Maintained generalization gradients in the monkey[1]

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A method was developed for obtaining generalization gradients in animals that has considerable advantages over previous methods since it (a) does not involve any prior discrimination training, (b) does not require testing in extinction, and (c) yields repeated daily generalization gradients.

If an animal is trained to respond to one stimulus, it will usually also respond to similar ones ("test stimuli"), a phenomenon termed stimulus generalization. If the test stimuli fall on a continuum, strength of response to these stimuli will vary inversely with distance on the continuum from the original training stimulus, forming a "generalization gradient."

In the past, two methods have been used for obtaining generalization gradients. In the first, or "extinction" method, initially only the training stimulus is presented and responses in its presence are rewarded; then rewards are withheld and the rate, latency or amplitude of responses in the presence of each of the test stimuli is measured (e.g., Guttman & Kalish, 1956). In the second, or "discrimination" method, the entire set of stimuli are presented from the start, but responses during only one of them are rewarded (e.g., Pierrel, 1958). Again, the strength of response during each of the stimuli is measured. With both methods, the generalization gradients obtained are transitory because responding in the presence of the test stimuli extinguishes since it is never reinforced. In this paper, we describe a technique for obtaining generalization gradients which involves neither testing in extinction nor discrimination training. It has the added advantage that stable generalization gradients can be repeatedly obtained from the same animal.

METHODS

The Ss were immature *Macaca mulatta*. Three were studied over several months. They were water-deprived, and 1.0 cc orange juice was the training reward. The manipulandum was a 3 cm diam translucent button mounted on one wall of the experimental chamber. The stimuli were projected onto this button. Two stimulus dimensions were used–light intensity and line tilt. The light intensities used were 20, 40, 77, 170, and 460 ft-L. The tilt stimuli consisted of three black stripes 3 mm wide with separations of 5 mm and a background luminance of 330 ft-L. The lines were tilted 20, 40, 50, 60 and 80 deg from the vertical. Prior to introduction of the generalization testing procedure, the monkeys were trained to press the button, first for a reward for each press and then for a reward on an average of once per minute, i.e., on a 1-min Variable Interval (1-min VI) schedule. Only monkeys that developed the smooth rates of responding typical of variable interval schedules within seven sessions were kept in the experiment.

Our procedure was designed to maintain responding in the presence of both the training and test stimuli. This was accomplished by making responding to the test stimuli necessary for the presentation of the training stimulus. Two conditions, a "training" condition and a "test" condition, were repeatedly presented in a random sequence in each daily session. In the training condition, one stimulus, the "training stimulus," was continuously present and responses produced, on a 1-min Variable Interval schedule, a reward followed by the next condition. The training stimulus for the intensity dimension was 20 ft-L and for the tilt dimension 20 deg from the vertical. In each test condition, one of the five stimuli (including one identical to the training stimulus) was presented and responses, on a 1-min VI schedule, produced the next condition but no reward. Thus, to be rewarded with orange juice, the monkey had to respond at least once in every test stimulus condition; otherwise the stimulus would never change and a training condition would never occur. That is, responding in the test condition was maintained by eventual presentation of the training condition in which orange juice could be obtained. Note that differential responding in the different conditions would not alter the frequency of rewards.[3]

In addition to the stimulus changes, responses during both conditions occasionally produced "pseudo-changes": the identical complex of visual and auditory stimuli accompanying the end of a test condition except that the stimulus remained the same. These "pseudo-changes" were programmed on another 1-min VI schedule. One consequence of combining the variable order of conditions with the pseudo-changes was that the monkey could not always tell whether it was in a test or training condition or when a transition occurred from a test condition to the next condition

Not more than five test conditions or four training conditions occurred in a row. Each session consisted of 40 training and 40 test conditions, and each of the five stimuli was presented during 8 test conditions. A session always began with at least one training condition, but the order of conditions was varied. Sessions were run on six or seven days each week.

