The critical mass is yet to be determined, but it appears that asteroids may be able to retain appreciable gaseous envelopes which they could have acquired by gravitational and electrostatic capture of interplanetary gas, its concentration by sorption on their surfaces [particularly effective if their surfaces are porous or dust-covered (*4*)], and radioactive decay of their lithosphere and the liberation of such gases as may be occluded in it. Yet such atmospheres would be substantially lost by more massive bodies.

Even so, the latter could not lose their atmospheres completely, for the agencies mentioned above will be at work on them as well. There must, therefore, exist a lower limit below which the ground atmospheric density cannot fall. This limit will depend on a host of factors, too numerous and too uncertain for generalization in useful mathematical terms. If, however, gravitational action is considered alone, the limiting ground density can be readily determined in the known case of the moon. The accuracy of such an estimate cannot go beyond the order of magnitude, so that there would be no point in more than a rough numerical calculation.

Let us assume that the moon is surrounded by an isothermal atmosphere obeying Eq. 1 at a temperature $T = 250°K$ and having a mean molecular weight 25 (it would be much higher in reality). By definition, this atmosphere is due solely to the gravitational concentration of interplanetary gas, the molecular density of which may be taken to be the same as it is in the vicinity of the earth, that is, about 10^3.

The atmosphere of the earth is known to extend in attenuated form up to 1000 km or so. That of the moon should extend farther out, owing to the lower surface gravity. To be on the safe side, we may take $1000 \text{ km} = 10^8$ cm as the upper limit z of this lunar atmosphere and put $g = 150 \text{ cm} \cdot \text{sec}^{-2}$ (below the real value).

Equation 1 may be written thus:

$$\nu_z = \nu_0 e^{-2hmga\,[z/(a\,+\,z)]} \qquad (2)$$

where ν_z is the molecular density at z and ν_0 is the molecular density at ground level. Our problem is to find ν_0.

$$\nu_0 = \nu_z e^{2hmga\,[z/(a\,+\,z)]} \qquad (2)$$

Numerically, putting $R \simeq 8 \times 10^7$ and $a \simeq 10^8$ cm,

$$\nu_0 = 10^3 \times e^{150/16}$$

whence, upon carrying out the operations, ν_0 is approximately 1.9×10^7.

The molecular density of any gas at normal temperature and pressure on the earth is given by Loschmidt's number $n = 2.69 \times 10^{19}$. Thus the ground density of lunar air resulting solely from the gravitational concentration of interplanetary gas would be of the order of 10^{-12} the terrestrial atmospheric density at sea level. It will be appreciated that this represents only the lowest possible limit, for it has been assumed above that the moon has never had any atmosphere of its own, that no gases, produced by radioactive decay or any other physicochemical processes or by meteoritic impacts, are liberated from its interior. The concentration of gas close to the lunar surface by the sorptive action of dust and porous pumice-like rocks of which this is expected to consist (*4*) is likewise disregarded. Moreover, if a convective atmospheric layer exists above the surface of the moon its density gradient will be higher than in the assumed isothermal atmosphere (*2*, *4*).

V. A. Firsoff

Glastonbury, Somerset, England

References

1. J. H. Jeans, *The Dynamical Theory of Gases* (Cambridge Univ. Press, Cambridge, 1925).
2. L. Spitzer, Jr., in *Atmospheres of the Earth and Planets*, G. P. Kuiper, Ed. (Univ. of Chicago Press, Chicago, ed. 2, 1952).
3. *Observatory* **78**, 196 (1958).
4. V. A. Firsoff, *Strange World of the Moon* (Basic Books, New York, 1959).

4 May 1959

Escape and Avoidance Conditioning in Human Subjects without Their Observation of the Response

Abstract. An invisibly small thumb-twitch increased in rate of occurrence when it served, via electromyographic amplification, to terminate or postpone aversive noise stimulation. Subjects remained ignorant of their behavior and its effect. Their cumulative response curves resembled those obtained in similar work with animals. Other subjects, informed of the effective response, could not produce it deliberately in a size small enough to qualify for reinforcement.

When the human subject has "voluntary control" of the response to be conditioned, experimental results are in general less predictable and reproducible than those obtained from animals. This is commonly attributed to "self instruction"—that is, to variables experimentally uncontrolled. In the study reported here this problem was circumvented by working with a response so small as to preclude a history of strengthening through discriminable effect upon the environment—in fact, so small as to occur unnoticed by the subject.

