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EXTEROCEPTIVE CONTROL OF RESPONSE UNDER DELAYED REINFORCEMENT

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Three white rats, after 50 continuous reinforcements, were exposed successively, under dim illumination, to reinforcement delays of 1, 3, 5, 7.5, 10, 15, and 20 sec, with prolonged training at the 20-sec level. Behavior was maintained at each level, and an increase in interval was accompanied by an increase in post-reinforcement pause. Subsequently, under both 20- and 30-sec delays, the animals were tested during half of each daily session to determine the effect of introducing darkness during each delay interval. The result of this stimulus "support" was to regularize and increase response rate for each animal at both interval values.

In the process of testing some new equipment in this laboratory, the authors have collected data on the effect of delayed reinforcement upon the bar-pressing response of albino rats. Some of the findings are reported here, mainly because of their bearing upon earlier reports in this field by Skinner (1938), Ferster (1953), and Dews (1960).

METHOD

Subjects

Three male albino rats (Alpha, Beta, and Gamma) served as subjects. These animals were from a Wistar strain maintained at the *Instituto Butantã.* They were about 100 days old and were experimentally naive at the start of the investigation. They were housed individually and fed a standard laboratory diet throughout the study.

Apparatus

The animals worked within a Grason-Stadler rat box of standard proportions, equipped with signal lights and two levers, only one of which was used in this study. A Brenner dipper, from the Columbia University laboratory, was fitted within the box to provide a 0.1 cc drink through an opening in the floor of the recessed area between the two levers. A Bell recorder was used to obtain cumulative records of the lever-pressing response.

Procedure

Experimentation took place during the months of July to October, 1961, on seven days a week, except for a few unavoidable lapses due to power failure and a short period of university shut-down. Food was at all times available in the home cages, but each animal was deprived of water for approximately 22.5 hr prior to experimentation, and was allowed to drink in his home cage for 30 min after each session.

In Part One of the experiment, each animal was shaped to respond to the lever and given a total of 50 reinforcements, crf. Then, in 1-hr periods of training, within a dimly-lighted response chamber, each was exposed successively to reinforcement delays of 1, 3, 5, 7.5, 10, 15, and 20 sec, in that order, with a total of 150 reinforcements at each delay. After reaching this number at the 20-sec level, it was kept at that delay value until it was clear that no systematic changes in response rate could be expected.

Throughout these steps, the arrangement of delay was basically the same as that employed by Skinner (1938, 77 ff) with rats, and by Dews (1960) with pigeons. Each bar-pressing response started a timer; at the end of the delay interval, if no further bar-pressing had occurred, the dipper mechanism was activated and the animal received a drink. Any response that occurred within the interval was effective only in re-setting the timer.

Between Parts One and Two of the experiment, one subject, Alpha, was returned to a 10-sec delay; another, Gamma, was moved up

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to 30 sec; while the third, Beta, was transferred to a reinforcement schedule of DRL 20. After several days of this, all three animals were returned to the 20-sec delay procedure in preparation for Part Two. The effects of these changes, which will not be further considered in this report, were as follows: Alpha showed a clear increase in response rate upon return to the shorter, 10-sec delay; Gamma continued to respond, but at a lower rate, when moved to a 30-sec delay; and Beta, when shifted to the DRL schedule, first moved quickly and smoothly to a high response rate before beginning the typical DRL slow-down. In agreement with the report of Dews on his pigeons, the stabilization of rate at the 20-sec delay, both before and after these changes, was achieved by each animal in a few experimental sessions.

In Part Two, two delay values were employed. A 20-sec delay was in effect for 10 days, followed by a 30-sec delay for six days more, for all three animals. The delay conditions were now altered, however, in the following way. For one half of each experimental session, each animal worked within a dimly-lighted chamber, just as he had before. For the other half of the session, however, *darkness* was in effect during each delay interval. Thus, each time that a response was made to the lever, the light in the chamber went off, and did not come on again until the period of delay was ended and the reinforcement arrived. A response that occurred in the darkness merely extended the darkness as it re-set the delay timer. The purpose of this procedure was simply to determine the effect (if any) of stimulus-correlated delays upon the maintenance of response rate. To facilitate comparison of the two conditions of delay (darkness and no-change), they were alternated from session to session in their order of presentation, with 30 min given to each condition.

RESULTS

Part One

Behavior was effectively maintained at all intervals of delay studied. The mean rates of response for each animal decreased clearly and quite steadily as the time between response and reinforcement increased (see Fig. 1). This decrease was not due merely to the inclusion of the delay periods themselves within the records; to a greater degree, it reflected, for each animal, an increase in the duration of post-reinforcement pauses. Typically, after receiving water, an animal would not return to the lever until after a period of time equal in length to, or greater than, the duration of the preceding delay. (This may be seen in the cumulative records of Fig. 2.) If more than one lever-press then occurred after this pause, the responses usually came in clusters (also to be seen in Fig. 2). There was no evidence of any timing of the sort that brought forth responding near the end of a delay interval.

