STIMULUS GENERALIZATION IN AN AVOIDANCE SITUATION[1]

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Investigators using the technique of Guttman and Kalish (1956) or related methods have reported a wide variety of generalization phenomena for behavior that is maintained by food reinforcement (e.g., Kalish & Guttman, 1957, 1959; Hanson, 1957, 1959; Pierrel, 1958; Thomas & King, 1959; Blough, 1959; Honig, Thomas, & Guttman, 1959; Jenkins & Harrison, 1960). The experiments to be reported here extend the series into the realm of avoidance behavior.

METHOD

Subjects and Apparatus

Two young male rhesus monkeys were used. They worked in a Foringer primate chamber, a 2-foot cubical space with the floor and one wall of stainless steel rods, and three walls and ceiling of aluminum sheeting. A telegraph-key lever was mounted on one wall, and an earphone was mounted outside at the level of the grid floor. The rods, walls, and lever comprised the shocking electrodes; and the shock, generated by a Foringer shock power supply, was delivered through a Foringer-type grid scrambler. Shock intensity was approximately 6 milliamperes for Monkey R-641 and 3 milliamperes for Monkey R-832. The values of shock duration are described below.

The click stimuli were generated by a Grass stimulator, with the frequency control replaced by a set of fixed resistors connected to an electrical stepping switch. The sequence of click frequencies was programmed automatically by the stepping switch and a system of relays and timers. Click rates were periodically monitored on a frequency meter.

Preliminary Training

The animal was shaped by receiving frequent brief shocks until it approximated a lever-pressing response. At that point, shocks were discontinued for 20–30 seconds. The response requirement was gradually restricted until the animal actually had to press the lever to terminate the shock sequence. From then on, the animal was shocked every 20 seconds unless it pressed the lever; each time it pressed the lever, it postponed the next shock for 20 seconds (Sidman, 1953a).

Auditory click stimuli were continuously presented to the animal, starting from the very beginning of the shaping procedure. The clicks sounded at either of two rates, or frequencies—2 clicks per second or 6 clicks per second. At first, the two click frequencies alternated every 15 minutes. When the clicks came at a rate of 2 per second (positive stimulus), the avoidance procedure was in effect; the animal was shocked if it did not press the lever rapidly enough. When the clicks came at a rate of 6 per second (negative stimulus), the animal could not receive any shocks, even if it failed to press the lever. The procedure, then, was a multiple schedule: shock avoidance in the presence of 2 clicks per second, and avoidance extinction in the presence of 6 clicks per second.

The procedure was continued until the animal was pressing the lever at a fairly steady rate, receiving few shocks when the positive stimulus was on, and rarely pressing the lever

[1]The assistance of Marie McArthur in conducting these experiments is gratefully acknowledged.

when the negative stimulus was on. (Approximately 5 per cent of Monkey R-641's responses were in the negative stimulus, and 10 per cent of Monkey R-832's responses.) Each session lasted 6 hours. The duration of the alternating stimuli was then gradually decreased from 15 minutes to 1 minute; positive and negative stimuli alternated every 60 seconds. The generalization phase of the experiment was then begun.

Generalization Testing

No shocks were delivered to the animal during generalization tests. In generalization sessions, the negative stimulus (6 clicks per second) was on during each alternate minute. In the 1-minute periods between each negative-stimulus presentation, test stimuli of 2.0, 2.5, 3.0, 4.0, or 5.0 clicks per second were presented to Monkey R-641 in mixed order; for Monkey R-832, the test stimuli were 2.0, 2.5, 3.0, 3.5, or 4.0 clicks per second. In a 6-hour session, the negative stimulus was presented 180 times, and each of the other stimuli were presented 36 times.

Interspersed between generalization sessions, on alternate days, were 6-hour reconditioning sessions in which the multiple avoidance-extinction procedure was in effect. One hour of this procedure also immediately preceded each generalization session.

