Reports

Suppression of Pain by Sound

Abstract. A procedure involving music and noise has been effective in suppressing pain in 5000 dental operations. The music promotes relaxation, and the noise (the main agent) directly suppresses pain. The dental procedure and results are described, and an explanatory hypothesis is suggested.

Certain types of pain may be reduced or abolished by intense acoustic stimulation (*1*). We have studied "audio analgesia" in dental situations and, with others, have obtained preliminary results in hospitals and laboratory (*2*).

In Wallace J. Gardner's dental office, suppression of pain by sound has been fully effective for 65 percent of 1000 patients who previously required nitrous oxide or a local anesthetic in comparable operations. For 25 percent, sound-induced analgesia was sufficiently effective that no other analgesic or anesthetic agent was required. For 10 percent, it was less than adequate. In only a handful of cases has a patient reported experiencing objectionable pain while listening to the intense sound.

During the last year, audio analgesia equipments have been used by eight other dentists in the Boston area. Their experiences have paralleled those just summarized. In about 90 percent of 5000 operations, sound stimulation has been the only analgesic agent required. Gardner has extracted over 200 teeth without encountering any difficulty or report of objectionable pain. The other dentists, also, have extracted teeth under audio analgesia.

The procedure usually followed in inducing the analgesic condition involves the use of music and of noise. The patient wears headphones and controls the stimuli through a small control box in his hand. Before the operation, and until a potentially painful procedure has to be employed, the patient listens to stereophonic music. As soon as he anticipates pain or feels incipient pain, he turns up the intensity of the noise stimulus. It is random noise with a spectrum shaped by low-pass filters to provide a compromise between analgesic effectiveness and pleasantness of quality.

The main function of the music is to relax the patient. For most patients, the noise is the main agent, the one that drowns out the pain.

Several factors operate simultaneously in producing the analgesia (*3*). The noise appears, in introspection, directly to suppress the pain caused by the dental operation. During cavity preparation, the noise also masks the sound of the dental drill, thereby removing a source of conditioned anxiety. The music promotes relaxation, and the noise, which sounds like a waterfall, also has a relaxing effect. When both music and noise are presented, the music can be followed only through concentration; it diverts attention from the dental operation. Patients enjoy having control over the massive acoustic stimulation; in their earlier experiences in dental offices, control of the situation had seemed entirely out of their hands. The procedure provides a needed channel of communication between the patient and the dentist: the dentist can judge the patient's state of anxiety or discomfort by noting whether the patient is using music or noise, and by observing the intensity level of the signal. All the foregoing factors appear to be important, different ones predominating in different situations and for different patients. Suggestion also plays a role, the significance of which has been difficult to estimate.

The results obtained in dental operations suggest that audio analgesia may be effective also in clinical medical situations. Preliminary observations have been made with the cooperation of physicians in the Boston area. The sources of pain included left heart catheterizations, removal of toenails, labor and childbirth, and the removal of a polyp from the shoulder of one of us. The audio procedure was effective in over two-thirds of these applications. When it was not effective, the patient was not relaxed, or the pain was well developed before the sound was turned on, or it was not feasible to continue intense stimulation throughout the operation. Exposure to intense acoustic stimulation must be carefully controlled in order to avoid the possibility of producing damage to hearing.

Audio analgesia is more effective against some kinds of pain than others. In the polyp removal, there was sharply localized pain ("pinprick") at the time of the incision and again when the suturing needle passed through the skin. The pain was clearly recognizable, but quite small and inconsequential. During the remainder of the operation, there was nothing that could be called pain—only pressure and tension. Some patients report no pain at all when the noise is on at high intensity. Others say that there is detectable pain, but that "it doesn't hurt."

Efforts to examine the phenomenon in the laboratory have encountered the difficulties noted in other nonclinical studies of analgesia (*4*). If the subject pays attention to the nociceptive stimulus and reports upon the magnitude of the resulting subjective pain, the effect of acoustic stimulation is usually small. It is possible, however, by duplicating the clinical context as nearly as possible, to set up demonstrations in which the subjective magnitude of a pain (deep pain of slow onset) is clearly modulated by the turning on and off of intense sound.

