Acupuncture Compared with 33 Per Cent Nitrous Oxide for Dental Analgesia:

A Sensory Decision Theory Evaluation

C. Richard Chapman, Ph.D.,* John D. Gehrig, D.D.S., M.S.D.,†
Michael E. Wilson, M.D., Ph.D.‡

Responses to electrical stimulation of the tooth pulp were obtained in both baseline and test sessions for subjects receiving acupuncture, 33 percent nitrous oxide, or control conditions. A signal-detection analysis across sessions showed that both treatment groups demonstrated reduced sensitivity to stimulation, and increases in bias against reporting strong stimuli as painful. (Key words: Acupuncture; Anesthetics, gases, nitrous oxide; Measurement techniques, sensory decision theory; Pain, sensory decision theory.)

Chinese physicians reported that acupuncture can create an analgesic state sufficient for surgery, but Western studies of the effects of acupuncture on the pain threshold have yielded inconsistent results. Andersson et al. observed that acupuncture increased the dental pain threshold, while Breton et al. reported that it did not. Mumford and Bowsher found a small increase in the dental pain threshold after acupuncture. Past investigations of pain and analgesia employing the threshold, e.g., early study of narcotic analgesics, also yielded inconclusive results, and their precedent suggests that a different approach might be more efficient in determining the analgesic efficacy of acupuncture. While thresholds do respond to changes in sensory capacity, they also vary with motivational states, moods, and social expectations so that attitudinal biases sometimes confound estimations of sensory changes.

Clark and Yang investigated the analgesic effects of acupuncture using the methodology of Sensory Decision Theory, which permits measurement of both sensory experience and attitudinal bias against reporting pain. These procedures, described previously in this journal, provide two indices of performance rather than a single threshold value: sensory sensitivity of the perceiver to the intensity difference between the two stimulus levels and response bias of the perceiver were both estimated. Studying the effects of acupuncture on discrimination of two levels of painful radiant heat stimuli in 12 volunteers, they reported significant changes in response bias, i.e., subjects were less willing to identify stimuli as painful after acupuncture, although they could discriminate one level of heat from another as clearly after acupuncture as under normal conditions. This observation suggests that reports of threshold changes in human teeth following acupuncture may reflect attitudinal shifts rather than sensory analgesia. The present study is an evaluation of the effects of acupuncture on the perception of painful dental stimulation using the methodology of Sensory Decision Theory.

Method

Subjects. Forty-two healthy men, ranging in age from 21 to 45 years, served as unpaid volunteers. These individuals were randomly assigned to three groups of 14 each, i.e., control, nitrous oxide, and acupuncture groups were established.

Apparatus. Teeth were stimulated via a 5-mm-diameter conductive rubber electrode (anode) mounted in a plastic probe, which was held by the subject except in the acupuncture sessions, when it was held for
him. The handle of the probe (cathode) was wrapped with conductive tape to complete the electrical circuit, but in the acupuncture sessions the finger of a male assistant, who held the probe, touched the subject's cheek to complete the circuit. The electrical stimulus to the tooth was produced by a Grass S-44 stimulator with constant current and stimulus isolation units. This provided monophasic pulses of as much as 25 \( \mu \)A intensity, 10 msec in duration, and 10 msec apart. A Grass S-4 stimulator, operated in tandem, triggered a 1-sec burst of pulses for each trial. The stimulus current was selected by a manual switch from four alternatives provided by preset potentiometers. Abnormalities in contact between the tooth and the probe were detected by observing the stimulus waveform on an oscilloscope. A jet of air forced through the handheld probe in all sessions insured that the dental surface remained dry. Subjects were seated in a dental chair in all sessions of the experiment.

Pretest Training. Volunteers attended a pretest session where the detection threshold for either an upper or lower central incisor was obtained by increasing the current of a continuous train of pulses from zero until the subject detected the stimulus. The mean current level for 20 trials was taken as threshold. Only healthy, unfilled teeth were used for testing. Mean threshold for all subjects whose upper incisors were tested was 11.9 \( \mu \)A, with a standard deviation of 2.3 \( \mu \)A, and the respective values for subjects whose lower incisors were tested were 10.7 \( \mu \)A and 2.7 \( \mu \)A.

On the basis of each individual's threshold value, three other stimulus intensities were established for use in a signal detection task. The lowest stimulus was set at 1 \( \mu \)A below threshold, while medium and high values were 1 \( \mu \)A and 3 \( \mu \)A above threshold, respectively. The fourth stimulus level was zero. All subjects experienced 100 practice trials during which the four stimulus levels were presented repetitively at .1 sec per trial, with intensities occurring in random order. The subject responded to each stimulus by giving either a verbal or a hand signal to indicate which of seven categories on a rating scale best described it. Rating scale categories were: nothing, possible sensation, prepain sensation, very faint pain, mild pain, moderate pain, and strong pain.

Testing Procedure. On subsequent days, each subject returned for two sessions similar to the practice trials described above. In each, he experienced 300 trials, 75 at each stimulus level. The first, baseline, sessions were identical for all three groups, while the second sessions were treatment sessions. During the treatment sessions, nitrous oxide and acupuncture groups were tested after a 20-minute analgesia-induction period. The treatment session for the controls was identical to the baseline session.