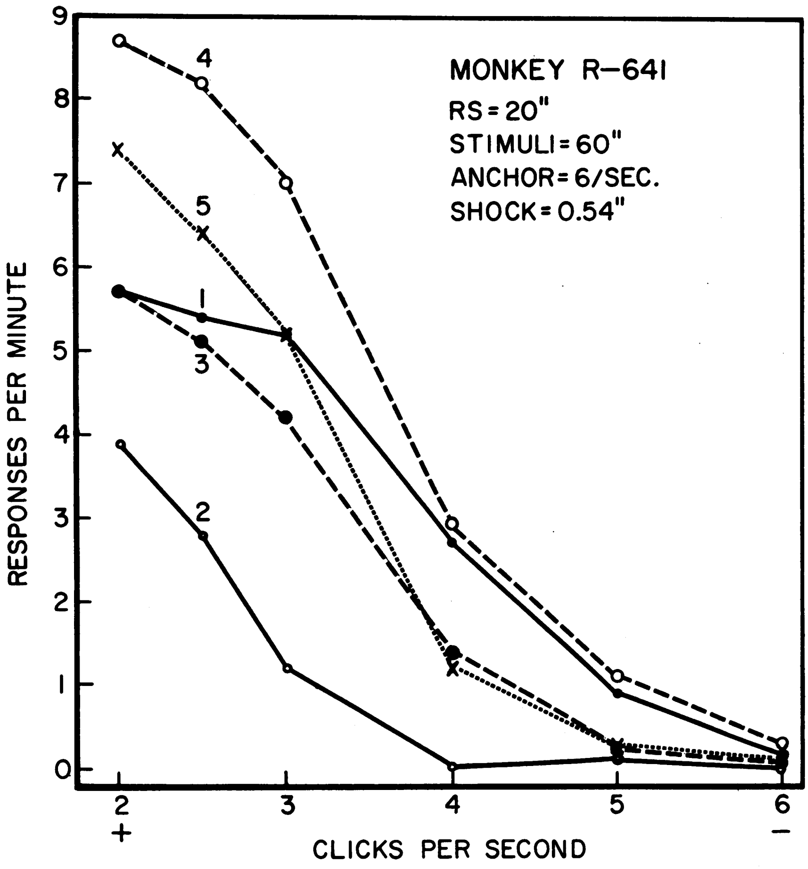

Figure 1. Response rate during each click frequency in the first five generalization sessions.

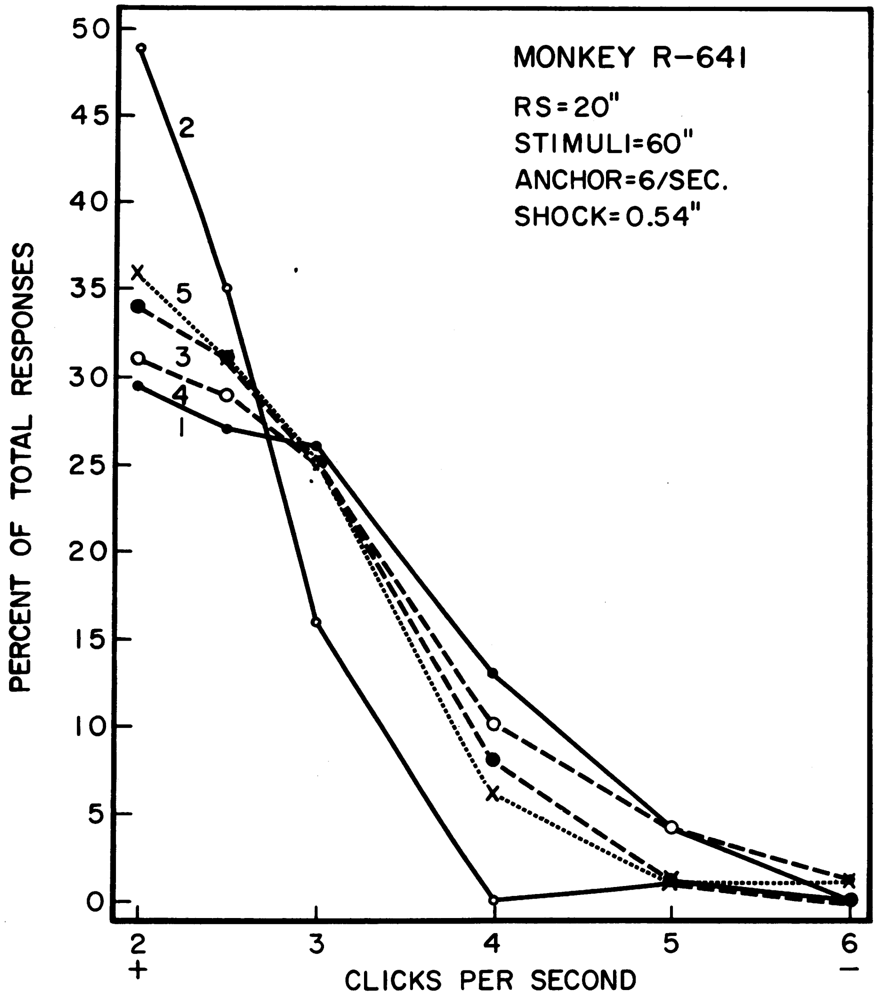

Figure 2. Relative generalization gradients corresponding to the curves of Fig. 1. Each point is the number of responses during each stimulus expressed as a percentage of the total responses during all stimuli.

Absolute and relative response rates during each stimulus, plotted against click frequency, yield one wing of a generalization gradient for each monkey during each generalization session. The shape of the gradient was studied as a function of response-shock interval, shock duration, anchoring stimuli, and length of the subject's involvement in the experiment.

RESULTS

The first five generalization gradients of Monkey R-641 are in Fig. 1, plotted in terms of absolute response rate as a function of click frequency. All the gradients show the animal responding less frequently as the test stimulus diverges from the positive frequency of 2 per second. Although the response rates vary considerably from one session to another, Session 2 is the only one in which the generalization gradient differs radically in shape from the others. This is brought out even more clearly in the gradients of Fig. 2, in which the animal's responses during each stimulus are expressed as a percentage of the total responses to all stimuli (corrected for the larger number of presentations of the 6-per-second stimulus). Except for Session 2, the percentage gradients are similar to each other, in spite of the wide variations in absolute response rates.

Figures 3 and 4 show similar and even more consistent data for Monkey R-832.

It was considered possible that the 6-per-second "anchoring" stimulus, which was presented both before and after each of the other stimuli, could affect the shape of the generalization gradient. During generalization tests 6–10, therefore, the positive 2-per-second stimulus was used as the anchor for Monkey R-641. In Sessions 11–15 the original procedure was repeated, the 6-per-second stimulus alternating with each of the others.