The pain-reducing effect of intense stimulation is not restricted to the auditory modality. Effect of vibratory stimulation has been observed by Weitz (*5*) and Wall (*6*). In our laboratory, Baruch and Fox recently demonstrated that a bright flash of light can inhibit the pain response to a localized electrodermal shock.

In thinking toward an explanation, we note that parts of the auditory and pain systems come together in several regions of the reticular formation and lower thalamus. The interactions between the two systems are largely inhibitory. Both the direct suppressive effect and the effects mediated through relaxation, reduction of anxiety, and diversion of attention, can be explained by assuming that acoustic stimulation decreases the "gain" of pain relays upon which branches of the auditory system impinge. The behavior of an analogue-computer simulation of the hy-

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Type manuscripts double-spaced and submit one ribbon copy and one carbon copy.

Limit the report proper to the equivalent of 1200 words. This space includes that occupied by illustrative material as well as by the references and notes.

Limit illustrative material to *one* 2-column figure (that is, a figure whose width equals two columns of text) or to *one* 2-column table or to *two* 1-column illustrations, which may consist of two figures or two tables or one of each.

For further details see "Suggestions to Contributors" [*Science* **125**, 16 (1957)].

pothesized process reflects the characteristics of audio analgesia observed in clinic and laboratory. Moreover, in a recent letter, Mountcastle reports that he has found, in the posterior group nuclei of the thalamus and in the cerebral cortex, pain-evoked neural activity that is suppressed by acoustic stimulation (*7*).

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References and Notes

1. W. J. Gardner and J. C. R. Licklider, *J. Acoust. Soc. Am.* **31**, 117 (Abstr.), 850 (Abstr.), (1959). For details of initial observations, see W. J. Gardner and J. C. R. Licklider, *J. Am. Dental Assoc.* **59**, 1144 (1959).
2. We use the word *analgesia* here in the sense of the dictionary definition, "insensibility to pain," which we interpret as "condition in which perceived pain is eliminated or significantly reduced, without implications concerning mechanism."
3. We are indebted to Dr. Ulric Neisser for his analysis of the psychological factors involved in auditory analgesia: "Auditory suppression of reactions to pain," unpublished manuscript, October 1958.
4. H. K. Beecher, *Pharmacol. Rev.* **9**, 59 (1957).
5. J. Weitz, *J. Exptl. Psychol.* **30**, 426 (1942).
6. P. D. Wall, personal communication, 25 May 1959.
7. V. Mountcastle, personal communication, 21 Nov. 1959.

18 March 1960

Arizona's Oldest Cornfield

Abstract. Flood-plain alluvium at the Cienega site, San Carlos Indian Reservation, central Arizona, contains two preceramic and one ceramic cultural horizon. Pollen of *Zea mays* appears in each, substantiating previous early records of agriculture in the American Southwest. Prehistoric cultivation extended through at least 2000 years, ending in the late 15th century.

The earliest southwestern record of corn (*Zea*), dated at about 5600 years ago, comes from Bat Cave, New Mexico (*1*). Confirmation of early agriculture associated with the preceramic Cochise culture appeared in Tularosa and Cordova caves, New Mexico (*2*). Pollen analysis of flood-plain sediment enables us to extend the record of Cochise cultivation into an adjacent part of Arizona and to locate a probable prehistoric cornfield.

While excavating the Cienega Creek site in Arizona, Haury collected sediment samples which we have used to construct a pollen profile (*3*). *Zea* appeared in 15 of 19 levels, a total of 42 pollen grains (Table 1). The locality lies along the Cienega Creek about 4 miles southeast of the University of Arizona Archaeological Field School on the San Carlos Indian Reservation, Graham County. Here at about 6200 feet elevation a natural meadow of grasses and forbs, locally with cattail and sedge, is surrounded by upland forest of ponderosa pine, pinyon, juniper, and oak. Stream erosion during historic time cut into alluvial deposits of the meadow, exposing prehistoric remains.