Subjects in the nitrous oxide group received 33 per cent nitrous oxide and 66 per cent oxygen through a nasal mask after advance instruction on nasal breathing. The reservoir bag on the Heidebrink dental anesthesia machine was closely watched to insure that leakage around the mask and oral breathing did not occur.

Subjects in the acupuncture group received bilateral needle insertions of 2 cm depth between the metacarpals of the thumb and first finger on the dorsal aspect of each hand (Hoku points). We connected the cathode lead from the Chinese Model 626 acupuncture stimulator8 to each needle, and taped the corresponding anode to the palmar surface of the forefinger ipsilateral to the electrode. Pulses of current ranging roughly from 6 to 15 \( \mu \)A were derived from a 9-volt source and delivered to the needles at approximately 2 Hz, making the needles twitch slightly.

Stimulus Reliability. The reliability of the dolorimetry employed depended on the consistency of electrical contact between the conductive rubber electrode and the dental surface. Accordingly, the waveform associated with each stimulus presentation was monitored on an oscilloscope. Two potential sources of error were easily detected from changes in the waveform: 1) moisture on the
dental surface which would carry the current into the soft tissues rather than through the pulp, and 2) inadequate contact pressure. Trials characterized by these problems were immediately aborted and repeated, generally before the subject had time to respond to the stimulus. Faulty stimulus conduction was rare in all conditions of the study. The high rate of successful trials was in part due to the 100-trial practice session in which subjects were coached to maintain good contact.

**Quantification.** Sensitivity, d', measures for each subject were obtained from responses associated with high-medium, medium-low, and low-zero stimulus pairs, according to the methods introduced by Richards and Thornton, and difference scores were obtained by subtracting the d' value obtained for each pair in session two from that obtained in session one at each of the three pairs of levels. Response bias was evaluated on the basis of per cent bias (PB), a nonparametric index based on the geometry of the unit square of the receiver operating characteristic. Bias has been scaled in percentage units such that no bias would be assigned a value of zero and extreme bias against using a given category on a rating scale would be given a value approaching 100.00. When the perceiver's bias favors the use of the category, the value would approach -100.00. In the present study, bias was assessed for the "very faint pain" response category, so that PB values would reflect the willingness of subjects to label the strongest stimulus as at least mildly painful.

**Results**

Mean d' values with standard deviations for all subjects in all sessions are listed in Table 1, while changes in difference scores across intensity levels are presented in figure 1 for all three groups. A mixed design analysis of variance performed on the difference scores yielded a significant difference between groups, f(2,39) = 19.91, P < .001, as well as a significant difference across intensity levels, f(2,78) = 5.66, P < .01. The interaction of groups by levels was not significant, f(4,78) = 1.52.

Tukey HSD Tests provided a *posteriori* comparisons among the three groups with regard to the total change across sessions, i.e., the sum of the change across levels. Both nitrous oxide and acupuncture groups were found to be significantly different in change across sessions from the controls (P < .01), but the groups did not differ significantly from one another in total change across levels. However, figure 1 suggests that acupuncture analgesia occurred consistently at all levels of stimulus intensity, while nitrous oxide analgesia occurred principally at the lowest level, with little effect occurring for the strongest stimulus.

Response bias was measured for each subject, and Table 2 lists the means and standard deviations of the groups for the "very faint pain" category in the high-medium discrimination. A one-way analysis of variance on the session one minus session two difference scores, f(3,39) = 11.66, P < .001, indicated that the groups differed significantly from one another, and HSD *a posteriori* tests showed that acupuncture and nitrous oxide groups differed significantly from the controls, but not from one another. Thus, both treatment groups demonstrated a significant increase in attitudinal bias against reporting pain, while the controls showed no change.
Discussion

The simple dental stimulator developed for this investigation has proven to be a convenient and reliable means of producing experimental pain. The device, similar to equipment described by Mumford and Newton, employed a constant-current source. To evaluate the analgesic efficacy of acupuncture for dental pain, we selected 33 per cent nitrous oxide as a standard agent for comparison, because subjects remain conscious and cooperative when it is employed, and this concentration is commonly used in conjunction with local anesthesia for dentistry. It was our intention to mimic clinical conditions rather than to adopt an elaborate procedure to maintain constant anesthetic conditions, and consequently, there may have been slight leaks, reducing the inspiratory concentration of nitrous oxide to below 33 per cent. Some subjects hyperventilated slightly, and hypocapnia may have contributed to the analgesia observed in these subjects.