The solid curve of Fig. 5 is the median gradient of the first five sessions, of which the day-by-day data were shown in Fig. 2. The curve represents the median percentage for each stimulus for the five sessions. When the anchoring stimulus was changed to 2 per second, the gradient (open circles of Fig. 5) became much steeper. However, the steeper gradient possibly did not result entirely from the use of the positive stimulus as the anchor, because when the negative 6-per-second stimulus was again presented during alternate minutes, the

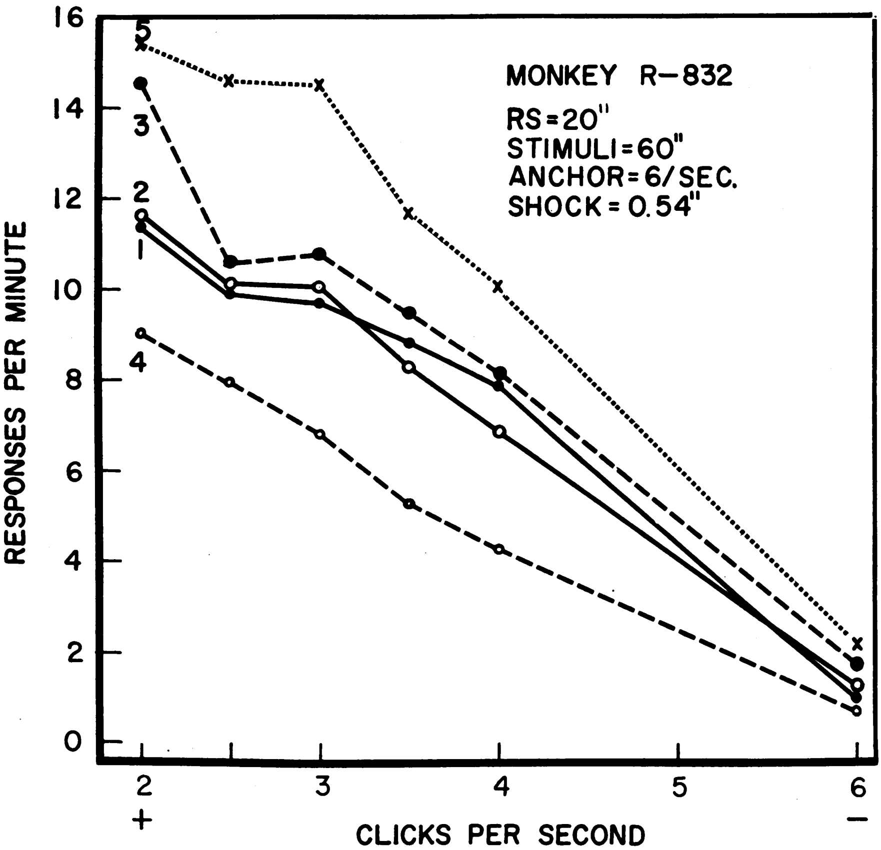

Figure 3. Response rate during each click frequency in the first five generalization sessions.

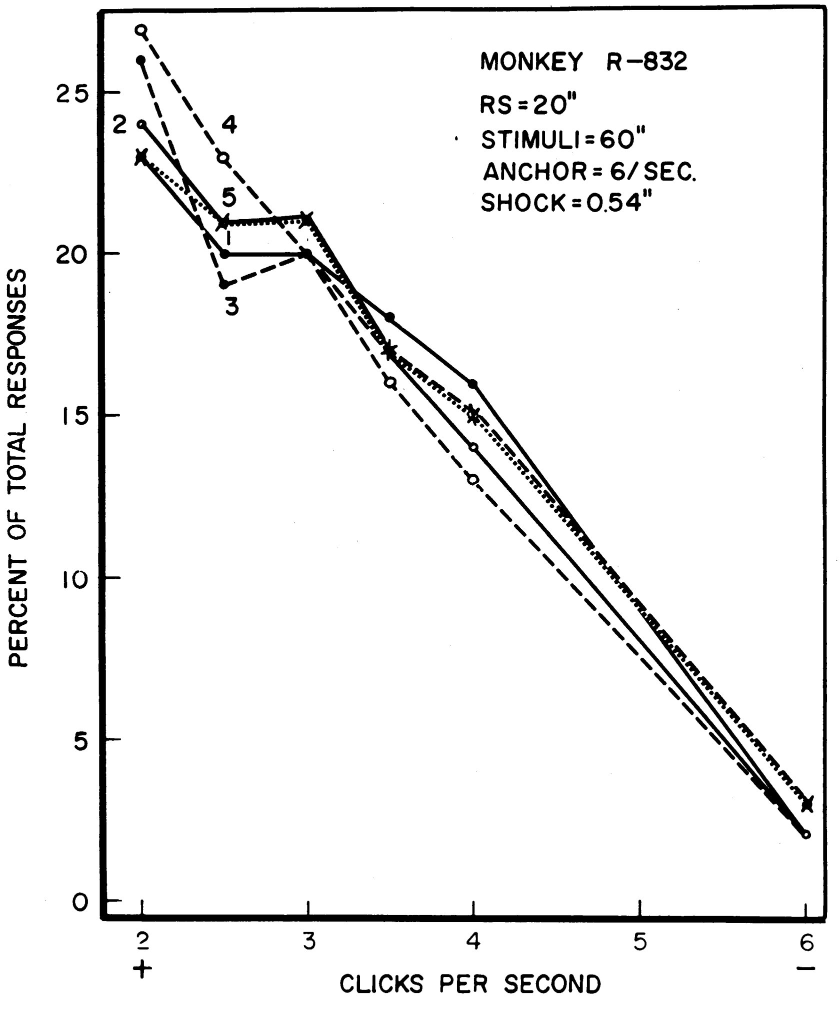

Figure 4. Relative generalization gradients corresponding to the curves of Fig. 3.

