Stimulus Generalization of a Positive Conditioned Reinforcer

Abstract. Stimulus generalization has been observed for discriminative, eliciting, and emotional functions of stimuli. In our study, in order to investigate the generalization of the reinforcing function of stimuli, pigeons were trained in a Skinner box to peck at an unlighted key to obtain aperiodic, brief exposures of light at a wavelength of 550 m_{μ} , the positive conditioned reinforcer, which was immediately followed by food reward. Testing in extinction, we obtained generalization gradients for the number of responses and the time the pigeons expended to produce exposures on the unlighted key of 550 m μ , 530 m μ , 510 m_{μ} , or no light. This finding suggests that stimulus generalization occurs with all functions of stimuli.

Stimulus generalization is usually defined as the tendency of an organism to respond to stimuli which are similar to but not identical with the stimulus used in training. Such a definition implies that the function of the stimulus is to elicit an involuntary response (eliciting function) or to set the occasion for a voluntary one (discriminative function). In either case the response measured is directly contingent upon and follows or is contemporaneous with the stimulus in question.

Stimuli, however, may have still other functions (1), for example, a stimulus may have an emotional effect whereby

it facilitates or inhibits ongoing behavior which is under the direct control of other stimuli. An electric shock or a tone which has been associated with an electric shock are examples of such emotional stimuli. Stimuli may also have a reinforcing function whereby they strengthen the behavior patterns which precede their presentation. Such stimuli include food (a primary reinforcer) and any initially neutral stimulus which has been associated with food (a secondary or conditioned reinforcer).

There are many examples in the literature of the generalization of eliciting and discriminative functions of stimuli. Recent evidence (2, 3) indicates that the emotional (inhibiting) function may generalize as well. Our study was designed to investigate the generalization of the (conditioned) reinforcing function of a stimulus.

Forty homing pigeons (not previously used for experimentation) were reduced to 75 percent of their normal weight and trained to peck at a translucent, unlighted key in a dimly-lit Skinner box. Initially, each pecking response produced a 2-second exposure of light at a wavelength of 550 m μ on the pecking key which was immediately followed by 3 seconds of access to food. The birds were not required to peck at the key, when it was illuminated, to receive food reinforcement. Next, they were successively subjected to fixed-ratio schedules requiring 15, 25, and 50 responses for each reinforcement in or-



Fig. 1. Stimulus generalization gradients for the reinforcing function.



Fig. 2. Stimulus generalization gradients of "superstitious" responding to a discriminative stimulus.

der to build up their response rates. Finally, they were reinforced according to a variable-interval schedule (the inter-reinforcement period averaging 30 seconds) for ½-hour sessions each day. As before, all food reinforcements were preceded by 2-second exposures of light on the otherwise unlighted pecking key.

After 10 days of variable interval (VI) training, four groups of ten birds each were tested for resistance to extinction with 2-second exposures of light at wavelengths of 550 m μ , 530 m μ , 510 m_{μ} , or no light on the key. During the test no food reinforcement was given, but the stimulus exposures were presented according to the same VI schedule used in training. Testing of individual birds was continued until an extinction criterion of no responding for a period of 5 minutes was met. On the day after this test, each bird was retrained with exposures of light at a wavelength of 550 m μ followed by food reinforcement. Daily training sessions continued until response totals met a stability criterion of less than 20 percent fluctuation on three consecutive days. At this time the birds were retested in extinction with a stimulus condition, during exposures, other than the one used on the first test. Retraining and retesting was continued until all birds had received four tests, one with each stimulus condition. The order of presenting these stimuli was randomized to control for extinction effects.

The reinforcement contingency was such that the bird was not required to respond to the conditioned reinforcing stimulus to receive reward. When this stimulus was shown, food reinforcement automatically was presented 2 seconds later without regard to behavior. In spite of this fact, all birds developed "superstitious" (4) responding to the stimulus during its 2-second presentations. These responses, as opposed to those given to the unlighted key, are not indicative of the reinforcing func-

tion, but reflect rather the discriminative function possessed by the stimulus. For this reason these responses, when they occurred during the extinction tests, were recorded separately from the responses to the unlighted key. This made possible the study of the generalization of "superstitious" responding to a discriminative stimulus at the same time that we were investigating the generalization of conditioned reinforcement.

Two measures of conditioned reinforcement were used in this study: the number of responses made to the unlighted key to produce the conditioned reinforcer and the number of minutes spent while responding to produce the conditioned reinforcer until the extinction criterion was reached. Generalization gradients obtained with each of these measures are presented in Fig. 1. In this figure, for each measure, both the generalization gradient obtained on the first extinction test and the mean of the gradients obtained on all four tests are presented. The values in the firsttest gradient are based on independent groups of ten each, whereas all values in the pooled-across-tests gradient are based on the same group of 40. The similarity between the first-test and pooled-across-tests gradients indicates that aside from the reduction in response level on repeated extinction tests, the procedure of retraining and retesting does not distort the gradients obtained. The pooling of the data across tests does reduce error variance sufficiently to produce statistical reliability, whereas first-test performance for both measures only approaches an acceptable confidence level (.05). For datafrom all tests, however, the gradient for responses to extinction is significant [F (3/117) = 5.27, p < .01] as is the gradient for time spent responding to produce the different stimulus values [F (3/117) = 6.31, p < .01].

