that is, between 0.6 and 1.0 mi from ground zero. This grass is widely but more sparsely distributed throughout most of Yucca Flat. The zone of increase in *Stipa* coincides with the zone of injury to the shrubs. On the sandy substratum in area 1, the zone of shrub injury is marked by an unusual abundance of another bunchgrass [*Oryzopsis hymenoides* (R. and S.) Ricker] and a perennial four-o'clock (*Mirabilis pudica* Barneby), which is a common roadside weed in this area. *Atriplex canescens* (Pursh) Nutt., a characteristic saltbush of sandy washes and dunes, silty playa margins, roadsides, and other disturbed areas, is extraordinarily abundant on disturbed sandy soil near ground zero 1, where it has apparently increased in proportion to the amount of dead or damaged *Grayia*. Other pioneer shrubs or subshrubs of dry washes and roadsides, such as *Hymenoclea salsola* T. & G. (burrobrush) and *Sphaeralcea ambigua* Gray (globe mallow) occur in unusual numbers on upland sites in the zone of injury to the original shrub cover, chiefly on the more compact type of substratum with desert pavement. These species appear to be invading at the perimeters of the totally denuded portions of certain ground-zero areas. That these short-term changes in perennial vegetation are analogous to succession is confirmed by observations of older disturbances in the same general area (*4*).

Few native plants have thus far invaded the central portions (0.3-mi radius) of most ground-zero areas; they did not do so even during 1958, a year of exceptionally heavy rainfall which promoted dense stands of native annuals on immediately adjacent sites. Of the numerous species of native annuals, only one, *Mentzelia albicaulis* Dougl. (stickleaf), has grown in appreciable numbers within a distance of 0.1 to 0.3 mi of ground zero (*5*).

Nevertheless, the central portions of all the ground-zero areas have repeatedly produced abundant crops of the highly invasive Russian thistle, *Salsola Kali* L. This annual tumbleweed, introduced from Eurasia, invaded the ground zeros en masse in the first growing season after the detonation of nuclear weapons (*6*).

References and Notes

1. "The effects of nuclear weapons," *U.S. Atomic Energy Comm. Publ.* (Washington, D.C., 1957).
2. R. L. Corsbie (director, Civil Effects Test Organization, U.S. Atomic Energy Commission), unpublished data.
3. The flowering survivors included *Coleogyne, Grayia, Larrea divaricata* Cav., *Lycium Andersonii* Gray, and *Menodora spinescens* Gray.
4. P. V. Wells, *Science* **134**, 670 (1961).
5. L. M. Shields and W. H. Rickard, annual reports to the U.S. Atomic Energy Commission for 1958 and 1959 (New Mexico Highlands Univ. Press, Las Vegas).
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1 August 1961

Method for Sensory Scaling with Animals

Abstract. Two pigeons were trained to peck at a transilluminated disk. The training procedure caused the rate of pecking to increase as a function of the luminance of the disk. The results suggest that the relation between apparent magnitude of light and physical intensity is a power function.

The customary subject in a psychophysical experiment is an adult human observer. This choice has been dictated by the obvious capacity of the human being to report on his sensory experiences. Severe practical problems would attend the use of a subhuman observer in a psychophysical experiment. Since the instructions to, and the responses from, the observer are usually verbal, the typical method of experimentation needs to be radically altered to accommodate animals.

Two principal difficulties have to be overcome when animals serve as observers. First, the experimenter must instruct an animal to attend to a stimulus. Second, the instructions must not limit too narrowly the answer the animal can give. The answer becomes trivial when no other answer is possible. Notwithstanding the difficulties, animals have been used successfully as observers for the determination of absolute and differential sensory thresholds. In most such studies, the animal is instructed to attend to a particular stimulus by the use of reinforcement. In the presence (or absence) of the stimulus, some behavior of the animal is reinforced, and in its absence (or presence), the behavior is not reinforced (*1*).

The study of sensation often involves more than the determination of thresholds. Human observers are instructed to respond, in some manner or other, to the apparent magnitudes of stimuli. From their responses, scales of subjective magnitude are constructed. Animals have not yet been used for sensory scaling, mainly because the "instruction" would presumably determine the outcome. If the animal's behavior is reinforced with respect to a stimulus continuum, then the experimenter seems to be building into the behavior the very scale that he would like the behavior to reveal. If the animal's behavior is not reinforced with respect to a stimulus continuum, then the animal is not being instructed to attend to the continuum.

The experiment reported here (*2*) used a method that partially resolves the dilemma just described. Two food-deprived pigeons (Nos. 109 and 110) were trained to peck a translucent Plexiglas disk and were reinforced by food for pecking at a prescribed rate. The disk was transilluminated with yellow light whose intensity changed at random intervals to one or another of five luminances spaced 0.6 log units (6 db) apart. The highest luminance was about 10 mlam. The variations in intensity of light were produced by changing the voltage across two 7-watt bulbs in parallel. A yellow celluloid filter minimized the apparent changes in hue. A MacBeth illuminometer was used for calibration. The various intensities succeeded each other in a random sequence. The pigeon was fed only if it pecked at a certain rate, and a different rate was correlated with each in-

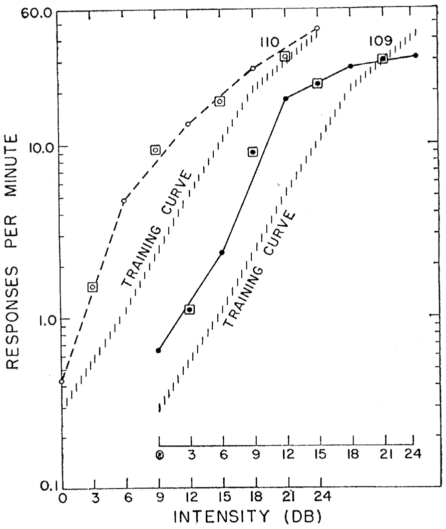

Fig. 1. Rate of pecking as a function of the luminance of the stimulus, for two pigeons (Nos. 109 and 110). The training curve shows the prescribed rate of responding at the training stimuli (0, 6, 12, 18, and 24 db). Points enclosed in squares give rates obtained with test stimuli (3, 9, 15, and 21 db), in whose presence responding was never reinforced.

