TEMPORAL AND INTENSIVE PROPERTIES OF HUMAN VOCAL RESPONDING UNDER A SCHEDULE OF REINFORCEMENT

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Several studies have shown that schedules of reinforcement control the rate of emission of human and subhuman operants in similar ways (Dews & Morse, 1958; Holland, 1958; Verplanck, 1956). In particular, human verbal behavior has been demonstrated to be amenable to operant control (Krasner, 1958; Lane, 1957). The present paper describes a technique for measuring some temporal and intensive properties of a vocal operant in humans, and the application of this technique to the analysis of responding on a DRL² schedule of reinforcement.

METHOD

A modification of J. G. Holland's procedure (Holland, 1957) for the study of "observing behavior" is used. A human subject is seated in a sound-attenuating cubicle in front of a panel (20 by 20 by 14 inches) on which a voltmeter is mounted. A box containing a light source is placed over the meter, and a viewing tube protrudes from the box. The following instructions are read to each subject.

You are participating in an experiment in observing behavior; your job will be to monitor this device. If you look in the viewing tube now you can see that it is dark. However, when we start the session, your voice will control a light in the viewing box: whenever you say the sound "oo" as in *boot* or *shoot*, a light will go on for a brief instant and you will be able to see a calibrated screen; on that screen there will be a needle. Now, if the needle is to the left, at about zero, the device is operating properly. But sometimes the device strays, and when you say "oo" and then look at the illuminated screen you will find the needle deflected to the right, to about 1.0. When this occurs, I would like you to introduce a correction by depressing this button, which you may hold in your hand. Please depress it as soon as you observe a deflection, and you will note that the needle will reset to zero. That, then, is your job: to check on this device as frequently as you think you need to, and to reset it when you find a deflection. I am placing this microphone on your head to implement your vocal control of the light. These earphones and noise are to simulate actual field conditions.

A Telex boom-type headset is secured to the subject's head with a crystal microphone mounted a constant distance from the subject's mouth. An oscillator supplies a masking tone to the subject's earphones. Each vocal response activates a voice-operated relay, which initiates a 1-second delay during which the experimenter may "cancel" the response if it is not the desired operant (e.g., a cough or sigh). When a response is canceled, the light in the viewing tube remains off and the inter-response time continues to cumulate. If the response is "passed," the viewing light goes on for 0.7 second, during which time the meter needle may or may not be deflected, according to the schedule of reinforcement. Deflections are introduced only when the meter is not illuminated. The subject reports a deflection by pressing the erase button. The meter needle then falls to zero and the viewing light goes out.

Every response is sent into a peak detection circuit whose output is monitored by a Sanborn graphic recorder, so that a continuous record of the intensity of vocalizing is obtained

¹This study was initiated while the author was an undergraduate at Columbia College, during the Spring of 1957. I am indebted to Dr. F. S. Keller and Mr. G. Geis for their guidance and assistance.

²Differential reinforcement of low rate (Ferster & Skinner, 1957). Under DRL, a response is reinforced only when it follows a period of no responding of at least n seconds.

(Fig. 1). Magnitude of response is taken as the peak amplitude of each response shown on the polygraph, and is measured in relative level units (RLU). It is first arranged that the extent of the pen deflection on the graphic recorder is a linear function of sound pressure at the microphone. The height of a deflection is then read from a linear scale, whose range is from zero (base-line position of pen) to fifty (maximum excursion).

Figure 1. Sample vocal-response sequence from strip chart recorder, with light-on and deflection indicated.

The subjects were three male and two female undergraduates. Each served for one session of from 30 minutes to 2 hours and under one or more DRL schedules whose values ranged from 10 to 45 seconds.

RESULTS AND DISCUSSION

Rate of Responding and Inter-response Times on DRL

During an initial session, the rate of vocal responding under a DRL schedule changes toward that which would maximize the frequency of reinforcement. Figure 2 is a cumulative vocal-response curve for one subject, ML, under a 15-second DRL. The line labeled RMR has the slope which would be generated by one response emitted every 15 seconds; this rate of responding maximizes the rate of reinforcement. The subject's rate approached but remained lower than the RMR. Figure 3 is the cumulative record of another subject, SK, on a 10-second DRL. Subject SK's rate of responding also shows a gradual approach toward the RMR. Gradual rate changes in the direction of the RMR may have an abrupt effect on the rate of reinforcement. When the number of reinforcements received under DRL is plotted cumulatively against time, the resultant function is positively accelerated. The curve for SK shows the sharpest discontinuity obtained (Fig. 4).

The data for five subjects were submitted to detailed analysis. All five (including ML and SK discussed above) generated rates of responding in the later stages of their first session on DRL which were less than the RMR (Fig. 2, 3, 7). For all five subjects, the mode of the inter-response time distribution was in the class interval just above the DRL value. Dews and Morse (1958) also report this latter finding for a human motor response under conjunctive fixed-ratio DRL schedules of reinforcement.

The sign or direction of rate changes as the rate of vocal responding approaches the RMR is a function of the prior history of the subject. Wilson and Keller (1953) and Sidman (1956)

Figure 2. Cumulative vocal-response curve for one human subject (ML) on a 15-second DRL.

found an orderly *decline* in rate when their subjects (rats) were reinforced under a DRL schedule for bar pressing. The animals in both studies had a prior history of continuous reinforcement (CRF) for bar pressing. In the Wilson and Keller experiment, the rats were placed on a 10-second DRL schedule following CRF, while in the Sidman experiment the

Figure 3. Cumulative vocal-response curve for one human subject (SK) on a 10-second DRL.