gradient did not return completely to its original form. Whether the gradient would have become steeper simply as a function of continued generalization testing, or whether the 2-per-second anchor produced a partially irreversible change is not entirely clear from these data. The steep gradient of Session 2, along with subsequent developments to be noted below, suggests that the test procedure itself produces some sharpening of the generalization gradient. However, the partial recovery of the gradient in Fig. 5 suggests that when the positive stimulus is used as anchor, the gradient becomes steeper than when the negative stimulus is so used, and steeper than would have been expected as a function of simple exposure to the procedure.

Monkey R-641 was then run for 5 sessions each on response-shock intervals of 10, 5, and 3 seconds, in that order. (The animal could receive shocks, of course, only during the reconditioning sessions and the hour before generalization tests.) With the reduction in response-

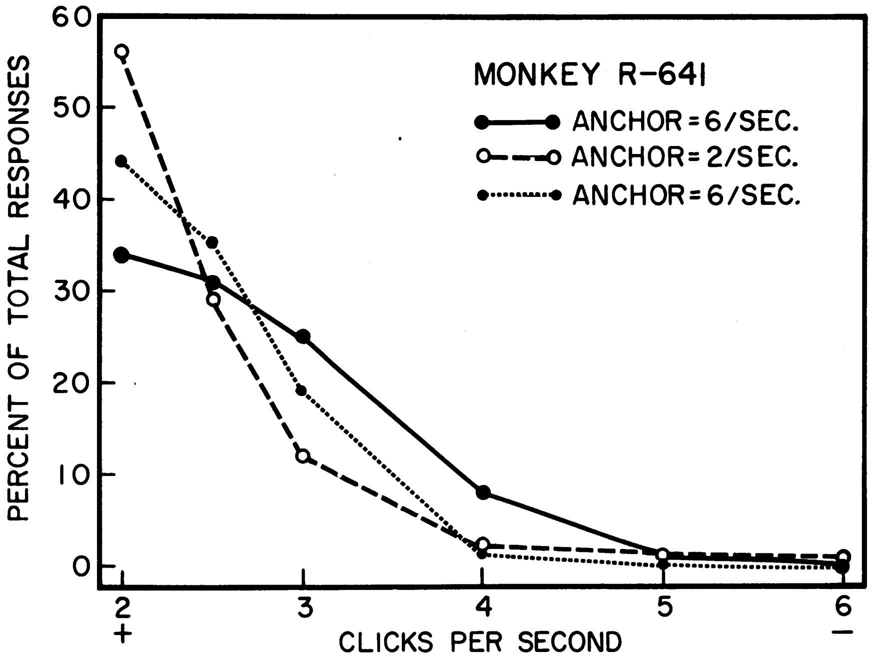

Figure 5. Median relative generalization gradients when the anchor was first the negative stimulus, then the positive, and then the negative again. The percentage of responses per session in each stimulus was calculated, and each point represents the median percentage for five sessions.

shock interval from 20 to 10 seconds, the duration of each stimulus presentation was also reduced from 60 to 30 seconds, where it remained for the rest of the experiment. Since the session duration remained at 6 hours, the 6-per-second stimulus was now presented 360 times during each generalization test, and each of the other stimuli was presented 72 times.

Figure 6 shows median generalization gradients for each response-shock interval, plotted in terms of absolute response rates during each stimulus. Except for the 3-second curve, the response rates increased (Sidman, 1953b) when the response-shock interval was lowered, as was to be expected. (Since the monkey was exposed to each response-shock interval for only five sessions, its behavior had probably not yet reached a stable state.)

The shorter response-shock intervals did indeed bring out more responses during click frequencies of 2.5, 3.0, and 4.0 per second; but, as Fig. 7 indicates, the increase was a simple multiplicative one. The percentage gradients are almost identical for each response-shock interval.

After its first five generalization tests, Monkey R-832 was given five consecutive reconditioning sessions in which the response-shock interval had been reduced to 10 seconds, with stimulus durations of 30 seconds. There were no generalization tests. Then, the response-shock interval was reduced to 5 seconds and the stimulus durations to 15 seconds. At this point, the session duration was cut down to 3 hours, keeping the number of stimulus presentations the same as those for Monkey R-641.

A comparison of median response rates per stimulus at response-shock intervals of 20 and 5 seconds appears in the two lower curves of Fig. 8. The percentage gradients may be seen in the corresponding curves of Fig. 9. Again, the shorter response-shock interval brings out many more generalized responses; but, with the unexplained exception of the 6-per-second stimulus, there appears to be a simple multiplicative relation between the two gradients.

