthesia. JAMA 218:1563, 1971
2. Liu WC: Acupuncture anesthesia: A case report. JAMA 221:87–88, 1972
3. Mann F: Acupuncture in dental surgery. Lancet 1:898–899, 1972
4. Andersson SA, Ericson T, Holmgren E, et al: Electro-acupuncture and the pain threshold. Lancet 2:564, 1973
5. Mumford J, Bowsher D: Electro-acupuncture and the pain threshold. Lancet 2:667, 1973
6. Mann F, Bowsher D, Mumford J, et al: Treatment of intractable pain by acupuncture. Lancet 2:57–60, 1973
7. Anderson DG, Jamieson JL, Man SC: Analgesic effects of acupuncture on the pain of ice water: A double-blind study. Can J Psychol 28: 239–243, 1974
8. Man SC, Barager FD: Hold sensory changes after acupuncture. Can Med Assoc J 109: 609–610, 1973
9. Berlin FS, Bartlett RL, Black JD: Acupuncture and placebo: Effects on delaying the terminating response to a painful stimulus. ANESTHESIOLOGY 42:527–531, 1975
10. Brennon RW, Veldhuis J, Chu R: Acupuncture anesthesia. Lancet 2:849–850, 1973
11. Lee PK, Anderson TW, Modell JH, et al: Treatment of chronic pain with acupuncture. JAMA 232:1133–1135, 1975
12. McNicol D: A Primer of Signal Detection Theory. London, George Allen & Unwin, 1973
13. Chapman CR, Gehrig JD, Wilson ME: Acupuncture compared with 33 per cent nitrous oxide for dental analgesia: a sensory decision theory evaluation. ANESTHESIOLOGY 42:532–537, 1975
14. Clark WC, Yang JC: Acupuncture analgesia? Evaluation by signal detection theory. Science 184:1096–1098, 1974
15. Clark WC, Dillon DJ: Signal detection theory analysis of binary decisions and sensory intensity ratings to noxious thermal stimuli. Perception and Psychophysics 13:491–493, 1973
16. Clark WC, Mehl L: Signal detection theory procedures are not equivalent when thermal stimuli are judged. J Exp Psychol 97: 148–153, 1973
17. Chapman CR, Gehrig JD, Wilson ME: Acupuncture, pain, and signal detection theory. Science 189:65–66, 1975
18. Hayes RL, Bennett GJ, Mayer DJ: Acupuncture, pain, and signal detection theory. Science 189:65–66, 1975