THE EFFECTS OF DEPRIVATION UPON TEMPORALLY SPACED RESPONDING

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Spaced responding, or "timing," may be generated in a free-operant situation by making reinforcement contingent upon the temporal spacing of responses (5). A response produces a reinforcement only if it is emitted after a fixed interval of time has elapsed without a response. Responses that occur before the fixed interval has elapsed are not reinforced, but, rather, reset a timer which starts the timing interval over again.

Differential reinforcement of low response rates (DRL), by selective reinforcement of spaced responses, yields a characteristic frequency distribution of inter-response times (IRT's) (3, 4). Frequency distributions of IRT's typically rise gradually to a mode at about the minimum inter-response interval that is required for reinforcement, and decline gradually at longer intervals. A gradient of generalization along a temporal dimension may be described by the relative frequency distribution of IRT's shorter than the minimum interval required for reinforcement. All IRT's greater than the minimum necessary for reinforcement are reinforced. The declining frequencies of these long IRT's, therefore, are under the control of a different variable than the generalization gradient. Anger (1) has shown that the decline in frequency of long IRT's is related to the reduction which they produce in the number of reinforcements possible within a given period of time, i. e., the rate of reinforcement.

The study to be reported here is an investigation of the effects of deprivation and progressive satiation upon performance in the DRL situation.

SUBJECTS AND APPARATUS

The subjects were five adult albino rats and a rhesus monkey. During each experimental session the animals were confined in metal boxes which contained levers that closed a microswitch and activated the control and recording apparatus when depressed. A motor-driven cup delivered the liquid reinforcement at appropriate times. A 6-watt lamp illuminated the cup when it was in the raised position. White noise in the experimental room masked auditory cues from the operation of the control and recording apparatus located in a separate room.

Responses and reinforcements were recorded on electrical impulse counters, and a cumulative-response recorder provided continuous records of lever-pressing.

A system of timers and counters automatically tabulated inter-response times in class intervals of 2 seconds and primed the reinforcement circuit at appropriate times.

PROCEDURE

General Training

Each animal received 2-hour training sessions daily. Each rat was given access to water for 1/2 hour following each experimental session. A reinforcement for the rats consisted of a drop of water. Purina chow pellets were continuously available in their home cages. The monkey, whose reinforcement was 1 milliliter of sweetened orange juice, received its daily food ration of bread, chimp crackers, lettuce, banana, apple, and carrot after its experimental session. It was given no liquid other than that contained in the diet and the reinforcements of orange juice.

The animals first learned to lever-press for continuous reinforcement. Then they were trained on the timing procedure in which only those responses were reinforced which occurred after at least 20 seconds without a response. This differential reinforcement of low rates was continued until the average response rate per session and inter-response time distributions for each animal showed no consistent change from day to day.

Variation of Deprivation

In the first part of the experiment the effects of a range of deprivation periods were studied. After the daily response rates and distributions of IRT's had stabilized for Rat GF-72 and Monkey R-10, they were each given a 2-hour test session once a week. The deprivations used for Rat GF-72 were: 9.0, 15.5, 21.5, 45.5, and 69.5 hours. The monkey was deprived for 0, 3, 7, 24, and 72 hours. Both animals were given three test sessions after each of the five periods of deprivation, with the deprivation periods varied from test to test in a mixed order. Between weekly tests the animals continued to receive their daily training sessions, after 21.5 hours of deprivation, except when such a session would have occurred during the period of deprivation being tested.

Responses, reinforcements, and frequency distributions of IRT's were recorded for each test session. The three test sessions at each deprivation were summated and treated as one in analyzing the results.

Progressive Satiation

In the second part of the study a different technique of manipulating the subjects' state of deprivation was used in order to determine whether the results obtained from the preceding technique would be confirmed. The animals first were deprived for a long period of time, and then were permitted to remain in the DRL situation until the accumulation of reinforcements brought them to states progressively approaching satiation.

The subjects were Rats AC-23 and AC-25. After stable performances on the DRL were obtained, they were given 3 days (approximately 69.5 hours) of water deprivation followed by a 10-hour test session. Total responses, reinforcements, and frequency distributions of IRT's were recorded over successive 2-hour periods during the 10-hour session.

Limited Hold

In the final part of this study, "timing" behavior under more stringent conditions of reinforcement was investigated. An upper limit was imposed upon the time interval after which a response could be reinforced (2); that is, after the minimum interval had elapsed, reinforcement was possible for only a brief period of time. Responses which occurred either before the minimum interval had elapsed or after the "limited hold" had elapsed were not reinforced. All unreinforced responses reset the DRL timer, starting the timing interval again.

Rats AK-8 and AK-11 were subjects in the DRL limited-hold experiment. They were first trained in the DRL procedure with no maximum limit on the duration of IRT's reinforced. All responses which were emitted any time after 20 seconds of no-responding had elapsed were reinforced. The rats were then trained with the limited-hold contingency of reinforcement added to the DRL. At first, only IRT's between 20 and 40 seconds were reinforced. The only effect of IRT's longer or shorter than these limits was to reset the DRL timer, starting the timing interval again. The duration of the hold was then reduced by gradual steps. Rat AK-11 was eventually able to perform consistently with a limited hold of only 2 seconds. The only responses reinforced were those emitted after a pause of 20 to 22 seconds. The behavior of AK-8, however, was not maintained with a hold less than 4 seconds. When a 2-second hold was attempted, AK-8 ceased responding entirely. Therefore, this rat was tested with the 4-second limited hold. Those responses which occurred after pauses of 20 to 24 seconds were the only ones reinforced. After their limited-hold behavior stabilized, each rat was deprived of water for 3 days and then given a 10-hour test session.