The response-shock interval was decreased rapidly for Monkey R-832 in order to avoid, if possible, a change such as had taken place in the gradient for Monkey R-641 after its extensive series of generalization tests. After the first four sessions of exposure to the 3-second response-shock interval, the gradient for Monkey R-641 suddenly became much steeper, as is indicated by the median curves of Fig. 10. This change is not a simple multiplicative one, and is probably correlated with the formation of a new discrimination based on the greater variety of stimuli experienced by the animal during generalization tests. The monkey never received any shocks during periods when the series of click

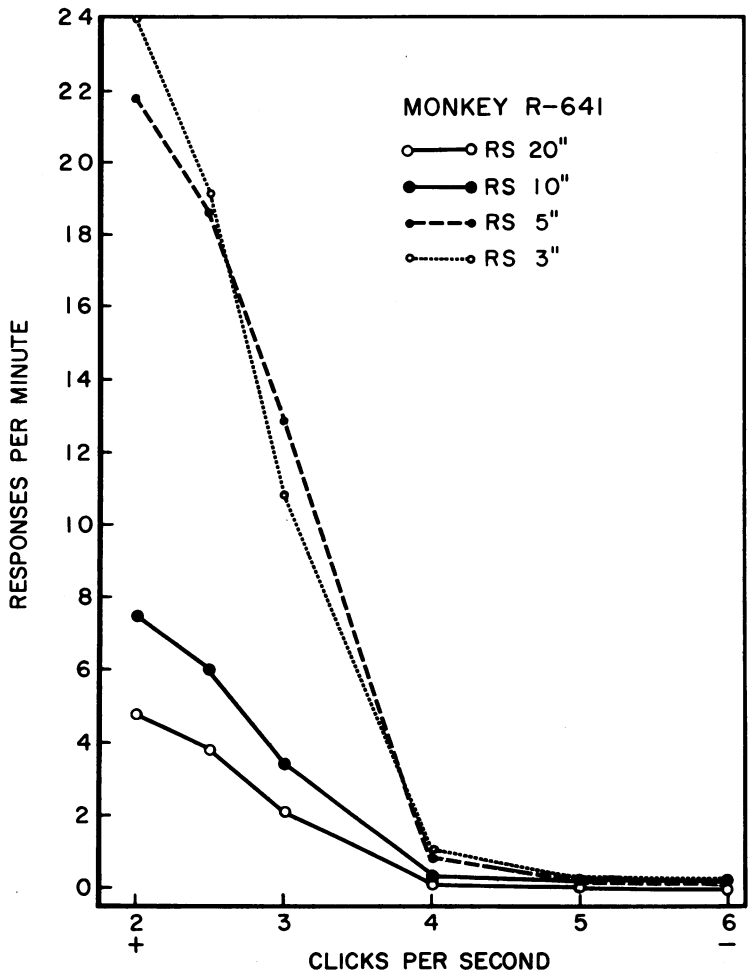

Figure 6. Median response rate during each click frequency for different response-shock intervals. The response rate per session in each stimulus was calculated, and each point represents the median rate for five sessions.

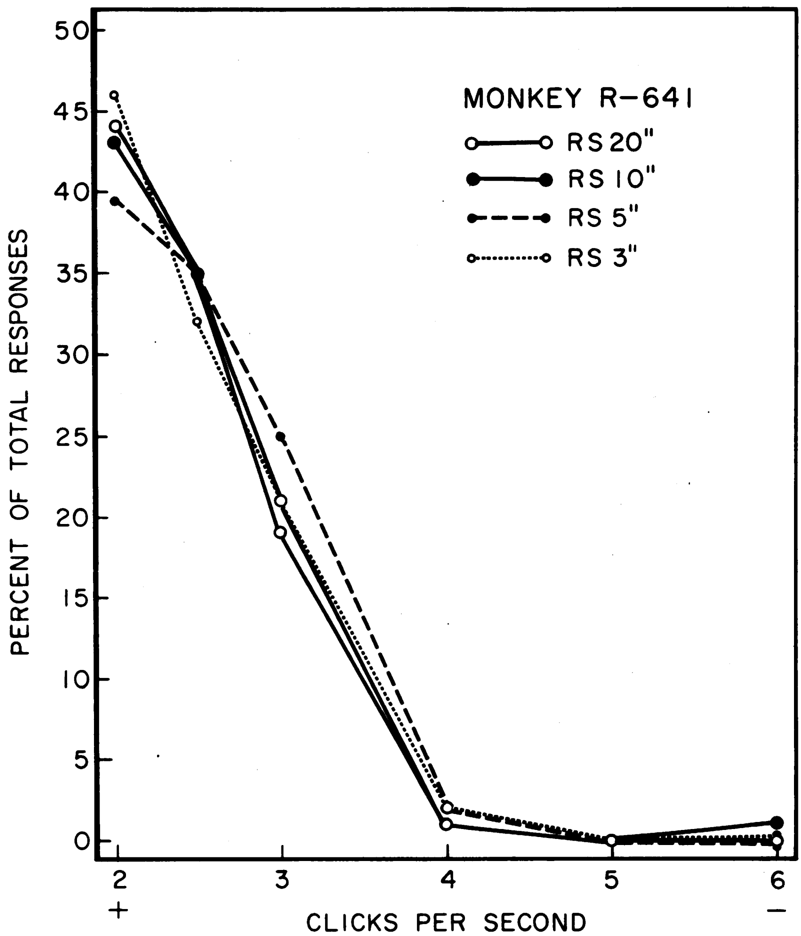

Figure 7. Median relative generalization gradients corresponding to the curves of Fig. 6.

frequencies between 2 and 6 per second was presented; therefore, this series may itself have become a negative stimulus for avoidance behavior. Evidence in favor of this interpretation comes from a marked decline in total responses during generalization tests at this time, with the animal responding normally at the start of the session but gradually tapering off until it rarely pressed the lever during the latter part of the session.

