RESPONSE PATTERNING DURING STIMULUS GENERALIZATION IN THE RAT¹

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Nine rats were trained to bar press in the presence of a clicking sound of 6.67 cps (S^D) for 1-min variable-interval food reinforcement randomly alternated with a clicking sound of 20 cps (S^A) signifying extinction. After a criterion of 90% of total responses in the presence of the S^D was obtained, a generalization test was administered, including values of 6.67, 10.00, 13.33, and 20.00 cps, with responses in the presence of the S^D continuing to be reinforced during testing. The test yielded a gradient of response strength with rate highest in the presence of the S^D and decreasing with increasing distance from this value. An inter-response time (IRT) analysis of responding during generalization testing revealed no systematic differences in modal IRT category or in median IRT to the different test stimuli. Mean IRT was lowest in the presence of the S^D and increased systematically with increasing distance from this value, supporting the hypothesis that the generalization gradient of response rate is primarily the result of an increasing proportion of "long" IRT responses to stimuli increasingly distant from the S^D .

Two recent studies have explored inter-response time (IRT) distributions of key pecking in pigeons during stimulus generalization testing following variable-interval training. Both Blough (1963) and Sewell and Kendall (1965) have reported essentially the same finding, *i.e.*, the response pattern remains remarkably uniform with most responses occurring in the same narrowly defined IRT category despite large differences in rate of responding in the presence of the various generalization test stimuli.

In analyzing IRTs in generalization with pigeons, Blough (1963) suggested that those responses which follow long IRTs (and are subject to change in relative frequency with stimuli) are under external (exteroceptive) stimulus control. Those responses following short IRTs are presumed to be primarily under the control of proprioceptive feedback from the preceding response.

The studies by Blough (1963) and Sewell and Kendall (1965) employed the key-pecking response in pigeons, single stimulus training, and a visual stimulus which was then varied in extinction. To assess the generality of their findings, the present study utilized the bar-pressing response in rats, auditory rather than visual stimuli in a discrimination training procedure, and generalization testing under the condition of continued reinforcement of responses in the presence of the positive stimulus (S^D).

METHOD

Subjects

Nine experimentally naive female rats of the Holzman strain, approximately 90 days old at the outset of training, were maintained at 85% of their free-feeding weights, which ranged between 250 and 290 g. They were fed at the same time every day and water was always available in the home cage.

Apparatus

Five different operant conditioning chambers for rats were used. Two were manufactured by Grason-Stadler, Inc., and the three others were copies of them. All five chambers were enclosed in sound-treated, light-proof chests located in a darkened room. Exhaust

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fans in the chests, as well as white noise transmitted through loud speakers located in the chests, masked laboratory and electronic noises. A Grason-Stadler white noise generator was used.

Each chamber was illuminated by a shaded 10-w bulb and contained a 2-in. wide lever located 2 in. above either the right or left side of a 1 $\frac{3}{4}$ cu in. food magazine. The lever protruded 1 $\frac{1}{4}$ in. from the front panels and required approximately 7 g of pressure to activate. Noyes food pellets, weighing 0.045 g, were used as reinforcers and dispensed by Gerbrands or Foringer rotary pellet feeders.

Procedure

On the first day of training, after approximately 30 min of magazine and lever-press training, the rats were subjected to the first of two consecutive daily 1-hr sessions of continuous reinforcement. Next, they were placed on a variable-interval schedule with a mean interreinforcement interval of 1 min (VI 1-min); each daily session lasted approximately 1.5 hr. For the first two VI 1-min sessions, an auditory stimulus, a clicking sound with a frequency of 6.67 clicks per sec (cps), was introduced into each experimental chamber. The click was generated by activating a 24-v d.c. solenoid relay with an electronic timer. The white noise continued during these training sessions, but the click was clearly audible.

Discrimination training began with the third variable-interval session. During this and subsequent sessions, two stimuli (6.67 and 20 cps) were scheduled in random order for periods of 5 min each. Responses were reinforced on the VI 1-min schedule in the presence of the 6.67-cps stimulus (S^D) but lever pressing was extinguished when the 20-cps stimulus (S^A) was present. A 2-sec blackout was provided between stimulus periods, during which the clicker and white noise stopped and the light went off. The blackout, serving as a cue to indicate a possible change in stimulus condition, interrupted the response chain, thus preventing a carryover of responding from one stimulus condition to the next.

Since a response might be secondarily reinforced if it occurred just before onset of an S^D period, a 5-sec non-response contingency was also introduced at the end of each S^A period. If an animal made a response during the last 5 sec of an S^A period, the onset of the

blackout was delayed an additional 5 sec. Each stimulus was presented the same number of times during a training session; however, the S^A periods were initially longer due to the non-response contingency.

