

SOME EFFECTS OF
RESPONSE-INDEPENDENT REINFORCEMENT ON
AUDITORY GENERALIZATION GRADIENTS

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Two groups of six rats received discrimination training with two auditory stimuli differing in intensity. During one stimulus, the schedule was variable interval; during the other, it was either variable time or extinction. Both the variable time and extinction schedules resulted in differential rates of responding in the presence of the two stimuli. Extinction resulted in an earlier and more stable difference. Stimulus generalization gradients obtained along the noise-intensity dimension revealed peak shift with both procedures. In addition, a secondary peak to stimuli in between the two training stimuli occurred with the variable-time schedule.

A commonly used procedure for producing differential responding to two stimuli presented alternately (multiple schedule) is to reinforce responding to one at irregular time intervals (variable-interval schedule or VI), while never reinforcing responses to the other (extinction, or EXT). Another procedure for reducing responding to one of the stimuli is to present a reinforcer at irregular intervals independent of responding (variable-time schedule, or VT). Several investigators have shown that the combination of VI and VT components in a multiple schedule produces differential responding, even though the rate of reinforcement remains identical in both (Boakes, 1973; Lattal and Maxey, 1971; Wilkie, 1972).

As well as producing differential responding, extinction and VT have been shown to share another property. When extinction is combined with VI in a multiple schedule, generalization gradients obtained along the dimension correlated with the extinction component are U-shaped around the specific value used in training (Terrace, 1966). A similar inhibitory gradient occurs with respect to the dimension correlated with VT (Weisman and Ramsden, 1973). However, differences also occur. Unlike a *mult* VI EXT schedule, which

enhances responding during the VI component (e.g., Reynolds, 1961), a *mult* VI VT schedule reduces responding in the VI component (Boakes, 1973; Weisman and Ramsden, 1973). Thus, the two conditions are not fully equivalent.

The similarities and differences hitherto observed between the effects of VT and extinction raise the question of whether another common effect of a *mult* VI EXT schedule—peak shift—would occur with *mult* VI VT. Peak shift refers to the observation that a generalization gradient obtained on the dimension correlated with VI will show a peak, not at the training stimulus, but at a value removed from it in a direction away from the value correlated with extinction (Hanson, 1959). To the extent that VT and extinction have equivalent effects, peak shift would occur with both. A number of studies have shown, however, that enhanced responding to the VI stimulus (behavioral contrast) and peak shift occur together (Terrace, 1972, p. 233). Since behavioral contrast has not been found after training on a *mult* VI VT schedule, peak shift might also not occur. Yet, incremental inhibitory gradients also seem to accompany peak shift, and these have occurred with a *mult* VI VT schedule. It is thus not clear what should be expected. The present experiment compared the nature of postdiscrimination gradients after training under a *mult* VI VT schedule with those obtained with training under a *mult* VI EXT schedule.

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METHOD

Subjects

Six Sprague Dawley albino and six Long Evans hooded rats were maintained at 80% of their free-feeding weights throughout the experiment. These experimentally naive rats were approximately 120 days old at the beginning of the experiment.

Apparatus

A Lehigh Valley Electronics model 1316 two-lever rat chamber was equipped with a standard pellet dispenser delivering 45-mg Noyes pellets as reinforcers. The left lever was replaced with a flat metal plate. The remaining lever required a force of 0.15 N to operate a microswitch. Continuous illumination inside the chamber was provided by a house-light. Three lights 2.5 cm above the lever flashed for 250 msec whenever a pellet was delivered.

The stimuli were auditory signals produced by a Grason-Stadler white-noise generator (Model 901B). Two auditory intensities were determined by transmitting signals through two decade resistance boxes (Aerovox Corp Model ARD-41), each calibrated to produce either an 87- or 78-dB white noise. Calibration of the decade resistance boxes was accomplished with a General Radio meter (Model 1551) with filter function set to the A band. Outputs from each decade box led to an electronic switch that determined which signal reached a University Sphericon 8-ohm Super Tweeter (Model T202) located in the forward wall 7.6 cm above the food trough and 5.1 cm to the left of the lever. Intensity readings were made with the microphone placed in a position approximating the vicinity of the rat's head while the rat was lever pressing.

The chamber was inside a Lehigh Valley cubicle (Model 132-02) placed inside of another Lehigh Valley cubicle (Model 132-16); each cubicle provided approximately 30 dB sound attenuation. The inner chamber was equipped with a ventilating fan. Standard automated scheduling and recording equipment was located in an adjacent room.

