A TECHNIQUE FOR MEASURING THE LATENCY OF A DISCRIMINATIVE OPERANT[1]

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The classical reaction time (RT) experiment with human subjects is in its simplest form a two-member chain. The first stimulus S_1^D sets the occasion for the "preparatory" response R_1, which is designed to place the subject in a position to make a response R_2 of "minimal" latency to a second stimulus S_2^D. The measured RT is between S_2^D and R_2. Instructions emphasize that the subject respond as rapidly as possible to the onset of S_2^D.

It is evident from Teichner's (1954) extensive review of the literature that in spite of the wealth of experimental data generated by RT experiments with human subjects, comparatively few quantitative generalizations can be made concerning the functional relation of RT to its controlling variables. The purpose of this paper is to describe a technique in which operant-conditioning procedures are used in order to provide a new framework for the investigation of RT. The instructional variable is eliminated; the subject's behavior is brought under stimulus control by manipulation of the appropriate reinforcement contingencies. Thus, the technique can be adapted for use with lower-animal subjects.

Recent application of operant procedures to the Békésy method for tracing human auditory thresholds (Adler & Dalland, 1959; Blough, 1958; Gourevitch, Hack, & Hawkins, 1960) has opened up a new area of research in animal psychophysics. As Sidman has pointed out (1960, p. 23), what is evolving is "a new conception of the problem of 'subjective sensation.'" Similarly, a reformulation of the classic RT experiment in terms of operant procedures should make possible a more thorough analysis of the variables of which RT is a function.

Skinner (1946), working with pigeons, and Stebbins (1960), with rats, have already described one method for measuring the latency of an operant under stimulus control. Selective reinforcement of responses occurring within a given interval following the discriminative stimulus produced stable and fairly short RT's in the experimental subjects. In both experiments, R_1 (the preparatory response) is not specified; that is, S_2^D followed S_1^D by a given interval of time, and its presentation was independent of the subject's behavior during S_1^D. Skinner (1950) has stressed the critical nature of the organism's behavior during the foreperiod in determining the latency of R_2 to S_2^D. Precise control is obtained over this behavior by making S_2^D contingent upon a specified response in S_1^D. If the response is also one which "leads in" smoothly to R_2, the result should be a decrease in RT and a decrease in the variability of the RT frequency distributions for individual subjects. In accord with the traditional RT experiment with human subjects, the following sequence should fit the requirements stated above: S_1^D ("ready" signal) ____R_1 (key depression) ____S_2^D ____R_2 (key release) ____reinforcement. In the present experiment, depression and subsequent holding of a telegraph key in the presence of a light produced a tone; release of the key during the tone was followed by reinforcement.

<center>METHOD</center>

Subjects

The subjects were four male, albino rats of Wistar stock approximately 1 year old at the beginning of the experiment. Purina Laboratory Chow was always available in the living cage, but water was supplied only as reinforcement during the experimental session. The animals worked for 2 hours daily at the same time of day throughout the experiment.

Apparatus

The experimental space was very similar to the standard Gerbrands rat box, with certain modifications. The manipulandum was a 3.75-centimeter-square stainless steel pedal attached to a Skillman telegraph key and located 2 centimeters from the grid floor. A force of 20 grams was sufficient to depress the key. A solenoid-operated dipper delivered 0.15 milliliter of water as reinforcement. A pair of neon lights with white translucent globes was located over the key. These lights served as S_1^D (the "ready" signal). A 4000-cps tone through a small speaker mounted between the lights was used as S_2^D. A 24-volt miniature lamp was mounted outside the cage and was not directly visible to the subject. It acted as a houselight, and provided illumination for the entire cage. This lamp was wired directly to the key contacts to provide additional feedback for the key press.

The programming and recording were handled by appropriate relay and timing circuits. Responses and reinforcements were recorded on counters. The RT's were recorded on a printing counter connected to a high-speed synchronous cam timer. The timer fed 20 pulses per second to the printing counter while the tone was on. Thus, RT's were measured in 20ths of a second.

Procedure

Conditioning. All subjects were trained to depress the key in the presence of S_1^D (the two neon lights). Reinforcement followed key release; approximately 200 reinforcements were obtained under this program.

Discrimination Training. Onset of S_1^D was contingent upon 27 seconds of no key pressing in its absence (dark); that is, each key press postponed S_1^D for 27 seconds. In the presence of S_1^D, a key press of at least 0.5-second duration (R_1) turned on the 4000-cps tone (S_2^D); S_1^D remained on. A key release (R_2) during both light and tone was reinforced. Following one reinforcement, both light and tone were terminated, and the sequence began again with a 27-second, response-free interval. A key press in the light of less than 0.5-second duration had no effect on the experimental conditions. Discrimination training continued until responding in the dark and responses of less than 0.5 second in the light appeared to have reached a minimal yet stable level.