The electromyographic setup employed was a modification of that previously reported (*1*). The subject sat in a shielded enclosure in a reclining chair. Recording electrodes were attached to the palmar base of the left thumb and to the medial edge of the left hand. Three additional sets of dummy electrodes were applied in some instances, to suggest that a comprehensive study of body tensions was being conducted. Muscle-action potentials across the left hand were amplified by a factor of 1 million and rectified, and their average momentary values were displayed on a meter. They were also permanently recorded by an Esterline-Angus recording milliammeter.

Twenty-four adults served as subjects. Records from 12 were ruined by apparatus failure, excessive artifact, or failure of the subject to sit still. Results are reported from eight men and four women ranging in age from 18 to 50 and divided into four groups of three each.

Group 1, with four sets of electrodes attached, were told that the study concerned the effects on body tension of noise superimposed on music. Their task was to listen through earphones and, otherwise, do nothing. Group 2, also with all electrodes attached, were told that a specific response, so small as to be invisible, would temporarily turn off the noise or, when the noise was not present, postpone its onset. Their task was to discover and make use of the response. Group 3 (with recording electrodes only) were informed that the effective response was a tiny twitch of the left thumb. Group 4 were given the same information as group 3 but had, in addition, a meter before them during the first half-hour of conditioning, which provided a potential basis for them to use the visual presentation of their response as a "crutch" for proprioceptive observation of the response.

Experimental procedure was identical for all groups. While the subject relaxed and listened to tape-recorded music through earphones, the experimenter watched the meter on his panel for 5 to 10 minutes to select for later reinforcement a response of a size occurring not more than once in 1 or 2 minutes. It was a ballistic swing of the pointer up and back over a few scale divisions. This represented, for a particular subject, a momentary voltage increment at the electrode of 1, 2, or 3 μv.

After the operant level for this response had been recorded for 10 minutes (*OL 1* in Fig. 1), conditioning was begun by superimposing on the music an aversively loud, 60-cycle hum.

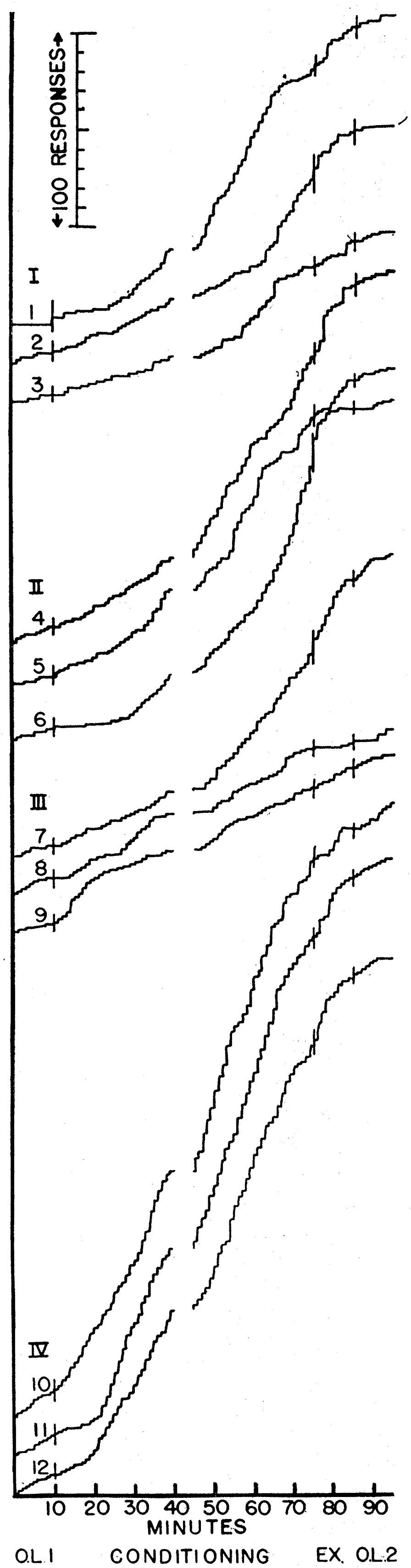

Fig. 1. Cumulative response curves for adult human subjects in a situation where an invisibly small and unnoticed thumb-twitch either terminated or postponed noise stimulation. *OL 1* and *2,* initial and terminal operant level determinations, respectively; *ex.,* extinction.