tensity of the light. The rate was specified in terms of the duration between two consecutive pecks (the "interresponse time"). At each intensity, a range of interresponse times were reinforced. Going from dimmest to brightest light, these ranges were, in seconds, 195 to 214; 51.9 to 57.1; 10.9 to 12.0; 2.79 to 3.07; and 1.35 to 1.48. The time range between the minimum and maximum reinforced interresponse time, at each intensity, was one-tenth of the minimum reinforced interresponse time.

Figure 1 shows the function (training curve) relating the reinforced rate of responding to the intensity of the light on log-log coordinates. The training curve has been plotted twice in order to facilitate inspection of each pigeon's performance. The training function has a slope of approximately 1.0 for the dimmer intensities and a lower slope for the brighter.

The five intensities may be designated the training stimuli because reinforcement was correlated with them. In addition to the training stimuli, there were four test stimuli. The intensity of the test stimuli bisected logarithmically the interval between successive pairs of training stimuli. Thus, the test and training stimuli constituted a series of nine stimuli in 3 db steps. When a test stimulus was present, no response was ever reinforced. Pigeons ordinarily cease responding to nonreinforced stimuli. The behavior was maintained in the present experiment presumably because the pigeons could not discriminate between training and test stimuli when there were nine stimuli that differed along only a single dimension. The pigeons were given several months of daily experimental sessions.

Figure 1 shows the rate of responding as a function of the intensity of the light. Medians of seven sessions are plotted. The session-to-session variability was sizable, but medians for seven-session periods did not change significantly over several months. Rates obtained with the test stimuli appear as points enclosed in squares. If a point falls on the straight line between the training stimuli, then the pigeon's rate for the test stimulus is the geometric mean of its rates for the adjacent training stimuli. To a fair approximation, the rates obtained with the test stimuli fall at the geometric means. This is what would be predicted if, as Stevens (*3*) has found with human observers, the subjective brightness were a power function of luminance. (The basic form of this relation is $R = kS^n$, in which R is the response, S is the stimulus, and k and n are empirical constants.) Fechner's logarithmic law of subjective magnitude would predict rates at the arithmetic means, and this prediction is not as well supported by the present data. Admittedly, no clear choice between the two hypotheses can be made on the basis of these data, partly because the interval between training stimuli was only 6 db. With a greater range for bisection, it would probably be possible to increase the certainty of a choice between arithmetic and geometric means.

It is primarily the arbitrary training curve, and not the sensory system of the pigeon, that determines the overall slopes of the curves in Fig. 1. We cannot, therefore, state the exponent of the power function controlling apparent brightness for pigeons. We can say only that the interpolations made to the test stimuli are compatible with power functions. Since these interpolations may have been influenced by the particular training curve we used, other training curves would have to be tried before our findings could be taken as general.

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Temperature Change: The Basic Variable in the Early Handling Phenomenon?

Abstract. Rats which had been handled or which had been subjected to lowered temperature without handling during the first week of life showed significant reduction of adrenal ascorbic acid when stressed, while appropriate controls did not. Exposure to lower temperature, and consequent lowering of skin or body temperature, may be the crucial factor in handling.

Laboratory rats which are handled during infancy are less emotional and more resistant to stress than nonhandled rats (*1*, *2*). Attempts to explain this relationship have implied that gentling (*3*), trauma (*4*), or stress (*2*) is the essential factor contributed by handling. Levine and Lewis (*5*) tried to specify what physical dimensions of the handling procedure are responsible for the effects obtained. To evaluate the effectiveness of various early treatments, they employed depletion of adrenal ascorbic acid due to stress as a convenient measure of physiological changes attributed to handling (*6*). They found that merely relocating the nest cage for 2 minutes daily was as effective as handling in producing animals which showed significant adrenal ascorbic acid depletion to cold stress at 14 days of age, while nonhandled control animals showed no significant depletion. Consequently, Levine and Lewis concluded that contact with the experimenter was not important and that the effects of handling are due to "any of several modes of extra-stimulation" (*5*, p. 369).

Handling is maximally effective during a critical period in the first week of life (*7*). Therefore vision and hearing, nonfunctional at this age, are obviated as modes of extra-stimulation in early handling. Since nonhandled pups receive frequent, and apparently intense, cutaneous stimulation from the mother, neither handling nor moving the nest cage seems adequate to provide significant added cutaneous (or proprioceptive) stimulation. In addition, it does not seem possible to augment olfactory or chemical stimulation by moving the nest cage. Temperature, the remaining sensory modality, demands further consideration.

Before moving the nest cage, Levine and Lewis removed the mother. In our laboratory this procedure scatters the nursing litter, exposing the pups to cooler air outside the nest. The poorly developed temperature-regulating mechanism, combined with a high surface-area-to-body-volume ratio in the hairless young rat, may result in lower skin or body temperature when a pup is out of the nest. Handling, as well as removing the mother (and dispersing the litter), exposes the pup to cooler air outside the nest. In addition to providing extra-stimulation via temperature receptors in the skin, this exposure might lower the body temperature of the pup enough to alter on-going enzymatic reactions involved in developmental processes, possibly producing permanent changes in physiological mechanisms underlying emotional- and stress-reactivity.

Direct measurements of skin or body temperature, and of neurologic,