

Stimulus control of counting-like behavior in rats*

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Four rats were trained to emit a run of three to four responses in the presence of one S^D and a run of more than 10 responses in the presence of a second S^D . Well-separated relative frequency distributions of run lengths in the presence of each of the stimuli demonstrated that the rats were capable of making this discrimination of amounts of their own behavior.

It has been demonstrated that animal Ss are able to discriminate amounts of their own behavior with convincing accuracy. In one procedure (Pliskoff & Goldiamond, 1966; Rilling & McDiarmid, 1965), pigeons, after making a sequence of responses on one key, were able to select the correct one of two additional keys according to whether the initial sequence of responses had been long or short. In another type of procedure (e.g., Hurwitz, 1962; Mechner, 1958; Millenson, 1966), Ss were able to produce a sequence of responses of some criterion length on one manipulandum before making a response to a second manipulandum to signal the end of the sequence. This procedure has been shown to yield a distribution of run lengths, the mode of which closely approximates the criterion run length.

The present study, similar to those of Schaeffer (1963) with a monkey, and Levison & Findley (1967) with baboons, sought to extend the findings of the latter procedure by showing that rats can make the further discrimination of amounts of their own behavior by producing a sequence of responses of one length or another dependent on the presence of an appropriate discriminative stimulus. Brief, response-dependent S^D s were chosen to provide clear feedback for response instances and in an attempt to prevent habituation.

SUBJECTS

Four female Long-Evans rats were about 300 days old at the start of the experiment. Their experimental history consisted exclusively of schedules requiring response runs similar to those described below. These schedules did not require the discrimination of external stimuli other than the discriminative stimulus for reinforcement. The rats normally

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received no water except that earned in the 90-min experimental sessions, but on days when they were not run they received 1 h access to water. Purina Lab Chow was continuously available in the home cages and in the experimental chamber.

APPARATUS

A standard Campden Instruments two-lever chamber was modified by mounting two relays on the outside wall, above the levers, to provide experimental stimuli. A force of 10 g was needed to operate the levers, which were located on either side of the 5 x 5 cm Plexiglas door to the reinforcement tray. The rats had access to water, only while the pump was working, by pushing open the door and licking through the hole. For as long as the pump operated, 2 sec, a 16-W bulb behind the reinforcement tray was lit and the 16-W overhead houselight was off. The chamber was housed in a sound-attenuating cubicle, and a fan provided ventilation and masking noise.

PROCEDURE

All the rats were accustomed to

making a "response run" for reinforcement, the response run consisting of a minimum number of consecutive presses on the right lever, followed by one press on the left lever. The sequence of experimental conditions tested in the present experiment is given in Table 1. Initially, the animals received from 10 to 12 sessions during which reinforcements could only be obtained after runs of eight or more right leverpresses. A "run" or "run length" is defined as a number of consecutive right leverpresses followed by a left one. Following a criterion run length on the right lever, a press on the left lever turned on the reinforcer and reset the right lever count to zero. Premature presses on the left lever reset the count without delivering the reinforcer. This reset contingency was in effect throughout the experiment. During this stage of training every right leverpress operated one of the relays inside the chamber for .1 sec, producing a "click."

When performance had stabilized on the single run length requirement, reinforcements were delivered either for run lengths of 3 or 4 or for run lengths greater than 10, depending on whether right leverpresses produced the click or a buzz. This procedure can be described as a two-component multiple schedule: during the "brief run" component, each right leverpress produced a buzz, and only run lengths of 3-4 ("brief runs") were reinforced; during the "long run" component, each right leverpress produced a click, and only run lengths greater than 10 ("long runs") were reinforced.

In the first exposure to this multiple

Table 1
Relative Frequency of Correct (Reinforced) Run Lengths in Each Condition

	Rat 1		Rat 2		Rat 3		Rat 4	
	BR	LR	BR	LR	BR	LR	BR	LR
1 Multiple schedule: components = 13 BRs, 6-8 sessions, last three shown	.58	.17	.39	.30	.44	.63	.28	.41
	.57	.21	.38	.36	.39	.79	.36	.20
	.73	.29	.62	.40	.42	.67	.49	.25
2 Probe: S^D s removed or reversed, 1 session	.28	.06	.35	.23	.21	.10	—	—
3 Multiple schedule: components = 13 BRs, 2-3 sessions, first session shown	.48	.15	.35	.16	.29	.31	.48	.35
4 Multiple schedule: components = 5 or 3 BRs, 4-5 sessions, last three shown	.48	.39	.42	.39	.36	.51	.50	.50
	.43	.28	.29	.29	.54	.44	.42	.58
	.58	.43	.36	.33	.38	.53	.52	.31
5 Multiple schedule: components = 1, 2 or 3 BRs, 4 sessions	.69	.55	.36	.44	.52	.73	.58	.67
	0	0*	.32	.22	.48	.67	.44	.33
	.54	.42	.17†	.41	.49	.56	.57	.46
	.38	.83	.33	.37	.48	.58	.63	.75