Traces of human activity (hearths, cremations, shallow wells, and artifacts) can be assigned to three periods: to Chiricahua and San Pedro stages of the Cochise culture, and to Mogollon-Pueblo occupation, roughly dated at A.D. 1000 (*4*).

Radiocarbon dates of various strata led to discordant results. University of Arizona determinations of bed D-1 (roughly equivalent to level 245 to 260 in Table 1) average about 4200 years before the present and exceed by 1700 years Michigan dates of the same material. On the basis of cultural chronology, Haury considered the former more reasonable. Regardless of age, pollen analysis provides an effective monitor of *Zea* cultivation. It supports the archeologist's suspicion that prior to the rise of a ceramic tradition corn was in general use throughout the Southwest (*5*), as it was in northern Mexico (*6*).

Admittedly, fossil Maydeae pollen is not identified quite as conclusively as are cobs or kernels. We base our determination on the absence of any similar large native grass pollen in the modern pollen rain trapped in cattle tank sediments in the study area ($N =$ 22,000); and on size-frequency measurements of grass pollen in three fossil strata compared with the size of alleged *Zea* plotted as a histogram on the same abscissa (Fig. 1). The largest native grass encountered in our count was 48 μ long with a pore diameter of 10 μ.

Compared with other Maydeae (*7*) the great size range of our measure-

Table 1. Corn at the Cienega Creek site. N = estimated total number of pollen grains scanned for *Zea* at each level.

Depth (cm)	*Zea*: Pollen grains (No.)	*Zea*: Frequency (%)	*Zea*: N
	Mogollon		
20	1	0.03	3500
45	1	0.18	560
65	1	0.13	760
80	1	0.74	136
	Cochise culture—Preceramic San Pedro		
110	0		1900
125	0		1520
145	4	0.03	14900
165	0		1820
175	1	0.03	3400
195	3	0.07	4420
210	2	0.15	1300
225	3	0.23	1320
235	1	0.07	1390
	Cochise culture—Preceramic Chiricahua		
245	7	0.47	1500
250	7	0.22	3200
260	1	0.03	3200
270	6	0.14	4400
280	3	0.04	6900
Totals	42	0.07 (av.)	56126

ments (55 to 104 μ total length, 11 to 17.6 μ diameter of annulus) and low average axis-annulus ratio ($\bar{X} = 5.7$, $N = 35$) suggests a mixed population. For two reasons we hesitate to make such a claim, that is, that some of this pollen is derived from *Tripsacum* or teosinte. First, these are unknown from the local archeological record; second, experimental evidence shows that pollen size in *Zea* is highly susceptible to environmental control (*8*). A third possible explanation for high variability in Point of Pine *Zea* pollen is poor preservation in alluvial sediment with attendant breakage, folding, shrinkage, and stretching.

Although it appears that corn was cultivated along the Cienega Creek for at least 2000 years, the archeological record at Point of Pines reveals population decline and abandonment by the

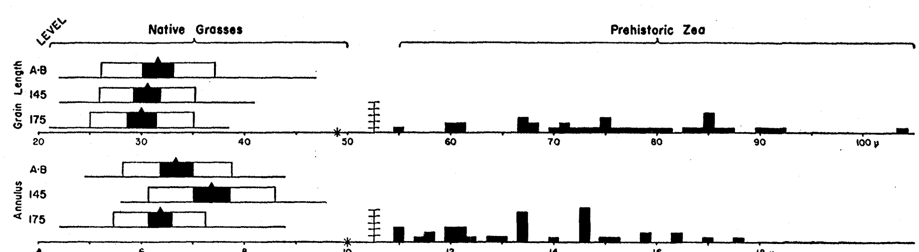

Fig. 1. Size frequency of grasses and *Zea* from the Cienega site. Mean, range, standard deviation (white bar), and twice standard error of mean on either side of the mean (black bar) represent three different populations of fossil grass pollen ($N = 50$ in each). The largest grass measured during analysis of the Cienega site profile is shown by an asterisk. Grains with total length equal to or exceeding 60 μ, or with annulus equal to or exceeding 11 μ in diameter, are considered Maydeae (*Zea*). Their measurements are plotted as a histogram on the same abscissa as the native grass populations.