The analysis of "superstitious" responding to the different test stimuli was performed as follows: since the time to extinction varied with the test stimulus, the different test stimuli were not presented equally often. For this reason the measure of responding used was the mean number of responses per minute during stimulus exposures. Because these responses were made during the presentation of the different stimuli, these data reflect the discriminative function, as opposed to the reinforcing function of the stimulus.

In Fig. 2 two gradients are presented: the first-test gradient and the pooled-12 JULY 1963

across-tests gradient. The similarity of the two is evident. With this measure, the first-test gradient is significant [F(2/27) = 26.85, p < .01] as is each of the four separate test gradients (not shown here). The pooled-across-tests gradient is also significant: [F(2/28)] =28.92, p < .01]. In general, the variability of the individual gradients reflecting the discriminative function of the stimulus (measured in the presence of that stimulus) was strikingly less than the variability of the gradients of conditioned reinforcement (measured during periods of stimulus absence).

Responding to a stimulus which precedes the presentation of a reward generalizes lawfully to similar stimuli despite the fact that reinforcement was in no way contingent upon such responding. Furthermore the presentation of such stimuli strengthens (or maintains) ongoing behavior to the degree that the stimulus is similar to the original (conditioned reinforcer.) Thus, reinforcement is seen as a stimulus function and is subject to the same laws and principles (for example, generalization) as are other functions of stimuli (5).

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References and Notes

- 1. B. F. Skinner, Behavior of Organisms (Apple-B. F. Skinner, Behavior of Organisms (Appleton-Century, New York, 1938).
 O. S. Ray and L. Stein, J. Exptl. Anal. Behavior 2, 357 (1959).
 H. S. Hoffman and M. Fleshler, *ibid.* 4, 371 (1957).

- H. S. Holman and R. Fromer, *inc.*, 7 (1961).
 B. F. Skinner, *ibid.* 38, 168 (1948).
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Spontaneous Electrical Activity in the Brains of Diapausing Insects

Abstract. The spontaneous electrical activity in cerebral ganglia of several insect species does not disappear during diapause. Some recordings of electrical activity in pupae of the cecropia silkworm (in which the brain is considered to be electrically "silent" during diapause) suggest that at least some activity is maintained, but possibly it is restricted to certain regions of the brain.

Most thorough research on diapause has been performed on pupae of Hvalophora cecropia (L.). The complete loss of spontaneous electrical activity in the brain as well as the inability to respond to electrical stimulation appear to be

features of its diapause (1). These changes in the cerebral ganglia were consistent with the altered biochemical relations; the amount of cholinesterase had diminished drastically whereas the titer of cholinergic substance increased steadily. Accordingly, a temporary retardation of development in pupae of Phalaenoides glycine Lew. was evoked (2) by inhibiting its cholinesterase activity through injection of eserine.

Diapausing pupae of Bupalus piniarius L. have been shown to possess spontaneous electrical activity in the brain (3). In order to establish whether the case of Hyalophora or Bupalus represents the "normal" situation, electrical activity during diapause in a number of insect species has been investigated.

The device for these recordings consisted of an unsharpened silver wire (diameter, 20 μ) with glass insulation as the active electrode (4), connected with a Tektronix a-c preamplifier $(100\times)$ and a Tektronix oscilloscope type 502. Action potentials with an intensity of > $50\mu v$ were easily distinguished on a noise level which amounted to about 20 μ v.

The insect species tested were: Leptinotarsa decemlineata Say (Coleoptera, Chrysomel.), Panolis flammea Schiff. (Lepid., Noct.), Hyloicus pinastri (L.) (Lepid., Sphing.), Bupalus piniarius L. (Lepid., Geometr.), and Hyalophora cecropia (L.) (Lepid., Saturn.). Some relevant details about their diapause may be mentioned. (i) Diapause was induced in Leptinotarsa by rearing from the egg stage at 20°C under short-day conditions. The beetles tested were dug up from the soil immediately before the experiment, 3 to 6 weeks after entering diapause. Nondiapausing beetles were obtained from a culture exposed to long-day conditions at 25°C. (ii) Panolis pupae contain adults within 2 to 3 weeks after pupation. These moths hibernate inside the pupal cuticle. From 32 pupae kept at 20°C for 12 weeks none of the moths emerged. Electrical activity in the brain was investigated in pupae kept at 20°C for 4 to 7 weeks. One day before this experiment the oxygen consumption of the insects amounted to 49 \pm 12 μ l g⁻¹ hr⁻¹ at 25°C. (iii) The Hyloicus pupae, which spent 7 to 14 weeks at 20°C after the pupal moult, did not show any sign of adult development at the time of the experiment. (iv) Bupalus pupae, which were investigated after a chilling treatment of 44 to 48 weeks at 3°C, showed distinct characteristics of adult develop-