*Rat 1 made no responses during this session. He was as active as usual and went immediately to the magazine on presentation of free water but did not press either lever.

†Rat 2 made 56% single alternations during this session when the BR S^D was on, a phenomenon not present before or after this session.

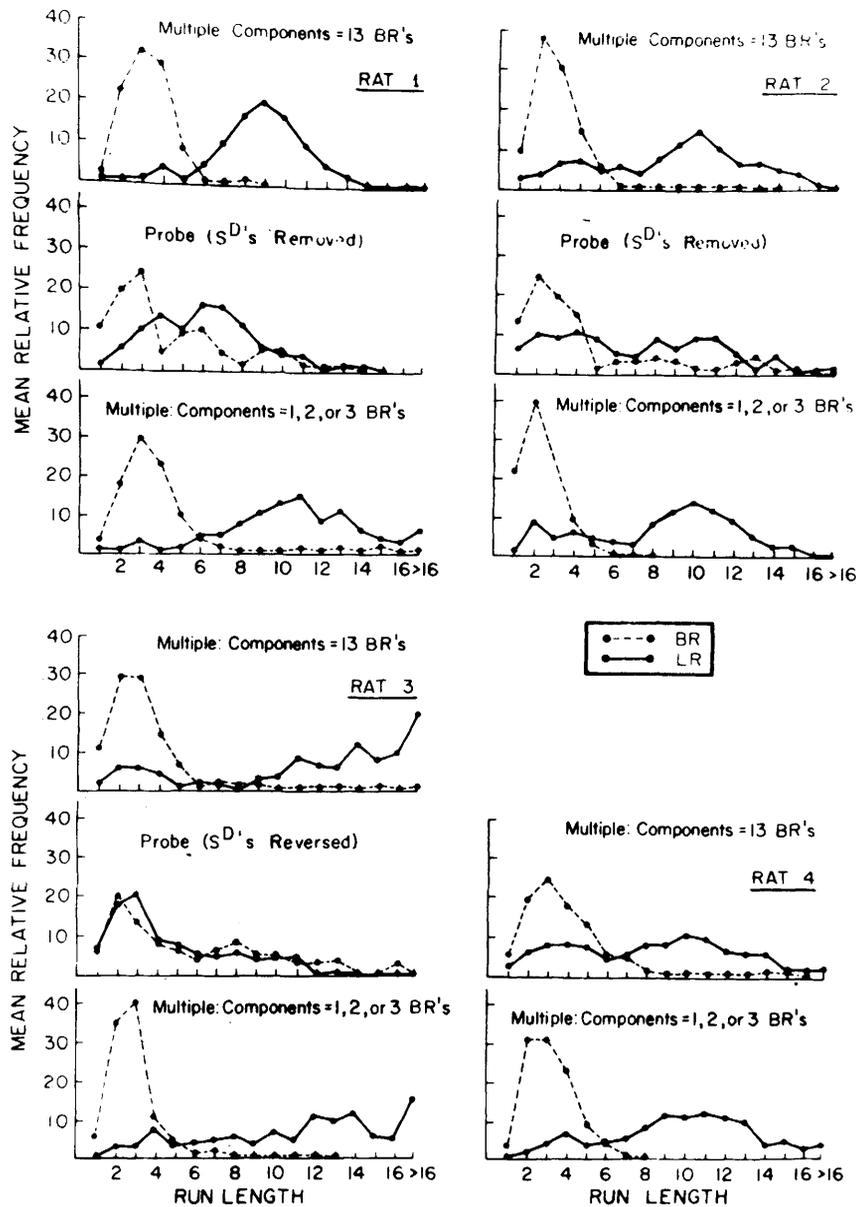


Fig. 1. Relative frequency of runs of length 1-16 under long run (LR) and brief run (BR) requirements.