Procedure

On the first day of training, each rat was magazine trained on a 1-min constant probability variable-time (VT) schedule of reinforce-

ment (Fleshler and Hoffman, 1962). On the second day, lever pressing was manually shaped, after which each of the next 100 responses provided a pellet. On Days 3 and 4, the schedule was shifted to constant probability variable-interval (VI) 30-sec.

Discrimination training. On the fifth training day, the six albino rats and the six hooded rats were randomly divided into two groups. Albino Rats 1, 3, and 5 and hooded Rats 21, 23, and 25 had a constant probability *mult* VI 1-min VT 1-min schedule. The two component schedules were identical except that the response-reinforcer dependency was eliminated during VT. The stimuli alternated every 2 min with probability = 0.50. The 87-dB noise signal was correlated with VI, and the 78-dB signal was correlated with VT for the albino rats. The stimuli were reversed for the hooded rats. Albino Rats 2, 4, and 6 and hooded Rats 22, 24, and 26 had a *mult* VI 1-min EXT schedule. For the albino rats, the 87-dB noise signal was correlated with EXT. For the hooded rats, the stimuli were reversed.

Each of the five daily training sessions per week lasted for approximately 1 hr and started with either schedule component on a random basis. As a result of apparatus failures, Rats 21, 23, and 25 received 29 training sessions; all others had 30 sessions.

Extinction tests. Discrimination training was followed by stimulus generalization tests. The test session began with a warm-up period of discrimination training that ended when each rat was exposed to each schedule component four times. No responses were reinforced while stimuli of 72, 75, 78, 81, 84, 87, 90, and 93 dB were presented. Each stimulus appeared for 45 sec. Each block of intensity values (composed of one presentation of each value) consisted of a semirandom series, with the restriction that the difference between two successive values was not greater than 9 dB (the difference between the training stimuli). Testing continued until each rat failed to respond during one complete block of test stimuli.

RESULTS

Response rates for rats trained on *mult* VI VT are shown on the left side of Figure 1. Response-rate differences appeared by the second session in S3 and S5 and continued

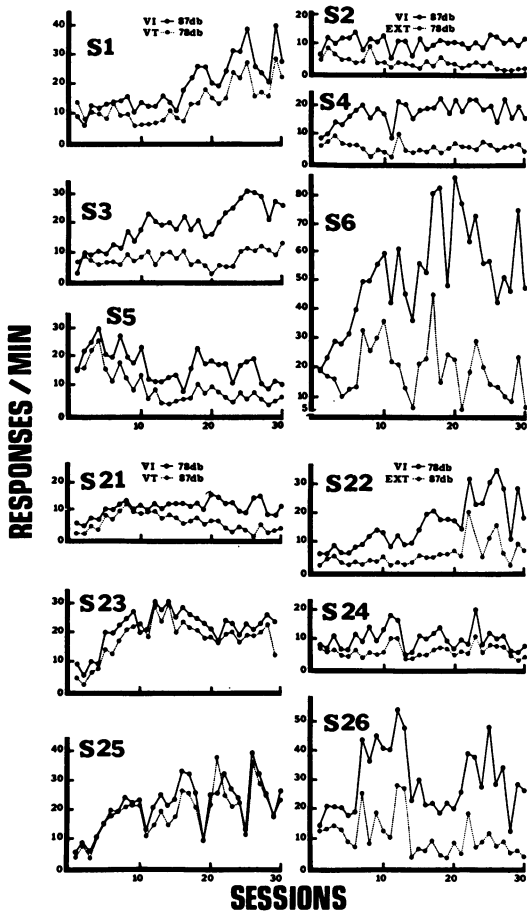


Fig. 1. Response-rate differentiation during *mult VI VT* or *mult VI EXT*.

throughout. A stable difference in rates of responding associated with the VI and VT components was obtained by about the tenth session with S1. With the stimuli reversed, only S21 showed a stable difference in responding to the two stimuli. There was a small unreliable difference for S23 and none for S25.

The right side of Figure 1 shows response rates for rats trained on *mult VI EXT*. A stable difference in rate of responding during the VI and EXT components was obtained by about the fifth session with S2, S4, and S6. With the stimuli reversed, differential responding occurred with S22 and S26, but not as strongly with S24.