Because discrimination performance was invariably poor at the beginning of each daily session (regardless of the stage of training), the first 20-min period was considered as "warm-up". These data were excluded from the computation of the discrimination index, which was the percentage of total responses in S^D . The criterion required that at least 90% of total responses be made during S^D periods on each of two successive days. The nine rats met the criterion in a mean of 18 sessions (range 16 to 21). A stimulus generalization test was administered on the day after the criterion was attained. After 20 min of regular training with the S^D and S^A , four auditory stimuli [6.67 cps (S^D), 10 cps, 13.33 cps, and 20 cps (S^A)] were each presented twice for 5-min periods in random order. During the test, responses emitted in the presence of the S^D continued to be reinforced according to the VI 1-min schedule; all other responses were extinguished. The test session, including the 20-min warm-up, lasted 1 hr. As in training, 2-sec blackouts intervened between stimulus presentations.

During the test, the number of responses in each 5-min test period was recorded on Gerbrands or Scientific Prototype cumulative recorders, on electronic impulse counters, and on an Esterline Angus event recorder with a chart drive speed of 12 in. per min.

RESULTS

Figure 1 illustrates the relative grouped frequency distribution of IRTs for each rat under each stimulus condition except 20 cps (S^A); responding in the presence of this value was so infrequent that the data were deleted from the analysis. The 21 IRT categories employed were 5 sec wide and extended from 0 to 0.5 sec up to 9.5 to 10 sec, plus a final category into which all IRTs greater than 10 sec were placed. In agreement with the data reported for pigeons, the rats failed to show a progressive increase in modal IRT category with stimuli increasingly removed from the S^D ; instead, they showed only a progressive increase in the greater than 10-sec category.

Fig. 1. Interresponse time distributions during generalization testing for each of the nine rats.

Rats A, B, D, G, H, and I showed relatively narrow IRT distributions, *i.e.*, a high proportion of responses in the same IRT category. On the other hand, Rats C and F showed no clearly defined mode other than that in the greater than 10-sec category. Only in the case of Rat D was there evidence of a systematic difference in modal IRT category with stimuli. For Rats A, B, G, H, the mode of responding (except for responses of greater than 10-sec IRT) occurred in the same category for all generalization test stimuli.

For each rat the frequency distribution of IRTs obtained under each stimulus condition presented during the generalization test was analyzed to obtain both the mean and the median IRT for each stimulus. Group means of these individual mean and median IRT scores were then computed for each stimulus, again with the exception of 20 cps. The results are presented in Fig. 2. The data sum-

marized by Fig. 2 were also subjected to an analysis of variance.

Since mean IRT is inversely proportional to response rate, a gradient was expected with this measure. Mean IRT is subject to inflation due to the positively skewed distribution of IRTs; to the degree that the typically obtained gradient of response rate is a function of the distribution across stimuli of occasional long IRTs, the median IRT across stimuli may show no gradient at all. As Fig. 2 indicates, this is precisely what occurred. The effect of occasional long IRTs was to increase the mean IRT to all stimuli, but particularly for stimuli increasingly distant from the S^D . The differences attributable to stimuli are significant with means [$F(1, 16) = 19.27, p < 0.01$], but not with medians [$F(1, 16) < 1$]; means (across stimuli) are significantly higher than medians [$F(1, 16) = 62.85, p < 0.01$], and the interaction between IRT measure and

Fig. 2. A comparison of mean and median measures of interresponse time during stimulus generalization.

stimuli is also significant [$F(2, 16) = 14.37$, $p < 0.01$]. This analysis provides statistical support for the contention that the response rate gradient of stimulus generalization is largely (if not entirely) a function of the differing proportion of long IRT responses in the presence of the different test stimuli.

DISCUSSION

The present results confirm those reported earlier with the key-pecking response in pigeons. Despite changes in species, response, stimulus dimension, training condition, and testing condition, the finding remains that the generalization decrement in response rate re-

sults mainly from a systematic increase in the relative frequency of long IRT responses with stimuli increasingly distant from the S^D .

In some of the rats in this study, the modal IRT was sufficiently short (*i.e.*, less than 0.5 sec) that the hypothesis that these responses are under the control of the proprioceptive feedback from the preceding bar press seems tenable. When the modal IRT is somewhat longer, *e.g.*, 3 or 4 sec, it seems more probable that collateral behavior intervening between these more widely spaced bar presses provides the proprioceptive stimulus for further responding. Unfortunately, observations of the rat's behavior which might reveal such collateral responses were not made, and this interpretation remains entirely speculative. Regardless of the mechanism which may account for the observed temporal patterning, studies which differ so widely in species of subject, type of response, training and testing condition, *etc.*, still yield modal or median IRTs independent of response-rate differences in generalization. This fact clearly demonstrates the need to consider the influence of unvarying characteristics of the response pattern on measures of exteroceptive stimulus control.

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