schedule, the components alternated after every 13th reinforcement. After six to eight sessions, Rats 1, 2, and 3 were given a single probe session to test the effects of removing or reversing the response-produced click and buzz. For Rats 1 and 2, these stimuli were withheld during the probe session, and for Rat 3, the stimuli were reversed, so that right leverpresses produced the buzz in the "long run" component and the click in the "brief run" component. Rat 4 did not receive a probe session, and the other animals were returned to the original multiple schedule after the probe. Training on the multiple schedule was then continued, and the component length was reduced by using a

26-reinforcement cycle containing four 5-reinforcement components (homogeneous run-length requirements) and two 3-reinforcement components. The sequence of "correct" (reinforced) long runs (LRs) and brief runs (BRs) in this cycle was: 5 LR, 5 LR, 5 BR, 3 LR, 3 BR. Finally, a random sequence of alternation between the two components was initiated. The cycle of "correct" runs was: 2 LR, 1 BR, 2 LR, 3 BR, 2 LR, 3 BR, 1 BR, 3 LR, 2 BR, 2 LR, 1 BR, 2 LR, 1 BR.

Throughout the experiment the number of runs of each length between 1 and 16 were measured every session, and a separate

distribution was taken for each component of the multiple schedule.

RESULTS

During a typical session, the rats received about 75-100 reinforcements for about 1,500 responses on the right lever. Data were recorded on counters yielding the number of runs of each length in the presence of each S^D ; a sequential analysis of runs was, therefore, not permitted.

Figure 1 shows the relative frequency of runs of each length for each rat. The upper segment for each rat shows the performance when the run requirement alternated after 13 reinforcements. The two distributions are well separated for each rat, with the mode occurring at or near the reinforced length. Table 1 shows the relative frequency of correct runs for each condition, with Row 1 showing the 13 BR condition. In the final session of this condition, no rat made fewer than 42% correct runs when the brief run requirement was in effect. When the long run requirement was in effect, all rats made at least 25% runs of the reinforced length; and the modal run length was at least nine. In general, the details of performance are better represented in the figure than in the table, as the degree of error of incorrect runs can be seen in the figure.

During the probe session, given three of the rats, there is a marked drop in the proportion of reinforced runs, as shown in Row 2 of Table 1. The middle portion of Fig. 1 for Rats 1, 2, and 3 shows the degree to which the distribution of run lengths overlap when the S^D s are moved (Rats 1 and 2) or reversed (Rat 3). In general, it appears that reversal of the S^D s was more disruptive of performance than was removal of the S^D s.

The lower portion of the figure for all rats shows the distribution of run lengths during the final condition, when the two components alternated randomly and S^D s were presented. Performance during this condition was roughly as accurate as during the 13 BR condition, and the relative frequency of correct runs during the last session was at least 33% (Table 1) for every rat on every requirement. The data here do not show what characteristics stable performance under the multiple schedule would have, but it is clear that within the short exposure to the schedule, the experimental stimuli used had acquired the property of controlling the response runs of the animals. One would suppose that continued exposure to this schedule would increase the accuracy and stability of performance, but this remains to be tested.

DISCUSSION

Given the separation of the run length distributions during the final training condition and the breakdown of performance when the stimuli were absent or reversed, we may infer that the stimuli were functioning as discriminative stimuli for a further discrimination of number of responses made. This is in agreement with previous findings that have demonstrated that the amount of S's own behavior can function as a stimulus.

A pilot study in the same apparatus indicated that the critical property of the stimuli was not merely that of response feedback. Of four rats trained to emit six to seven responses on the right lever and then to switch to the left, two trained with the buzz as a feedback stimulus were no more accurate than two trained without the feedback stimulus.

Interpretations of the results in term of units of behavior (cf. Findley, 1962) are possible. The two run lengths may be considered separate units of behavior, demonstrated by the

fact that each is under the control of a different discriminative stimulus. An interpretation in terms of "counting" in rats will likely prove more semantic than empirical (Schaeffer, 1962) and "continues to demand a suitable experimental paradigm for its solution [Hurwitz, 1963, p. 454]." The present data offer no new insights into this question.

The procedure may also prove to be an alternative to previous procedures designed as direct scaling methods for subhuman Ss (e.g., Boakes, 1969; Cumming & Eckerman, 1965). After training similar to that described above, but using stimuli from some quantitative dimension, stimuli of intermediate values may produce intermediate run lengths.

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