Results of the generalization tests following *mult VI VT* are shown in Figure 2. Eleven of the 12 rats (the exception was S25) showed clear evidence of peak shift. The gradients rose beyond the value of the stimulus pre-

viously correlated with VI to a point of maximum responding in a direction away from the stimulus correlated with either VT or EXT. Thus, peak shift appeared in both multiple schedule conditions.

Figure 2 also shows a secondary peak midway between training stimuli in five of six rats trained on *mult VI VT*. This peak did not occur following the *mult VI EXT* schedule. To determine whether peak shift and the secondary peak occurred simultaneously or at different times during the test phase, the gradients were analyzed by blocks of test trials. Figure 3 shows the total number of responses to each test stimulus for each of several blocks of stimulus series for each rat trained on *mult VI VT*. Both the peak shift and the secondary peak occurred simultaneously at the beginning of testing for S1, S3, and S23. The exception was S5, which showed a flat gradient during the first two series. The temporal course of the two peaks shows that neither peak is consistently more susceptible to extinction than the other. In some rats, responding to the stimulus associated with the peak shift reached extinction first, whereas in others, both peaks extinguished simultaneously. The secondary peak did not occur for S21 at any time during testing.

Since it is not clear from Figure 3 whether or not the peak shift and the secondary peak occurred independently, the relationship between discrimination performance and the relative height of the peak shift and secondary peak was examined. If both peaks are a function of the same training variables, then the correlations between discrimination performance and the magnitude of each of the peaks should be comparable. If, on the other hand, the peaks are a function of separate training variables, there could be large differences in the values of the correlations between discrimination performance and the magnitude of each peak. A high correlation between discrimination performance and each of the peaks would indicate nonindependence, whereas a high correlation between discrimination performance and the peak shift and a low correlation between discrimination performance and the secondary peak would indicate independence between peaks.

Discrimination performance (based on the last five training sessions) was computed by dividing rate of responding during the VI

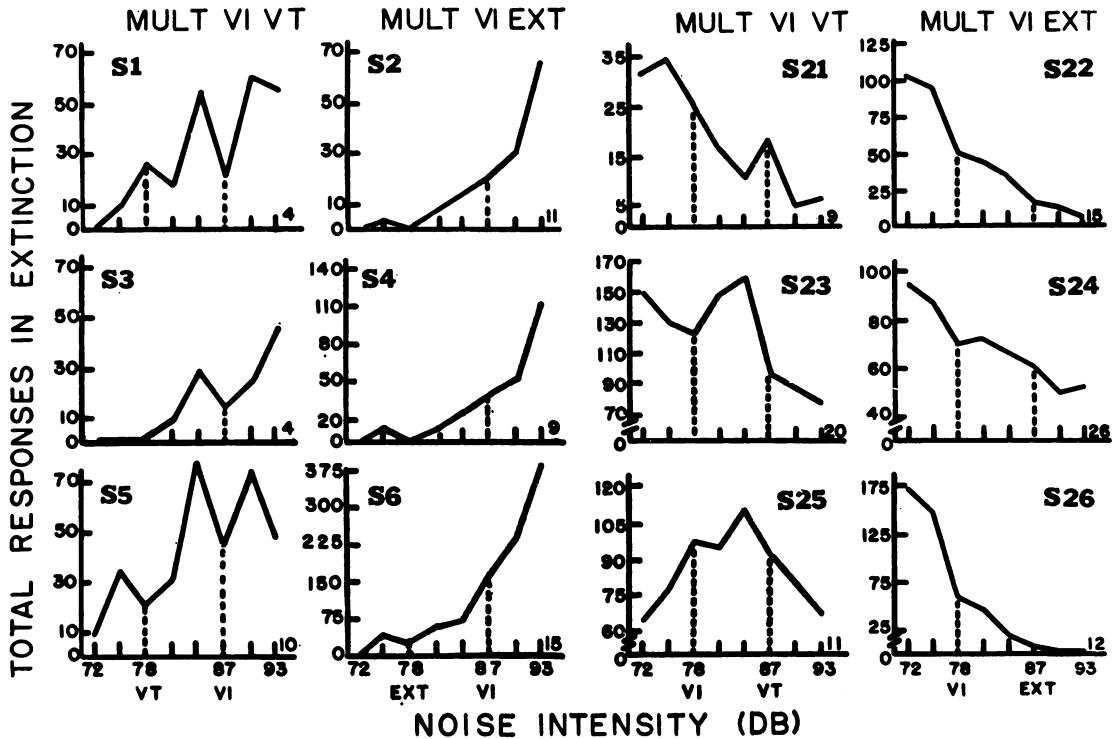


Fig. 2. Postdiscrimination noise-intensity generalization gradients following training on *mult VI VT* or *mult VI EXT*. The number in the lower-right corner of each graph indicates the number of stimulus series completed during testing.