Figure 4. Reinforcements obtained by SK on a 10-second DRL, as a function of time.

sequence was CRF followed by DRL 20 seconds. Although neither study presents the inter-response time distributions for bar pressing on CRF, it may be supposed that most of the IRT's during the later stages of CRF conditioning were well below the value required by the subsequent DRL schedule. This assumption is supported by the results of a recent study by Kelleher et al. (1959). Response-probability distributions for the bar-pressing response of rats under DRL after conditioning on CRF and after conditioning on fixed-ratio schedules of reinforcement showed that the probability of a short IRT decreases whereas the probability of a long IRT increases during conditioning under the DRL member. However, if some other history of reinforcement were used (one which generated inter-response times of a value considerably greater than the subsequent DRL), or, alternatively, if the transition had been from operant level to, say, 10-second DRL, then it may be assumed that an *increase* in rate would be observed rather than a decline. That is to say, the prior history of the organism is a key determinant of the sign of the initial rate change under DRL.

Re-examination of Fig. 2 reveals that ML's rate of responding was initially lower than the RMR and increased, while SK's rate of responding (Fig. 3) was greater than the RMR and declined. Of the five subjects whose data were analyzed, three showed an increase in rate as the RMR was approached, and two a decrease. Subject ML was receiving reinforcement for almost every response throughout the early part of the session; nevertheless, a pattern of responding evolved which increased the number of reinforcements earned per unit of time. By comparison, Subject SK received no reinforcements during the first quarter of the session and only 11 reinforcements up to the last quarter of the session, when the rate decelerated and 31 reinforcements were received.

Figures 5 and 6 show the temporal differences between the first and second members of successive IRT pairs as a function of successive responses. A positive value indicates an IRT

pair in which the second IRT is smaller than its predecessor. Figure 5 plots IRT differences for ML, and Fig. 6, those for SK. It will be seen that ML, whose rate increased during acquisition, also became more regular in pace. On the other hand, SK showed an increase in variability of inter-response times concomitant with a decrease in rate. Terminally, the variability of each subject had approximately the same magnitude.

Figure 5. IRT differences as a function of successive responses for Subject ML on a 15-second DRL.

Transition from DRL of One Value to DRL of Another Value

A few subjects were run on a DRL of one value; then, during the session, the value of this DRL was changed but the subject was not informed. Figure 7 is the cumulative vocal-response curve for JL under 15-second DRL. This curve is similar in form to that obtained with SK, discussed above (Fig. 3). Initially, the rate of responding is higher than the RMR. Subsequently, the rate decreases until, terminally, it is slightly lower than the RMR. Figure 8 shows the typical effect on the cumulative-response curve of a change in the value of the DRL from 15 to 30 seconds. The subject continues for some time at the rate at which he had stabilized earlier, although no responses were reinforced. Then, the rate decreases abruptly, and a relatively stable performance ensues.

The reverse effect, an increase in rate, would presumably be observed if the schedule sequence were a 15-second DRL followed by a much shorter DRL. Since the lower limit of short DRL schedules is effectively continuous reinforcement, a DRL-CRF transition may be examined. Figure 9 is the cumulative record for ML during his first session of CRF

Figure 6. IRT differences as a function of successive responses for Subject SK on a 10-second DRL.

Figure 7. Cumulative vocal-response curve for JL on a 15-second DRL.

Figure 8. Cumulative vocal-response curve for JL on a 30-second DRL, following conditioning on 15-second DRL (Fig. 7).

Figure 9. Cumulative vocal-response curve for ML on CRF, following conditioning on a 15-second DRL.

following 32 minutes of DRL conditioning (Fig. 2). A rapid increase in rate is observed. Figure 10 shows that this subject, after accelerating abruptly, stabilizes at a fairly regular pace, so that IRT differences oscillate about zero.

We may conclude that the sign of the rate change (acceleration or deceleration) under the second member of the DRL sequence depends on the prior steady-state performance in the first member.

Figure 10. IRT differences as a function of successive responses for ML on CRF.

Duration and Magnitude of Responding

Response durations were measured and analyzed for five subjects. The variability in the duration of responses was very small—of the order of the reliability of the measurement technique; therefore, duration will not be discussed further in this paper. Figure 11 presents cumulative magnitude (in RLU) as a function of responses emitted for Subject ML under 15-second DRL. (See Fig. 2.) The data are typical of those obtained from our other subjects: cumulative magnitude does not fluctuate appreciably during the session. Nor was cumulative magnitude of responding found to change when the value of the DRL schedule was changed. It should be noted that neither the contingencies nor the schedules of reinforcement in this study were such as to selectively reinforce intensity of response.³

³However, in an experiment in which magnitude also was not explicitly reinforced, Notterman (1959) found that under CRF the mean peak force of a bar-pressing response by rats increased, whereas during extinction it decreased.

Figure 11. Cumulative magnitude as a function of cumulative responses for ML on a 15-second DRL.

SUMMARY

A technique is described for the analysis of human vocal responding under the control of schedules of reinforcement. Instrumentation for presenting reinforcements and for recording the temporal and intensive properties of responding is discussed.

Two kinds of performance in human vocal responding during the early stages of DRL conditioning are distinguished, based on whether the responding accelerates or decelerates from its initial value. In the case of a deceleration of responding, a shift in the IRT frequency distribution is observed which parallels that obtained with subhuman organisms. In both cases (acceleration and deceleration), the terminal rate of responding on DRL is found to fall short of that rate which would maximize the frequency of reinforcement. Duration and magnitude of vocal responding on DRL remained relatively constant throughout each session.

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Received January 25, 1960