Penalty Procedure. Following discrimination training, a further restriction was introduced in an attempt to extinguish key-release responses which occurred in the presence of S_1^D but prior to S_2^D. If an "anticipatory" response occurred in S_1^D, the lights were terminated and the 27-second period of no responding in the dark began again. Requirements for stable behavior were similar to those described for the preceding period of training.

Differentiation Training. At this stage the duration of the holding response necessary to produce S_2^D (tone) was increased from 0.5 second to 2 seconds (in 0.5-second steps). Responses of less than 2 seconds' duration incurred the penalty described above.

Tone-out Probe. After approximately 150 experimental sessions, it was decided to test the effectiveness of the tone (S_2^D) as a discriminative stimulus. The tone was omitted for two animals during the second hour of one standard 2-hour session. Other conditions remained the same. On the following day the tone was reinstated.

Extinction. Extinction was begun for three subjects 2 days after the tone-out probe. For two of the animals, extinction lasted for one session. For the third animal, extinction was continued for three consecutive sessions (6 hours). During extinction, water was omitted from the liquid dispenser.

RESULTS

Figure 1 shows typical RT frequency distributions for the four subjects. Although these distributions were obtained near the end of the experiment, no significant change in the RT
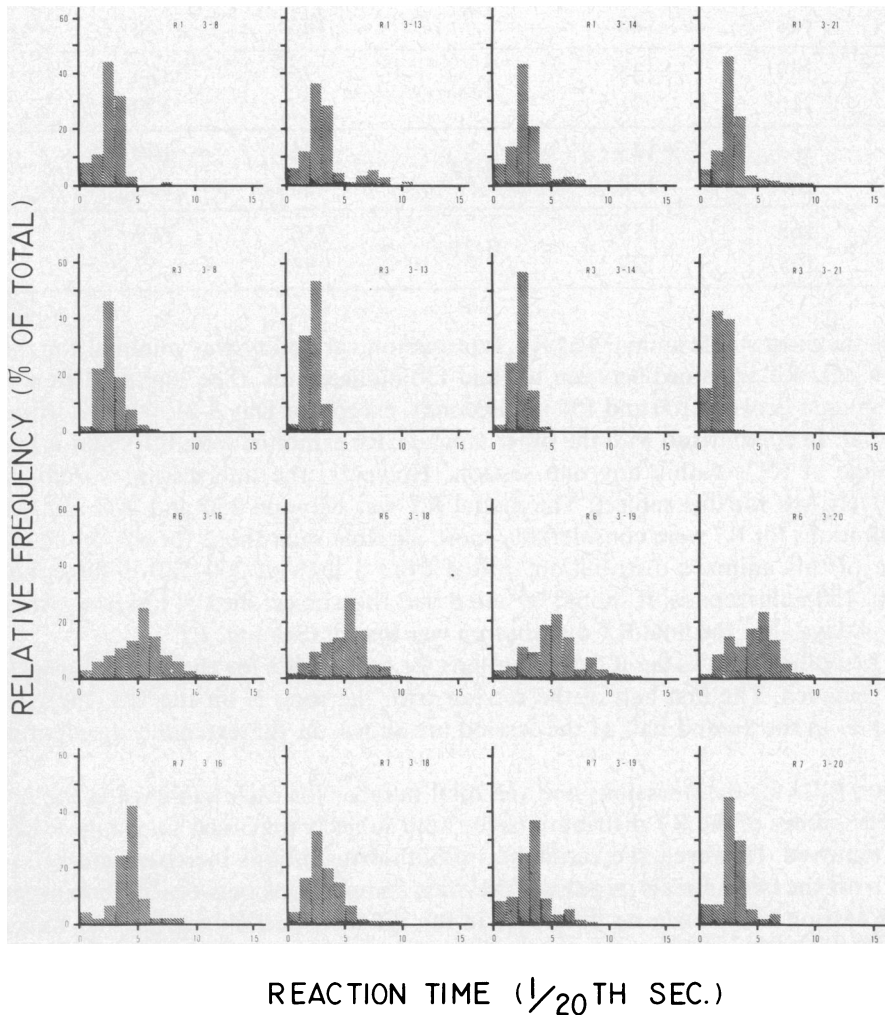

REACTION TIME ($1/20$ TH SEC.)

Figure 1. Typical reaction-time distributions for the four subjects for four 2-hour experimental sessions.

distributions had occurred since about the 10th session following the introduction of the 2-second foreperiod.[2] The size of the class interval is 0.05 second (or 50 milliseconds). Since the millisecond unit appears more frequently in RT studies, it will be used in the ensuing discussion of the data for individual subjects.

The mean RT's for each session and the total number of RT's represented in each distribution are given in Table 1.