Because of the changed gradient, the effects of any new operations could not be evaluated with respect to the previous data. The steeper gradient, however, was used as a base line for examining the effects of an increased shock duration. During previous experiments, the shock duration was 0.54 second, and it was now increased about threefold to 1.69 seconds, keeping the response-shock interval at 3 seconds. The longer shock duration produced only a slight increase in Monkey R-641's response rate and no great change in the amount of generalization, as may be seen in Fig. 10.

The shape of the gradient for Monkey R-832 remained stable at a response-shock interval of 5 seconds; and when the shock duration was increased, the response rate increased considerably (Fig. 8). Figure 9, however, indicates no consistent change in the percentage gradient for the longer shock duration.

The data may be summarized by a generalization surface (Guttman & Kalish, 1956). For each test stimulus, the subject's response rate in the presence of that stimulus is plotted against the over-all rate for the session. In this analysis, no distinction is made among changes in over-all rate produced by variations in response-shock interval, shock duration, or uncontrolled factors.

The generalization surface for Monkey R-641 (Fig. 11) includes all sessions from Session 11 (return to the negative anchoring stimulus) up to the point where the animal began to discriminate the generalization procedure. (See Fig. 10.) The relation, fitted by the method of averages, is a positive linear one for all stimuli, with the slope decreasing as the test stimuli diverge from the positive stimulus. (Beyond a click rate of 4 per second, the response rates were so low as to yield essentially zero slopes.) If the slopes of these curves are plotted against click frequency, an idealized generalization gradient can be derived which is independent of over-all response rate.

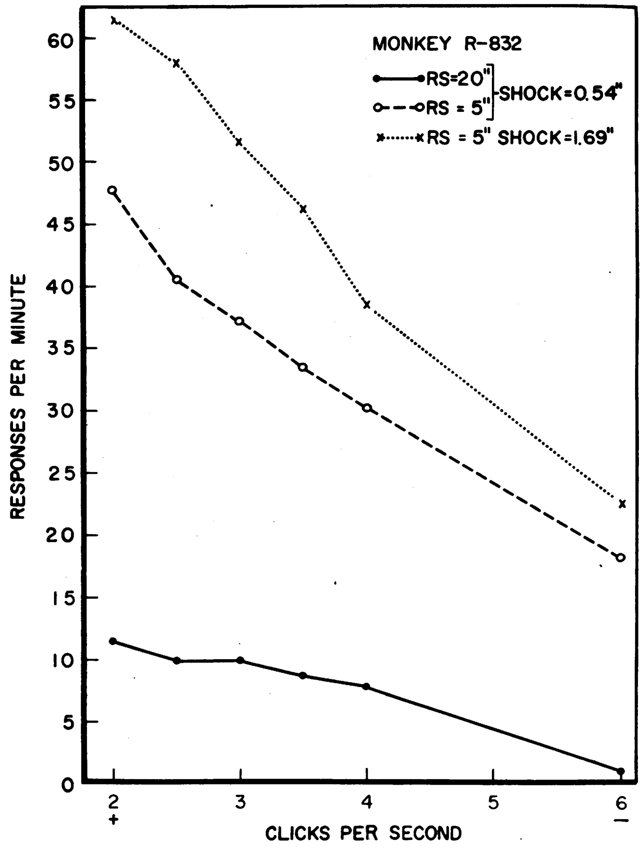

Figure 8. Median response rate during each click frequency for two response-shock intervals and two shock durations.