component into the rate of responding during VT for *mult VI VT* and EXT for *mult VI EXT*. The discrimination index was then correlated with the per cent total responses in the region of the secondary peak (81 and 84 dB) or per cent total responses in the region of the peak shift (either 90 and 93 dB or 72 and 75 dB). The correlation coefficient (Pearson r) for discrimination performance and peak shift was $r = 0.96$, $df = 5$, $p < 0.01$ for *mult VI EXT* and $r = 0.68$, $df = 5$, $p < 0.05$ for *mult VI VT*. The correlation coefficient for discrimination performance and the secondary peak was $r = 0.31$, $df = 4$, $p > 0.05$. The low correlation between discrimination performance and the secondary peak occurred because per cent total responses in the region of the secondary peak varied only between 30% and 32% for five rats, regardless of differences in discrimination performance.

DISCUSSION

The results supported earlier findings that response-rate differentiation occurred at a slower rate when rats were trained on *mult*

VI VT, compared to training on *mult VI EXT* (Boakes, 1973).

Previous studies (Lattal and Maxey, 1971; Weisman and Ramsden, 1973; Wilkie, 1972) have shown that prolonged nondifferential training on *mult VI VI* before switching to *mult VI VT* maintained substantial responding during the VT component. Although nondifferential training was not given in the present experiment, a comparable substantial rate of responding was observed during the VT component. This suggests that a prolonged history of nondifferential reinforcement before training on *mult VI VT* is not responsible for the substantial rates obtained during the VT component of *mult VI VT*.

The present results showed that peak shift followed discrimination training on both *mult VI VT* and *mult VI VT EXT* schedules. The occurrence of peak shift following training on *mult VI VT* supports earlier findings (Terrace, 1968; Weisman, 1969; Yarczower, Dickson, and Gollub, 1966) that a reduction in rate of responding without a reduction in reinforcement frequency is a sufficient condition for peak shift.