Table 1

Mean RT's in Milliseconds (M) and Total number of RT's (N) for the Distribution in Fig. 1

	R1	R3	Date	R6	R7	Date
M	158	159	3-8	289	246	3-16
N	148	180		186	45	
M	189	135	3-13	276	184	3-18
N	116	41		195	120	
M	167	145	3-14	291	190	3-19
N	108	132		193	136	
M	168	113	3-21	256	169	3-20
N	158	129		193	57	

Perhaps the most stable animal was R1. Intersession variability was minimal for this subject. The modal RT remained between 100 and 150 milliseconds. (See Fig. 1.) The mode for R3 also centered between 100 and 150 milliseconds, except for Day 3-21, when it shifted one class interval. In comparison with the other animals, R6 exhibited long RT's and a more extended range of RT's within any one session. However, the intersession variability was comparatively low for this subject. The modal RT was between 250 and 300 milliseconds. The distributions for R7 were considerably more variable than those for the other subjects. The mode of this animal's distribution shifted from a high of 200–250 milliseconds to a low of 100–150 milliseconds. It should be noted that this subject died of unknown causes on Day 3-24, 4 days after the final RT distribution was found. (See Fig. 1.)

Figure 2 (top half) shows the RT distributions for R1 and R3 for the session in which the tone was removed. The first half of the session with the tone is on the left; the effects of tone removal in the second half of the session are shown in the extended distributions on the right.

The mean RT's for these sessions and the total number for each half-session are given in Table 2. The modes of the RT distributions for both subjects remained unchanged when the tone was removed. However, the variability of both distributions increased markedly. The mean RT's for the two animals increased. Previous comparisons between different segments of a single session had shown no difference in the RT distributions for the first half versus the second half of a session.

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[2]For several individual sessions, foreperiods of 1, 3, and 4 seconds had been used. These different foreperiods had no effect on the RT frequency distributions. Consequently, the experiment was continued with a 2-second foreperiod.
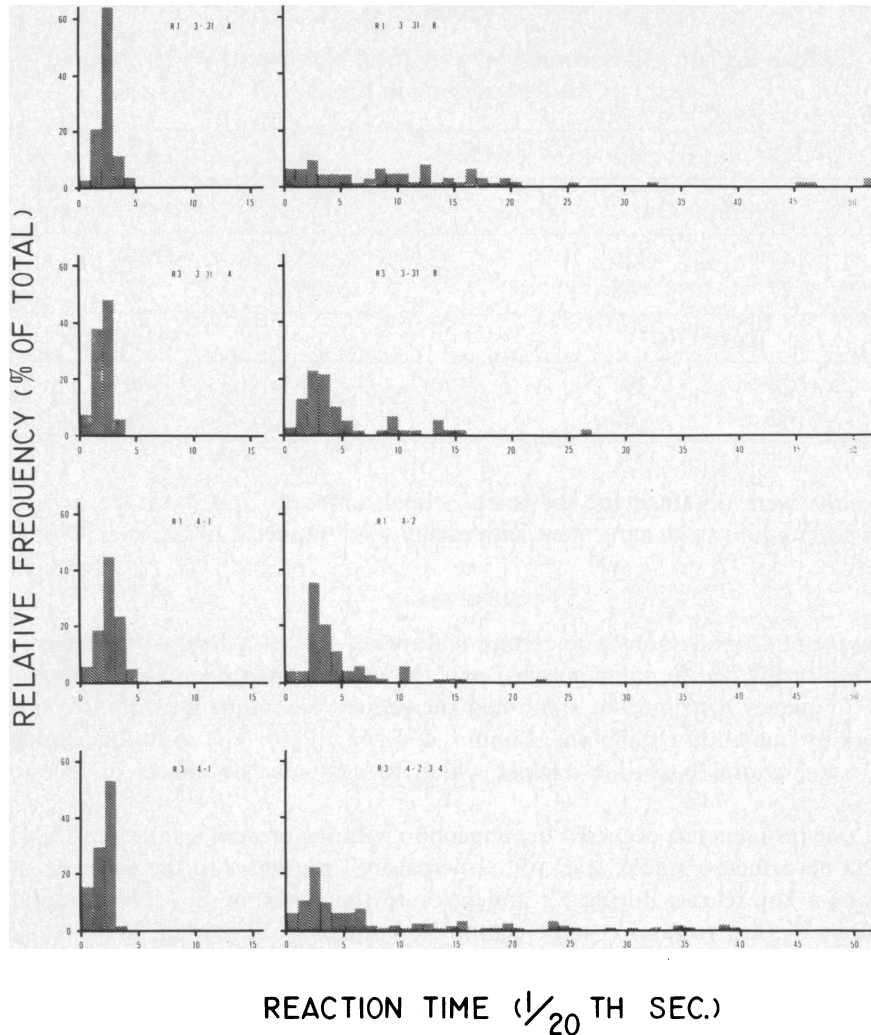
REACTION TIME ($\frac{1}{20}$ TH SEC.)

