Skin Sensory Afterglows

Abstract. *Brief stimulation of the upper lip with the tip of a nylon thread frequently produces an "afterglow" sensation that may persist as long as several minutes after cessation of stimulation. The duration of afterglow is increased by strong suggestion, and decreased by vibration of the skin prior to stimulation. The afterglow may be followed by a period of acute "awareness" of the area, distinctly different from the stimulus and afterglow sensations. The afterglows produced by a warm stimulator applied to the back often well up into a painful sting.*

Momentary, gentle stimulation of the inner part of the nose with a pencil tip often evokes a tickling-tingling sensation that may continue for many seconds or minutes, and stops only when the area is rubbed. Similarly, stimulation of a finger with the tip of a nylon thread, at near-threshold intensity, frequently produces an "afterglow" which begins after the sensation of definite touch has subsided and lasts from 5 seconds to 2 minutes or more (*1*). It is unlikely that such gentle stimulation of the finger is able to produce long-lasting mechanical or vascular changes. Moreover, while cutaneous receptor afterdischarges may last as long as 10 seconds (*2*), none have been reported that continue for as long as minutes. Rather, the data suggest that brief somatic stimulation may evoke prolonged activity in the central nervous system. We have determined some of the properties of skin sensory afterglows.

The subjects were 27 male and 17 female students. They first received a trial period to become acquainted with the experimental procedure. They were seated and informed that they would be stimulated, while their eyes were closed, on the upper lip with a nylon thread. They were instructed to press a button (which activated a timer) when they first felt the stimulus and to press it again (which stopped the timer) when all sensation (rather than mere physical removal of the stimulus) had ceased. One side of the upper lip (about 1 to 2 cm from the midline, and 1 to 2 mm below the lip-line) was then touched for 2 seconds with the tip of a nylon thread .15 mm in diameter. Thirty seconds after the subject reported that all stimulus-evoked sensation had ceased, the stimulus was again presented. This procedure was repeated until the subjects were stimulated 5 or 10 times (depending on the duration of the afterglows). The duration of each afterglow was recorded throughout the session. At the end of the trial run, the subjects were asked to draw a graph of the intensity of sensation as a function of time, and all comments, which were made spontaneously without questioning, were recorded.

Thirty-one of the subjects were then assigned to one or more of four groups. Group 1 was chosen from those subjects that reported afterglows of short duration (less than 3 seconds), and an attempt was made to see whether the afterglow duration would be increased by strong suggestion: they were told that most subjects reported afterglows that lasted many minutes, and they would as well if they concentrated harder. All other subjects were assigned randomly to the following groups. Group 2 was given distracting problem-solving tasks (adding numbers or counting randomly timed clicks); group 3 was tested to study the effects of brief vibration on the duration of afterglows: a vibration at 60 cycle/sec was applied gently on the lip for 5 seconds and followed 10 seconds later by stimulation with the thread; group 4 was a control group which received no further instructions.

All four groups received two sets of five or ten stimulus presentations. The procedure for the first set was the same as that for the trial run, and was identical for all groups. The experimental or control presentations were made on the second set.

Figure 1 (A–C) shows the distribution of mean afterglow durations for the trial run and for the first and second sets of stimulus presentations for all subjects. None of the subjects confused the afterglows with the sensation produced by the stimulus itself. The cyclic temporal property of the afterglows (Fig. 1D) was reported by most of the subjects. This property often led a subject to prematurely press the "stop" button at the trough of a cycle, even though the afterglow subsequently welled up again. These errors, made most frequently at the beginning of the trial presentations, were rarely made afterward by the majority of subjects. Those subjects that persistently made these errors were not tested further. Two subjects that reported afterglows of 27 minutes or longer were not given the full set of presentations and are excluded from the analysis. Figure 1B shows that, for experienced subjects, about 33 percent of the afterglows last less than 12 seconds, 20 percent have durations of 12 to 59 seconds, and 47 percent last more than 60 seconds. The duration of afterglows is significantly increased by strong suggestion (group 1) and decreased by vibration prior to stimulation (group 3) (Table 1). Distraction (group 2) and mere repetition (group 4) fail to produce significant changes in afterglow duration.