RESULTS AND DISCUSSION

The procedure succeeded in maintaining responding in both the test and training conditions. In fact, the rate of responding in each condition remained stable over the several months of testing. Moreover, the monkeys responded at different rates in the different test stimulus conditions. The rates were ordered

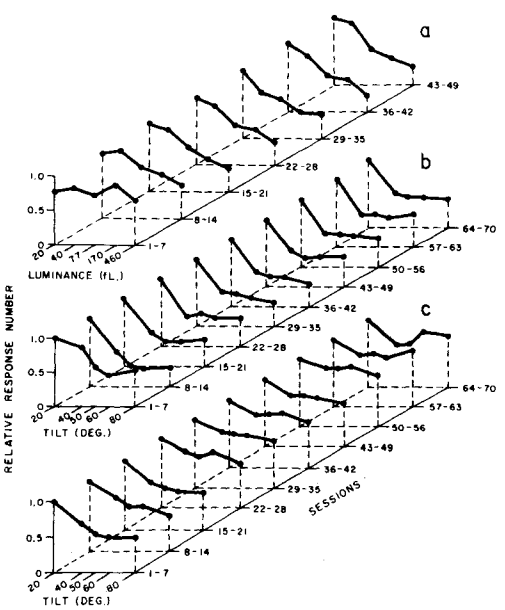

Fig. 1. Relative rate of responding as a function of test stimulus in successive seven-day blocks for three animals. In each session, the rates of responding in the presence of the five test conditions were expressed as a per cent of the rate in the test condition that yielded the highest rate for that session. Each curve is the median relative rate in seven successive sessions.

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lesion in the septum in the rat is to disturb arousal and to reduce the efficiency of an inhibiting mechanism. Consequently, we would have expected an additive effect with the stereotyped movements appearing at a lower drug dosage for the lesioned animals than for the controls. This expectancy was not achieved.

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NOTE

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along the stimulus dimensions, with the highest rates for the stimuli that were also used in the training condition. In other words, the rate of responding in the test conditions formed a generalization gradient with its peak at the training stimulus (Fig. 1).

In most animals, a clear gradient was obtained in the first or second session (Fig. 1b, c). In others it took several sessions to emerge (Fig. 1a). Typically, the gradient obtained in the first or second week remained constant over several months of training. However, in one animal (Fig. 1c), the gradient became flatter after about 21 sessions and essentially disappeared after 70 sessions. Two of the long-term animals were run on both dimensions and, terminally, the dimensions were alternated daily. Each animal produced similar gradients for the two dimensions although the gradients for the two animals differed slightly in shape.

Except for their relative permanence, the generalization gradients were similar to those previously reported. Exploratory studies have suggested that the use of pseudo-changes and randomization of test and training conditions may be necessary for the maintenance of the gradients but not for their occurrence in the first few weeks of testing.

Responding in the presence of the test stimuli was maintained because, unlike previous generalization procedures, this one did not extinguish responses in the test condition; rather, such responses were necessary to produce a change of stimulus, which sooner or later provided an opportunity to obtain orange juice. In conventional parlance, the stimulus change would be termed a secondary reinforcer.

Why did the monkeys respond at different rates in the different test stimuli conditions? There was no differential reinforcement in the different test conditions: a blind monkey would receive as many rewards as one who understands this paper. Note, however, that the monkey could never tell the test condition from the training condition except by the stimulus (and this did not work for the test stimulus that was identical to the training stimulus). Thus the generalization gradient in this study (and perhaps all generalization studies) may reflect the animal's perception of similarity or confusability. In support of this interpretation, procedures which increased the confusability of the stimuli such as randomization of the order of conditions and use of pseudo-changes seemed to prolong the generalization gradients.

We think that this method has several practical advantages over previous methods of generalization testing. In the first place, the generalization gradient obtained is a steady state phenomenon that can be used as a dependent variable. For example, the effect of various drugs on the same generalization gradient in the same animal can be repeatedly measured. Similarly, in brain lesion studies, an animal's postoperative gradient can be compared to its preoperative one. In the second place, the procedure offers a permanent baseline rate of responding from which the extent of generalization can be measured. Thus there is no limit to the number, type or range of test stimuli that can be used. With previous methods, since generalization is measured during the declining curve of extinction, the number of stimuli is severely limited, and if the test stimuli are very dissimilar to the training one, extinction often occurs before adequate data can be collected. Finally, one can study progressive changes in generalization as a function of some concurrent procedure, such as discrimination training.

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NOTES

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2. Now at Department of Biophysics, University of Pennsylvania Medical School.

3. This procedure is derived from one developed by J. L. Cole, Personal Communication, 1965, and is based on the chained schedule of C. Ferster and B. F. Skinner, *Schedules of Reinforcement*, (Appleton-Century-Crofts: New York, 1957). Cole obtained stable intensity gradients in pigeons with a procedure in which the training and test conditions were alternated.