Whenever the experimenter saw on the meter an instance of the selected response, he pressed a key. This turned off the noise for 15 seconds or, when it was already off, postponed noise resumption for 15 seconds. [This type of avoidance schedule, mentioned in 1950 (*2*), has been extensively employed by Sidman in animal work (*3*).]

After an hour of conditioning, with a 5-minute intermission at the half-hour point, 10 minutes of extinction occurred during which the subject's response was ineffective in terminating continuously present noise. During final 10 minutes of music only, the extent of recovery of the original operant level was recorded.

Figure 1 presents cumulative response curves for each subject. Conditioning is clearly indicated by the positive acceleration in the rate of responding for all subjects except subjects 2 and 3 in group 3. These two kept so busy producing voluntary thumb-twitches that the small, reinforceable type of response had little opportunity to occur.

When interviewed later, all members of group 1 still believed that they had been passive victims with respect to the onset and duration of noise, and all seemed astounded to learn that they themselves had been in control. Subjects 1 and 2 of group 2 reported that they early gave up searching for an effective response and thus, in effect, transferred themselves to group 1. Subject 3 of group 2 professed to have discovered an effective response sequence, which consisted of subtle rowing movements with both hands, infinitesimal wriggles of both ankles, a slight displacement of the jaw to the left, breathing out—and then waiting. Subject 1 of group 3 gave evidence of conditioning perhaps because he misconstrued the instructions. Instead of making the response a quick contraction, he spent his time very gradually increasing pressure on an imaginary switch button. This may have kept deliberate activity at a level low enough for the correct response to break through and be reinforced.

Group 4 subjects, provided with their own meter, obtained many more reinforcements than the others, an effect which continued through the second half-hour of conditioning, with the meter removed. While the meter did not enable them to achieve direct control of the discrete response, it seems to have provided a basis for rapid responding within a range which included the reinforced size. This showed on the meter as rapid oscillation.

The technique employed in this study (*4*) offers possibilities for investigating human behavior, in a sense, at the animal level. Research now in progress is concerned with attempts to clarify the circumstances under which the human subject may come to discriminate verbally—that is, to become conscious of—his small responses.

RALPH F. HEFFERLINE
BRIAN KEENAN
RICHARD A. HARFORD
Department of Psychology, Columbia University, New York

References and Notes

1. R. F. Hefferline, *Trans. N.Y. Acad. Sci.* **20**, 739 (1958).
2. ———, *Genet. Psychol. Monographs* **42**, 231 (1950).
3. M. Sidman, *Science* **118**, 157 (1953).
4. This investigation was supported by research grant M-2961, National Institutes of Health, U.S. Public Health Service, and by grants from the Higgins Fund and the Columbia University Council for Research in the Social Sciences.

16 July 1959

Elementary-Body Virus Isolated from Clinical Trachoma in California

Abstract. From an adult white resident of California with clinically typical early trachoma a virus was isolated by growth in embryonated eggs. Morphologically and serologically the virus belongs in the psittacosis-lymphogranuloma group. When it is instilled into monkey eyes it produces acute follicular conjunctivitis with typical inclusion bodies.

It is estimated that over 400 million people, mainly in Africa, Asia, and parts of Europe, suffer from trachoma as a serious eye disease. In the United States this disease was widespread in the past, but at present it occurs only at a low endemic level, most frequently in the West and Southwest. In San Jose, Calif., indigenous clinical cases of trachoma occur occasionally.

On morphological grounds the elementary bodies and inclusion bodies found in the conjunctival scrapings from many patients with trachoma have long been accepted as the probable etiological agent. Recently T'ang *et al.* (*1*), Collier and Sowa (*2*), and Murray *et al.* (*3*) have grown from trachomatous eyes in China, Gambia, and Arabia, respectively, strains of elementary-body viruses antigenically related to the psittacosis-lymphogranuloma group. Upon inoculation into the eyes of volunteers, some of these viruses have produced typical acute trachoma (*2*). We report here the isolation of a similar agent from a patient with clinical trachoma in California.

A 36-year-old white machinist, a long-time resident of San Jose, developed a red left eye on 10 Jan. 1959, with moderate yellow discharge and a nontender left preauricular lymph node.