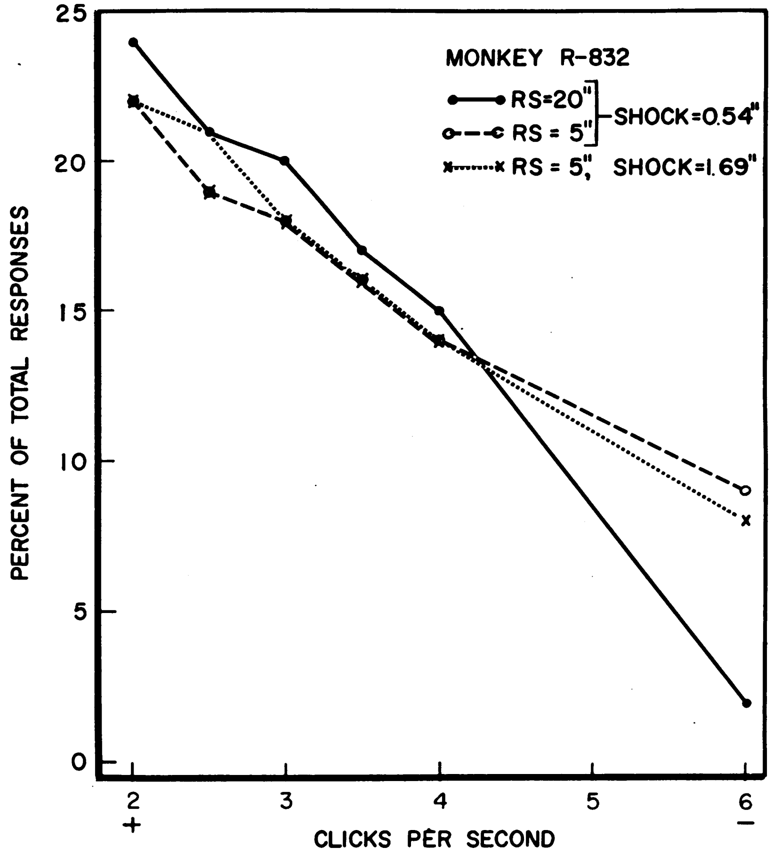

Figure 9. Median relative generalization gradients corresponding to the curves of Fig. 8.

Figure 12 shows similar results for the complete data of Monkey R-832. However, there is somewhat more variability around the fitted lines.

The generalization gradient is thus observed to be independent of changes in over-all response rate over the range of variables tested here. These findings add great generality to the earlier work of Kalish and Guttman (1957), who used a different organism (pigeon), a different stimulus dimension (wavelength), food reinforcement rather than shock avoidance, and a different training procedure.

A comparison of the slopes of corresponding curves in Fig. 11 and 12, however, suggests an exception to the rule that the shape of the generalization gradient is independent of the rate of avoidance responding. The slopes for Monkey R-832 are considerably steeper than those for Monkey R-641; the two sets of data could not legitimately be combined into a single generalization surface. Among the uncontrolled variables that account for these individual differences, there must be one or more that change the generalization gradient in a nonlinear fashion as a function of the over-all rate of avoidance responding.

SUMMARY AND FURTHER DISCUSSION

Generalization of avoidance behavior to auditory clicks differing in repetition rate was studied with two monkeys. After the subjects had received extended discrimination training

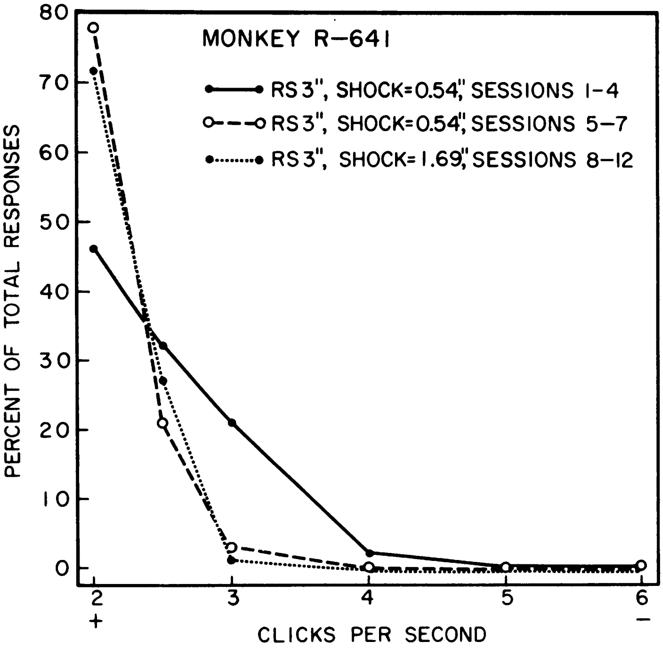

Figure 10. Median relative generalization gradients as a function of continued testing and shock duration.

(positive stimulus, 2 clicks per second; negative stimulus, 6 clicks per second), the shape of the generalization gradient was found to be independent of response-shock interval and of shock duration. However, there was some indication that extended exposure of the subject to generalization testing decreased the amount of generalization and sharpened the gradient. Except for unknown factors contributing to intersubject variability, the shape of the gen-

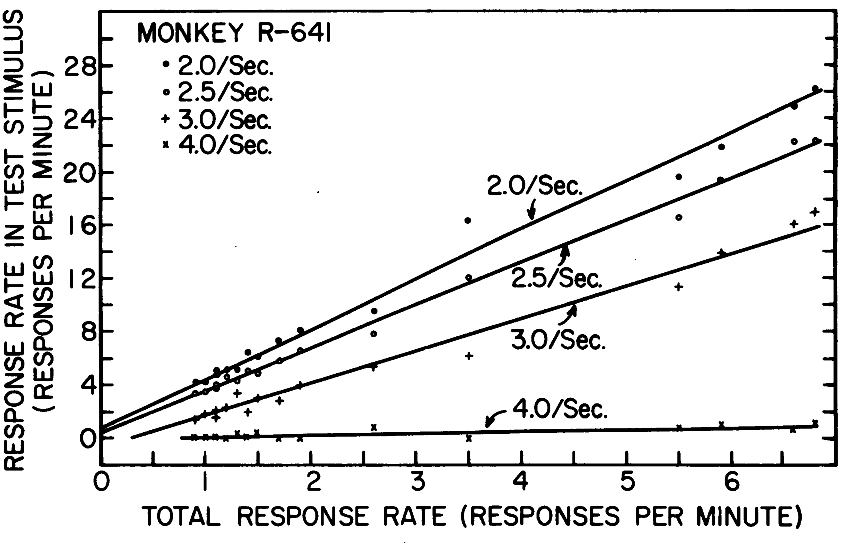

Figure 11. Rate of responding during the test stimuli as a function of the over-all response rate for each session.