Figure 2. Reaction-time distributions for two subjects prior to and during both the tone-out probe and extinction. For further explanation, see text.

Figure 2 (bottom half) shows RT distributions for the same animals. The distributions on the left represent standard 2-hour sessions. These sessions show complete recovery from the tone-out probe, which had taken place on the preceding day. The distributions on the right give the effects of extinction which began on the following day. The distribution for R1 represents a 2-hour extinction session. The data for R3 summarize 6 hours (three consecutive 2-hour sessions) of extinction. For Subject R3, three responses (2 per cent of the total) had latencies between 2.7 and 3.2 seconds. These are not included in the distribution in Fig. 2. Means and number of responses are given in Table 2. The results are similar to those for the tone-out probe. Modal RT's for both subjects did not change. There was a corresponding increase in the mean RT's and in the variability of the RT distributions.

Table 2

Mean RT's in Milliseconds (M) and Total Number of RT's (N) for
the Distribution in Fig. 2

	R1	R3	Date	R1	R3	Date
	Pre-tone Out			Pre-extinction		
M	147	126	3-31	154	120	4-1
N	77	68		173	77	
	Tone Out			Extinction		
M	624	291	3-31	253	504	4-2
N	62	60		73	135	

Similar results were obtained for the third animal, although the data are not presented here. This finding is in strict agreement with earlier work reported by Skinner (1946, 1950).

DISCUSSION

The present findings demonstrate certain features of RT as a behavioral measure. Both the reduction in RT (in the same species) and the considerable decrease in the variability of the RT frequency distributions show that the present technique is an improvement over earlier work by one author (Stebbins, Lundin, & Lyon, 1960). The technique should prove useful as a behavioral base line against which to evaluate the effects of a number of variables.

At least one problem has occurred in connection with the present technique. This involves the low, but nevertheless stable, level of "anticipatory" responses to the tone. Anticipatory is defined as a key release during S_1^D and prior to the onset of S_2^D. The question arises as to whether R_2 (key release) is under complete control of S_2^D (tone). With a fixed fore-period, the possibility of a temporal discrimination arises. Then, the stimuli produced by the animal's own behavior during the foreperiod conceivably could control R_2. This question led to the tone-out probe. (See Fig. 2.) The data for R1 indicate that the tone was the primary, if not the only, stimulus controlling key release. The data for R3 indicate also that the tone was important; its removal produced marked changes in the frequency distributions. However, in spite of these changes, the general shape of the distribution was retained. This suggests that control of R_2 (key release) may have been shared by the tone and by response-produced stimulation during the foreperiod. Some form of joint control over R_2 is indeed a possibility, even in RT studies with human subjects. One way of eliminating a temporal discrimination during the foreperiod is the use of a variable rather than a fixed foreperiod. An experiment is now in progress in which a variable foreperiod is used. Hopefully, this will further reduce anticipatory responding and minimize the effect of response-produced cues as discriminative stimuli for release of the key.

SUMMARY

A technique is described for measuring the reaction time (RT) of the rat. The use of operant-conditioning procedures within the framework of the classic RT experiment yielded

short RT's and stable RT frequency distributions for individual animals. Water-deprived white rats were required to depress and hold down a modified telegraph key in the presence of a light. Following a 2-second foreperiod, a tone was presented. Release of the key during the tone was reinforced with a drop of water. Data are also presented for one session in which the tone was omitted and for a later session during which extinction took place.

ACKNOWLEDGEMENT

REFERENCES

Adler, H. E., and Dalland, J. I. Spectral thresholds in the starling (Sturnus vulgaris). *J. comp. physiol. Psychol.*, 1959, **52**, 438–445.

Blough, D. S. A method for obtaining psychophysical thresholds from the pigeon. *J. exp. anal. Behav.*, 1958, **1**, 31–43.

Gourevitch, G., Hack, M. H., and Hawkins, J. E. Auditory thresholds in the rat measured by an operant technique. *Science*, 1960, **131**, 1046–1047.

Sidman, M. *Tactics of scientific research.* New York: Basic Books, Inc., 1960.

Skinner, B. F. Differential reinforcement with respect to time. Abstract. *Amer. Psychol.*, 1946, **1**, 274–275.

Skinner, B. F. Are theories of learning necessary? *Psychol. Rev.*, 1950, **57**, 193–216.

Stebbins, W. C., Lundin, R. W., and Lyon, D. O. The effect of alcohol upon reaction time in the white rat. *Psychol. Rec.*, 1960, **10**, 15–19.

Teichner, W. H. Recent studies of simple reaction time. *Psychol. Bull.*, 1954, **51**, 128–149.