In the statements volunteered by the subjects, the afterglows were generally described as a tickling-tingling sensation, with rhythmic properties (Fig. 1D) in which the peaks were more localized than the valleys. In addition, nine subjects reported that the afterglows shifted position from the side of the lip (where they were stimulated) toward the center of the lip. Six subjects reported a second, simultaneous afterglow in other areas of the face, often the mirror area on the other side of the upper lip or on the lower lip. The afterglows were usually abolished when the subjects rubbed or bit their lips. The most remarkable observation, however, was that of a "zone of awareness." Several subjects reported that, instead of an afterglow, or after the afterglow had ceased, they were "aware" of the area in a unique way: some reported simply the feeling of a zone of heightened awareness or sensitivity, while others reported pulsations from the area which, they believed, reflected their breathing rate or pulsing blood vessels in the skin. The subjects reported that the "zone of awareness" subsided slowly, although some could later evoke it by intense concentration on the area.

Attempts to study afterglows in other skin areas showed that stimulation of the boundary between the lower nose and cheek, and of the inner part of the nose or the ear (particularly hair movement) produces prolonged, intense afterglows. Stimulation of the eyelids, fingertips and back of the hand was less effective in eliciting them. Observations of the skin during stimulation showed that the lip was sometimes dented and blanched slightly by the thread but returned to normal immediately after its removal. An attempt was therefore made to determine whether these mechanical or vascular effects were the cause of the afterglows. It was found that extremely gentle movement of the thread along the lip or the boundary between the

Table 1. Effects of experimental treatments on mean afterglow durations. +, increase; 0, no change; —, decrease; P is based on the binominal test (9); NS, not significant.

Group	Treatment	Number	Mean afterglow duration changes			P
			+	0	—	
1	Suggestion	10	7	2	1	.035
2	Distraction	9	5	0	4	NS
3	Vibration	10	0	0	10	.001
4	Control	8	5	0	3	NS

lower nose and cheek produced no observable deformation or blanching of the skin; nevertheless, it elicited afterglows of several minutes duration, sometimes so intense that the subject felt compelled to rub the skin to terminate them.

Afterglows were also produced by brief thermal stimulation of the skin. Metal probes 4 mm in diameter were heated to a temperature that felt warm to each subject when the probe was held firmly between the fingers. The tip of the warm probe was then applied gently to the dorsal part of the hand and the back, using the procedure described above for tactile stimulation. These tests were soon terminated, however, because of persistent reports that the skin was being pinpricked or a hair was pulled sharply. The subjects reported feeling the warm stimulus, but after its removal, a sensation of warmth persisted and, in the majority of presentations, welled up into a distinct, pricking sting (*3*). Sensations reported when the thoracic back was stimulated were even more bizarre: not only was sting reported when the warm stimulus was used, but it was often reported when a blunt, metal ballpoint-pen cap, at room temperature, was used as the stimulus. Indeed, even when subjects were shown the stimulus and informed that they would be touched gently with it, interspersed randomly with the warm-probe stimuli, they persisted in reporting sting sensations. It was clear, moreover, that the report was no simple fabrication: the subjects drew away sharply, and accused the experimenter of using a burning hot stimulus rather than the cool metallic cap that was shown to them before stimulation. This phenomenon never occurred when the cap was presented alone.