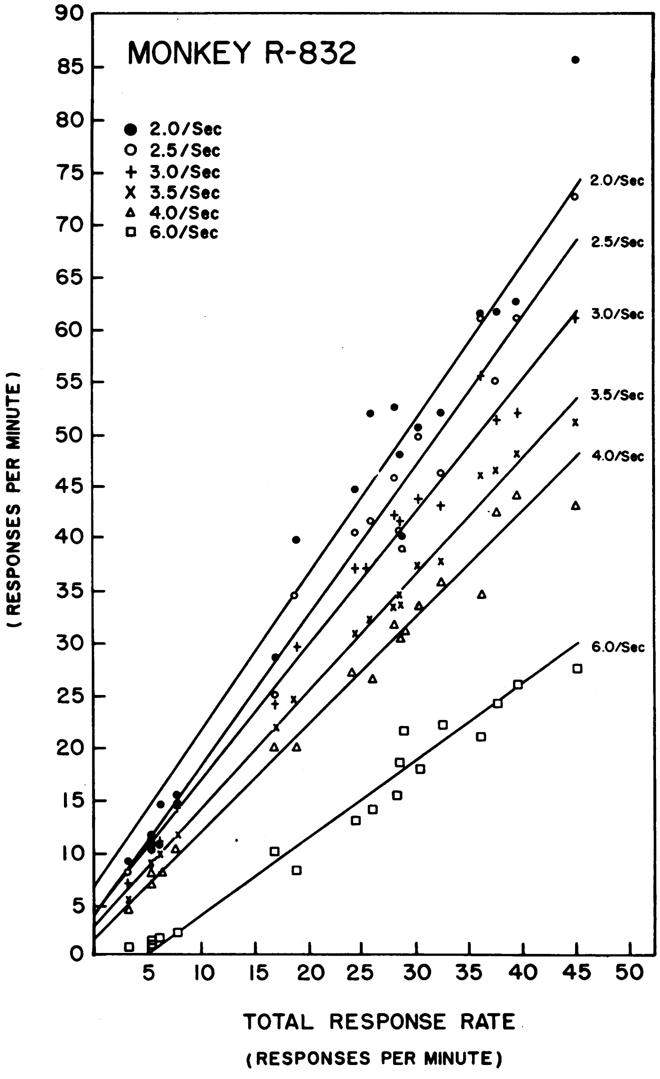

Figure 12. Rate of responding during the test stimuli as a function of the over-all response rate for each session.

eralization gradient was independent of variables that altered the subjects' rate of avoidance responding.

At least one qualification must be appended to these findings: the subjects were tested for generalization after they had been given extended discrimination training. The simple fact that the animals had to be given specific training before they began to press the lever at different rates in the positive and negative stimuli indicates that the gradient was relatively flat both during and for some time after initial avoidance conditioning. Hearst[2] has provided empirical confirmation of the flat generalization gradient for avoidance behavior before the animal has specific discrimination training.

[2]Personal communication, 1960.

REFERENCES

Blough, D. S. Generalization and preference on a stimulus-intensity continuum. *J. exper. anal. Behav.*, 1959, **2**, 307-317.

Guttman, N., and Kalish, H. I. Discriminability and stimulus generalization. *J. exper. Psychol.*, 1956, **51**, 79-88.

Hanson, H. M. Discrimination training effect on stimulus generalization gradient for spectrum stimuli. *Science*, 1957, **125**, 888-889.

Hanson, H. M. Effects of discrimination training on stimulus generalization. *J. exper. Psychol.*, 1959, **58**, 321-334.

Honig, W. K., Thomas, D. R., and Guttman, N. Differential effects of continuous extinction and discrimination training on the generalization gradient. *J. exper. Psychol.*, 1959, **58**, 145-152.

Jenkins, H. M., and Harrison, R. H. Effect of discrimination training on auditory generalization. *J. exper. Psychol.*, 1960, **59**, 246-253.

Kalish, H. I., and Guttman, N. Stimulus generalization after equal training on two stimuli. *J. exper. Psychol.*, 1957, **53**, 139-144.

Kalish, H. I., and Guttman, N. Stimulus generalization after training on three stimuli: a test of the summation hypothesis. *J. exper. Psychol.*, 1959, **57**, 268-272.

Pierrel, R. A generalization gradient for auditory intensity in the rat. *J. exper. anal. Behav.*, 1958, **1**, 303-313.

Sidman, M. Avoidance conditioning with brief shock and no exteroceptive warning signal. *Science*, 1953a, **118**, 157-158.

Sidman, M. Two temporal parameters of the maintenance of avoidance behavior by the white rat. *J. comp. physiol. Psychol.*, 1953b, **46**, 253-261.

Thomas, D. R., and King, R. A. Stimulus generalization as a function of level of motivation. *J. exper. Psychol.*, 1959, **57**, 323-328.

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