RESULTS

Fig. 1. Response rates at five test periods of deprivation.

With those animals whose deprivation was varied, the response rate increases sharply at the lower deprivations, and then more slowly as the hours of deprivation increase (Fig. 1). The progressive-satiation animals, including those on the limited-hold procedure (Fig. 2 and 3), show a drop in response rate late in the session, after a large number of reinforcements had been received. Rat AC-23 showed a less marked decrease in rate. Even though this rat had accumulated over 500 reinforcements by the end of the 10-hour session, its response rate was still above 2.0 per minute. Circumstances made it unfeasible to continue the session long enough for the rat to reach complete satiation. The response rate of AK-11 is relatively constant until it ceases responding entirely after 9 hours.

The relative-frequency distributions of IRT's after each of the deprivation periods, and during the successive 2-hour periods of progressive satiation, resembled those which have been published elsewhere (e.g., 1, 3, 4). There was little change in these distributions, except at extreme satiation and at low deprivation levels.

Fig. 2. Response rates as a function of progressive satiation during a 10-hour test session.

Fig. 3. Response rates as a function of progressive satiation during a 10-hour test session on the limited-hold procedure.

Fig. 4. Inter-response time distributions at decreasing stages of progressive satiation during a 10-hour test session of limited-hold DRL. Black sections indicate reinforced inter-response times.

The IRT distributions for the limited-hold animals appear in Fig. 4, with the shaded portions of the distributions indicating the relative frequencies of reinforced IRT's. Peak frequencies occur prior to the reinforced intervals. The effect of approaching satiation takes place rapidly for both animals. The distribution of IRT's between the sixth and eighth hours of the session for AK-8, just before it ceases responding, is somewhat flattened and the frequencies of longer intervals are beginning to increase. On the other hand, the effect on AK-11's distribution of IRT's is almost missed. The peak of this animal's distribution is just beginning to deteriorate between the eighth and ninth hours of the session. The frequencies of long IRT's have increased, and short IRT's, except for those less than 2 seconds ("bursts"), have disappeared. Responding ceases completely after 8.5 hours.

A large proportion of IRT's are less than 2 seconds. Although such "bursts" of responding can also be observed in the monkey's distributions, they are much less frequent. These "bursts" are typically produced by rats, pigeons, and monkeys in the DRL situation, yet little is known to explain them adequately. There has been some indication that they are related to the timing process, since the probability of their occurrence was shown to be the highest after IRT's just short of the minimum required for reinforcement (3).

Fig. 5. The effect of deprivation upon the percentage of long and short IRT's.

The systematic changes that occurred in the IRT distributions are brought out by an analysis of the percentages of long (greater than 30 seconds) and short (less than 10 seconds) IRT's. In calculating these percentages, the IRT's less than 2 seconds were not included. Figure 5 shows that the percentage of short IRT's in GF-72's distributions remains relatively constant in the deprivation periods tested. It varies only slightly between 13 and 16 per cent. On the other hand, the percentage of long IRT's decreases sharply from 45 per cent after 9 hours' deprivation to 9 per cent after 21.5 hours' deprivation. At the two longer deprivations the percentage of long IRT's continues to decrease slightly. A similar analysis of the distributions for the monkey yields similar results.

The decreases in rates of responding are closely related to the increasing percentage of long IRT's after the short periods of deprivation. The lower response rates correlated with increases in the frequencies of long IRT's are associated with increases in the percentage of responses reinforced, even though there are fewer total reinforcements.

With the progressive-satiation animal, AC-25 (Fig. 6), the percentage of IRT's less than 10 seconds remains constant at about 9 per cent for the first 5 hours of the session, and then shows an increase to 20 per cent before the rat ceases responding. The percentages of IRT's over 30 seconds are also fairly constant, remaining under 5 per cent for the first 5 hours, but then increasing to 34 per cent

Fig. 6. The effect of progressive satiation upon the percentage of long and short IRT's.

Fig. 7. The effect of progressive satiation upon the percentage of long and short IRT's during a 10-hour test of limited-hold DRL.

before the rat ceases to respond. Rat AC-23, which did not satiate within the 10 hours, also did not show the rise in percentage of long IRT's.

Figure 7 illustrates similar trends for the limited-hold animals. The percentage of IRT's under 10 seconds remains relatively constant, under 5 per cent, for as long as lever-pressing is maintained by Rat AK-8. The long IRT's, however, increase from under 5 per cent after the first hour to nearly 24 per cent after the seventh hour, with the greatest change toward the end. For AK-11, IRT's less than 10 seconds remain under 2 per cent throughout. The long IRT's are also under 2 per cent except at the very end when they increase to 9 per cent.

SUMMARY

Five rats and a rhesus monkey were trained to space their responses at least 20 seconds apart. The performances of the monkey and one rat were tested after five periods of deprivation ranging from zero to 72 hours and 9 to 69.5 hours, respectively. Two rats received a 10-hour test session during which the accumulation of reinforcements produced satiation. Two other rats were trained to space their responses by at least 20 seconds but not more than 24 seconds. The last two animals were also tested in a 10-hour satiation session.

In all cases the major effect upon performance of manipulating deprivation in the DRL situation was observed to occur only after short deprivations or when the animals were near satiation. With greater satiation, long IRT's became more frequent and response rates dropped. Over a wide range of deprivations, little change in the performance could be detected.

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