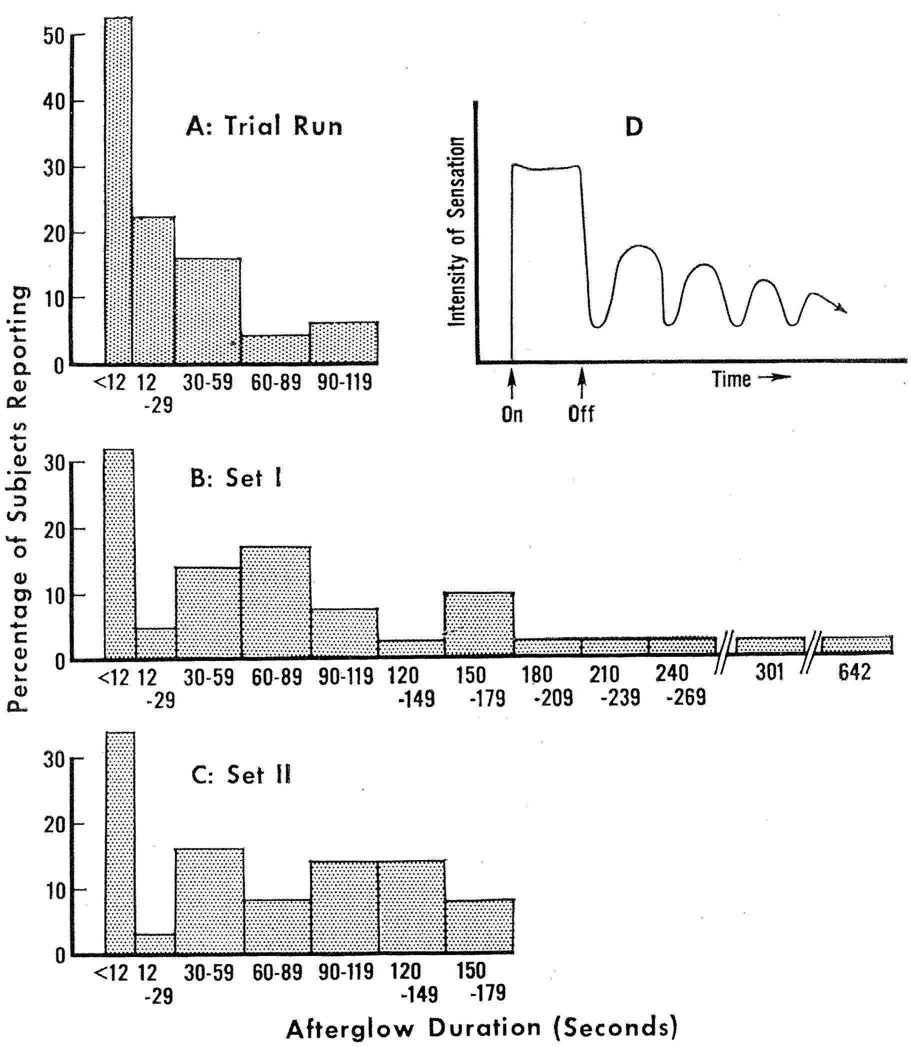

Fig. 1. Distribution of mean durations of afterglows for the trial run (A) and for the first (B) and second (C) sets of stimulus presentations. (D) typical drawing of intensity of sensation during and after stimulation.

These observations, taken together, refute the one-to-one relationship between stimulus and sensation implicit in the traditional specificity theory of skin sensory mechanisms (see *4*). Afterglows of long duration after brief stimulation of the skin appear to be common events in normal subjects, although they may be most striking in cases of neuropathology (*5*). There are reasons for believing that the afterglows are not due simply to suggestion or excessive imagination: (i) the volunteered reports of temporal, spatial, and other properties of the afterglows were remarkably uniform from subject to subject, although the subjects were never given information about such properties; and (ii) stimulation of areas other than the lip (the eyelid and the hand) produced relatively few afterglows, although there should be no difference if the sensations are due to suggestion or imagination.

Observations of the effects of gentle stimulation at the boundary of the lower nose and cheek indicate, moreover, that the long afterglows cannot be attributed to mechanical deformation or vascular changes. Furthermore, cutaneous nerve afterdischarges may last as long as 10 seconds (*2*), but the majority of afterglows had durations of more than 12 seconds. The data suggest, then, that stimulation of the skin sensory system produces prolonged activity in the central nervous system (perhaps supported by the spontaneous, ongoing peripheral input) which is monitored by brain cells for long periods of time (see *6, 7*).

The effects of vibration are best understood in terms of gate control theory (7), which proposes that the effects of a skin sensory input are determined, in part, by the balance of activity in large and small fibers. The brief period of vibration preceding tactile stimulation would tend to close the gate to the stimulus, thereby shortening its central effects (7, 8). Since the vibration produced an afterglow itself, there is the possibility that its effect was due simply to distraction. However, this is unlikely since the subjects reported that the tactile stimulation itself was perceived, after vibration, as being more (rather than less) distinct, and distraction by problem-solving tasks did not have a demonstrable effect on afterglow durations.