Both nitrous oxide and acupuncture reduced d' when baseline and test sessions were compared, indicating that subjects were less able to detect and discriminate among the stimuli. Shifts in d' associated with each condition were small but statistically significant. It is notable that nitrous oxide had little effect upon the detection of the strongest of the stimuli. This observation is in accord with that of Tomlin et al., who found that nitrous oxide had to be inhaled
TABLE 2. Mean PB ± sd for Grading the
High-intensity Stimulus as
Very Faint Pain

<table>
<thead>
<tr>
<th></th>
<th>Session 1</th>
<th>Session 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acupuncture</td>
<td>-75.99 (± 22.70)</td>
<td>34.15 (± 59.44)</td>
</tr>
<tr>
<td>Nitrous oxide</td>
<td>-63.30 (± 50.15)</td>
<td>33.44 (± 72.79)</td>
</tr>
<tr>
<td>Control</td>
<td>-54.71 (± 50.94)</td>
<td>-53.63 (± 60.63)</td>
</tr>
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almost to the point of unconsciousness before analgesia to pinprick could be demonstrated. The increase in sensitivity to stimulation observed in the control group across sessions was probably due to practice effect.

Clark and Yang employed a different testing procedure, studying the effects of acupuncture on sensory sensitivity to painful radiant heat. Employing a Sensory Decision Theory analysis, they did not find a significant change in d', either during acupuncture stimulation or afterwards. There are two possible explanations for the discrepancy between their report and the present one.

First, it is difficult to conclude that a procedure has no effect on the basis of a single study, since a large number of trials may be necessary to establish statistical significance, if that effect is weak. In this study, 75 presentation per stimulus level were employed, whereas Clark and Yang used only 24 trials (presumably 12 presentations at each stimulus level) during each session. Thus, the present study may have demonstrated statistical significance through greater precision in measurement.

Second, subjects in our experiment received a 20-minute acupuncture induction period during which no testing occurred. The acupuncture needles remained in place and electrical stimulation was delivered through them during our test session of approximately 45 minutes. In contrast, Clark and Yang measured performance during acupuncture induction, removed the needles, and measured again after acupuncture when stimulation had ceased. In clinical anesthesia prac-
tice in China, the needles are always left in place and they are generally used for manual or electrical stimulation for the duration of the operative procedure. In observing numerous surgical procedures in China, one of us (Chapman) noted that needles were continuously stimulated, and that the intensity of electrical acupuncture stimulation was periodically increased or adjusted as operations progressed.

The Peking Acupuncture Anesthesia Research Group reported that the cutaneous pain threshold increased over time with continuous acupuncture stimulation. The effects of the stimulation were small at 15 minutes or less, and maximal at 40 minutes. Removal of the needles at 50 minutes led to a gradual drop in the threshold over the next 30 minutes. All areas of the body were observed to respond, and no appreciable differences between sites ipsilateral and contralateral to acupuncture were observed. While threshold measures are notoriously unreliable, these results do suggest that sustained stimulation beyond a 20-minute period is necessary before testing.

Interest in acupuncture analgesia centers about two primary questions: does acupuncture stimulation produce analgesia and, if so, what is the mechanism? Our study answers the first question in the affirmative: detectability of painful dental stimulation was significantly reduced by acupuncture. The observed effect was weak hypalgesia rather than analgesia. However, and it was comparable to 33 per cent nitrous oxide inhalation, which is insufficient for surgical procedures.

The second question, which concerns the mechanism of acupuncture analgesia, is more difficult to answer. Most explanations of acupuncture's effect postulate that it is due to 1) attitudinal change resulting from suggestion or other psychological factors, or 2) interference with the transmission of pain information within the central nervous system. The response bias changes we observed indicated that significant psychological change was associated with both acupuncture and 33 per cent nitrous oxide within the context of our study, and that this change was similar in nature to that observed with placebos.
However, the sensory loss evidenced in the d' data suggested that some change in neurologic function also occurred.

Although our experiment was not specifically designed to reveal the mechanisms of acupuncture, we were able to look at the masking, or counter-irritation hypothesis, i.e., acupuncture creates a background level of sensation against which it is difficult to appreciate pain. This explanation would predict a greater drop in sensitivity to pain for lower-intensity stimuli than for high-intensity stimuli, but such differences were not observed in the acupuncture data. Surprisingly, the effects of 33 per cent nitrous oxide have fitted this pattern, which suggests that masking or distraction may have contributed to its analgesic effects.

References


Respiration

FLAIL CHEST: MORBIDITY AND MORTALITY This is a five-year retrospective analysis of 85 flail-chest injuries. All patients had tracheostomies and were ventilated. Thirty patients (35 per cent) died. As might have been expected, the mortality was greater in the more severely injured patients, especially those with cranioencephalic injuries. The two major causes of death were hypovolemia and pulmonary infection. Of the 28 head-injured patients, 19 died: 7 from bronchopneumonia, 3 from aspiration pneumonia, 3 from hypovolemia, 2 from cerebral injury, and 4 from other causes. Of the 57 patients without head injury, 11 died: 2 from bronchopneumonia, 2 from hypovolemia, and 7 from other causes.

Pseudomonas aeruginosa was cultured from the tracheas of about 70 per cent of all patients. The organisms occurring more frequently in those who died than in survivors were A. aerogenes, P. vulgaris, E. coli, and K. pneumoniae. (Reihan, M., and Lithum, M.S.: Morbidity and Mortality Associated with Flail Chest Injury: A Review of 85 Cases. J Trauma 13:663–671, 1973.)