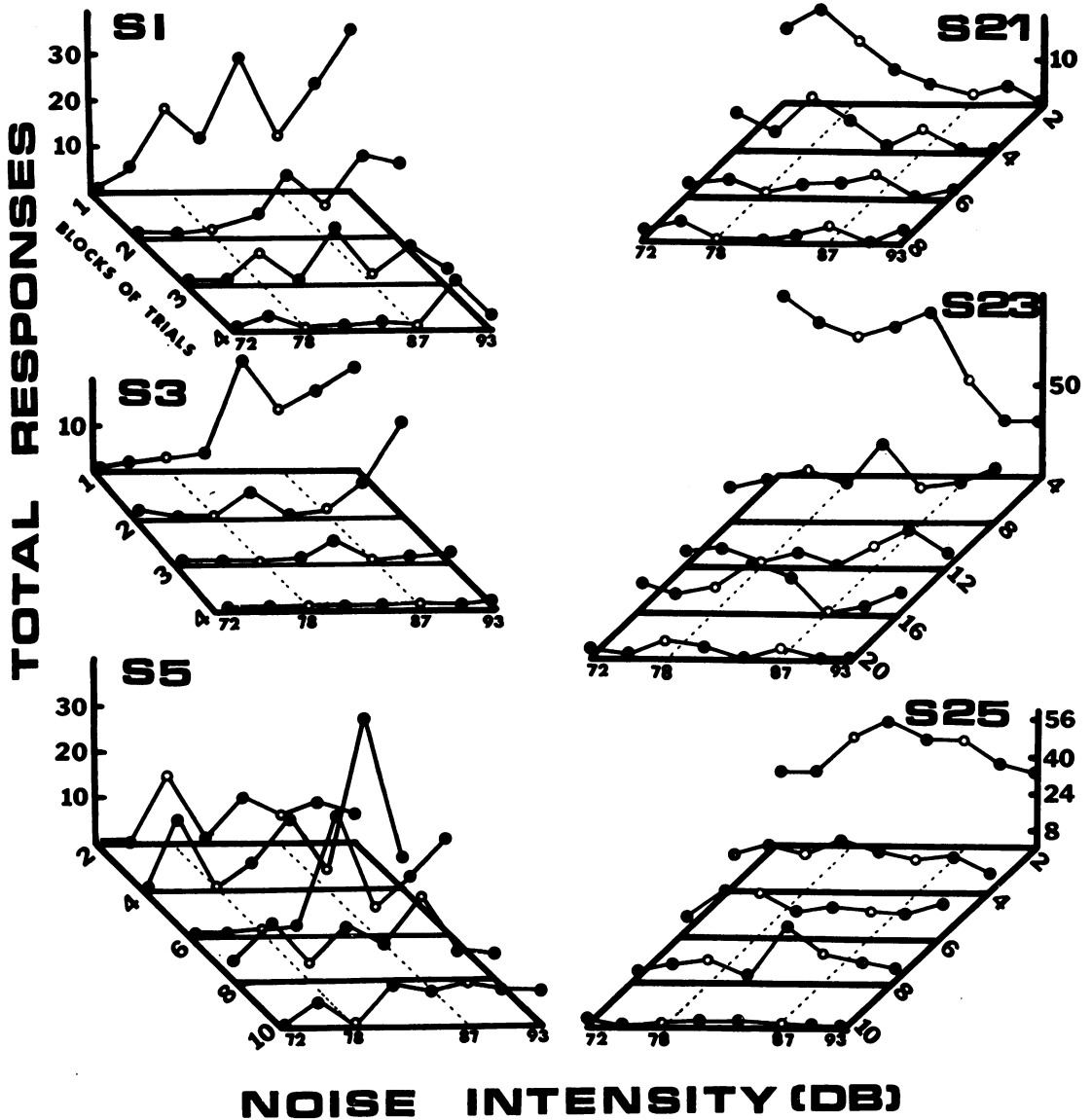


Fig. 3. Blocks of generalization test trials for rats trained on *mult VI VT*.

The shape of the generalization gradients following *mult VI VT* were dissimilar to gradients following *mult VI EXT*, in that a secondary peak occurred in five of six gradients at a point between stimulus values correlated with VI and VT. The increase in responding at a point between training values suggests two possibilities: (1) a preference in rats for a region on the noise continuum at 84 dB or (2) summation of excitatory control associated with the stimuli correlated with VI and VT during training. A preference in rats for 84 dB is less likely, in that the number of responses

represented in the secondary peak was high relative to the total number of responses emitted during generalization testing. It is unlikely that a preference could account for that much variability in responding. In tests for stimulus intensity effects, Blue, Sherman, and Pierrel (1971) using a 4-KHz tone, and Thomas and Setzer (1972) using a 1-KHz tone, found no indication of a consistent preference for intensity values in the region of 84 dB. In addition, the block-by-block analysis of the gradients revealed that for four of five rats that showed the secondary peak, the maximum of the peak

varied in location from beginning to end of testing. This suggested no preference for a given stimulus value.

A primary question regarding the simultaneous occurrence of the two separate peaks is whether or not they are independent. The results indicate that they are, in that discrimination performance was highly correlated with the peak shift, but not with the secondary peak. The independence of discrimination performance and the secondary peak were clear in S25, which showed no differential responding and no peak shift but did show the secondary peak. It is also clear from the breakdown of test trials into blocks, that the secondary peak did not emerge during testing but, like peak shift, was present throughout testing. This rules out the possibility that the secondary peak was a transitory effect related to the peak shift and indicates that the secondary peak followed directly from *mult* VI VT training.

Summation effects have been found following training on *mult* VI VT schedules (Kalish and Guttman, 1957, 1959). They consisted of an elevation in responding to stimuli lying between the training stimuli; however, a secondary peak like that of the present experiment has not been reported previously. If the secondary peak represents gradient summation, it is a larger effect than that observed previously.

Use of the VT schedule as a component in *mult* VI VT was a sufficient condition for the production of separately controlled and otherwise antagonistic generalization phenomena. The VT schedule makes it possible to reduce overall rate of responding without lowering rate of reinforcement. Therefore, it is possible to control behavioral effects based on reduction in rate of responding while simultaneously and independently controlling effects based on rate of reinforcement. The simultaneous operation of the peak shift, which is associated with inhibitory control (Terrace, 1972), and the secondary peak, which in the present experiment appeared to be a gradient summation effect, indicates that inhibitory and excitatory processes can function simultaneously and independently within a single organism trained on *mult* VI VT.

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