The intriguing report of a "zone of awareness" suggests that central control processes, such as attention (7), may facilitate central transmission of all inputs from a skin area. The pulsatile property of the experience reported by some subjects indicates that it may reflect, in part, input from blood vessels or surrounding tissue. Similarly, the mislabeling of the warm-probe (or cool cap) stimulation as stinging pinpricks may also be due to central effects on the input. It is possible that when insufficient or ambiguous cutaneous information is applied to the skin, the input undergoes maximal summation and is perceived as pain. Whatever the mechanisms, the results suggest that brief stimulation of the skin produces central neural activity that may continue as long as several minutes after cessation of stimulation, and that the sensory input is modulated on the basis of both sensory and central neural mechanisms.

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Zircon Lead Loss: A Kinetic Model

Pidgeon, O'Neil, and Silver (1) reported the loss of up to 63 percent of its lead by a metamict Ceylon zircon subjected to a fluid pressure of 1000 bars at 500°C. In their experiments the rate of loss decreased rapidly during the first 10 hours and very slowly afterward. They suggested that the loss mechanism became inhibited by a second process, possibly related to recrystallization of the zircon. The lead isotopic ratio 206/207 remained constant throughout the removal process, indicating that hydrothermal leaching of zircons can produce discordant uranium-lead isotope relationships of the "episodic" type (2). It is thus of some interest to attempt to model the removal process and define parameters which can be tested for consistency.

The simplest model consistent with the results of Pidgeon *et al.* was found to be one in which the lead-loss process is instantaneously first-order with a variable rate constant reflecting in turn a first-order "annealing" process (the term "annealing" is used in order to avoid the implication that actual recrystallization must be a first-order process, since dimensional factors may be involved in the inhibitory mechanism). The overall loss process is then described by the two equations

$$d \ln f/dt = -k \quad (1)$$

$$d \ln (k-k^*)/dt = -a \quad (2)$$

where f is the fraction of the original lead still present in the crystal, k is the variable rate constant for the leaching process, k^*, is the "fully-annealed" limiting value of k, and a is the annealing-time constant. If the initial value of k is denoted by k_0, the fraction of original Pb left at any time is

$$\ln f = -k^*t - \frac{(k_0 - k^*)}{a} \times (1 - \exp[-at]) \quad (3)$$

The calculated curve for the data of Pidgeon *et al.* is shown in Fig. 1; deviations of the experimental values are in accord with their experimental errors of ±3 percent of lead concentration (3). Values of the constants used in Eq. 3 are $k_0 = 0.105$; $a = 0.12$; $k^* = 0.0002$.

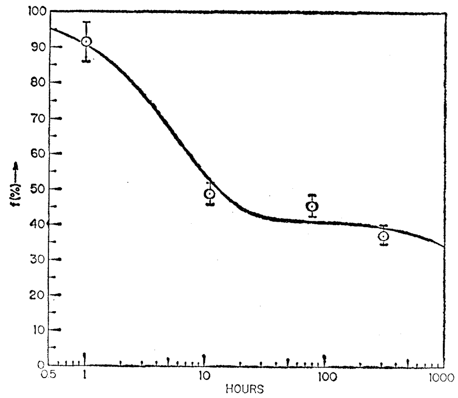

Fig. 1. Solid curve: fraction of original Pb remaining in zircon crystals plotted against time, calculated from Eq. 3; circles are experimental points from Pidgeon *et al.* (1, 3).

The instantaneous rate constant k decreases by a factor of 500 in a relatively short time because of the exponential nature of the "annealing" process built into the model. The first-order dependence in Eq. 1 may be consistent with the very low lead concentration in the zircon and the fact that finely ground powder (−100 to +200 mesh) was used; bulk crystals might obey a different law because of volume effects. Equality of k values for the lead isotopes 206 and 207 is required by the experimental data, which show that the leaching process is nonselective, as assumed in the episodic model.

With three parameters it is relatively easy to fit the data from one experiment. The usefulness of such a model must therefore be based upon reasonable and consistent relations between the parameters, correlated with such variables as temperature and degree of crystal metamictization in more detailed experiments extending the interesting observations of Pidgeon *et al.*

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3. Experimental values plotted in Fig. 1 were calculated from the concentration data in Table 1 of Pidgeon *et al.* (1); they differ somewhat from the fractions used in the text and Fig. 1 of (1).

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