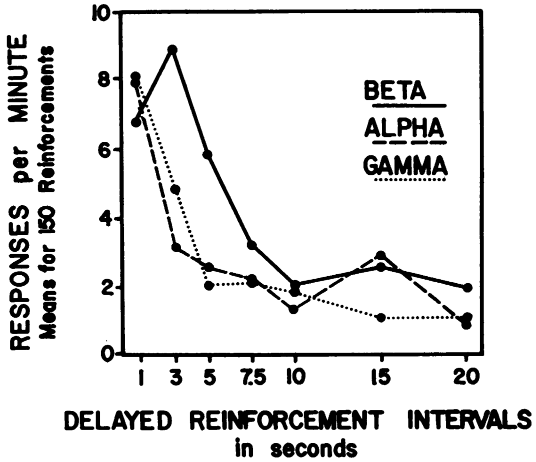

Fig. 1. Change in response rate as a funtion of increase in delay of reinforcement.

The behavior of each animal during the delay periods, as well as in the post-reinforcement breaks, can best be described as that of *active employment* in the immediate vicinity of the dipper, sometimes interrupted by a turn about the response chamber. Most frequently, after making a bar-press, the animal inserted its head within the dipper area where it seemed to remain in constant motion (licking, sniffing, or nosing the empty dipper?) until the delay ended and the water was provided.

Part Two

The introduction of darkness during the delay period, at interval values of both 20 and 30 sec, produced an appreciable effect, regularizing and increasing the response rate in all but a few instances. A reverse effect showed itself when the stimulus conditions changed in direction. This can be seen readily in the

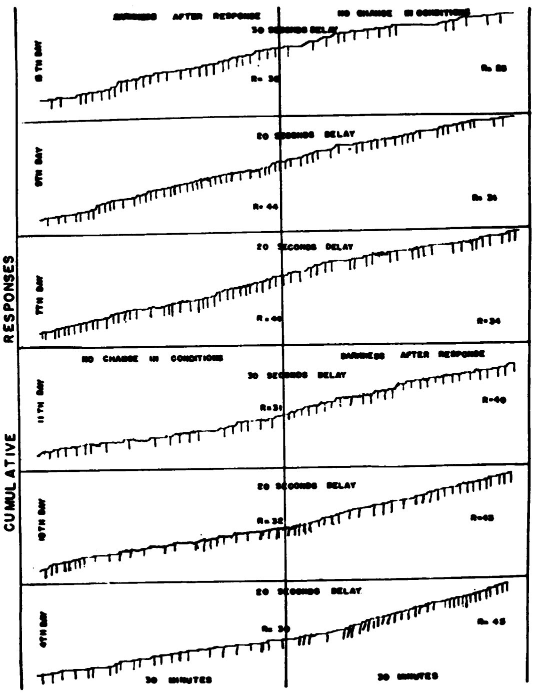

Fig. 2. Six cumulative response curves from Beta, showing the effect of adding or subtracting stimulus support during sessions of 20- or 30-sec delay of reinforcement. Response totals are indicated at the end of each half-hour record.

six records from Beta, reproduced in Fig. 2, and in the rate summary for all three rats, presented in Fig. 3. Beta's records are typical in showing the almost immediate result of introducing, or removing, the stimulus "support" during the experimental hour, despite considerable day-to-day variations in over-all response rate.

DISCUSSION

The behavior of our subjects in bridging delays of reinforcement as long as 30 sec (we did not try to extend the interval further) suggests that rats perform comparably to pigeons (Ferster, 1953; Dews, 1960), perhaps with even greater stability at the 30-sec interval (see Fig. 1 and 4, Dews 1960). We made no effort to record the mediation of this delay, as did Ferster, but observation of the animals in action after most instances of bar-pressing leads us to believe that they repeatedly engaged in some sort of dipper contact, with a regularity similar to that which typifies ratio responding. In agreement with such an interpretation, is the increase (observed in the cumulative records) in post-reinforcement break which accompanied the increase in delay requirement (see Boren, 1953, on the relation of fixed-ratio size to post-reinforcement pause). A relevant experimental question is that of the effect of *variable* delay upon this break.

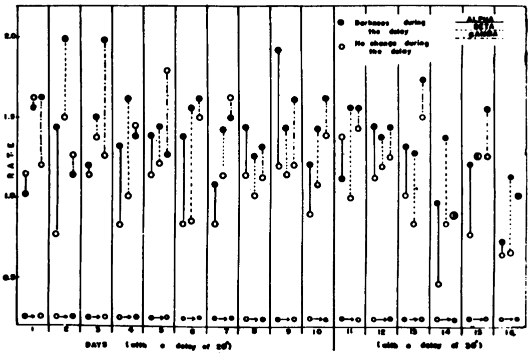

Fig. 3. Showing rate, in resp/min, with and without stimulus change during reinforcement delay, for three animals, on 16 days, with two different delay-intervals.

To account for the effect of stimulus support upon response rate in Part Two of this study, we may appeal to Ferster (1953). He suggests that, in the case of no change in exteroceptive stimulation, the reinforcement maintains bar-pressing by way of other-than-bar-pressing behavior during the delay. When there *is* a change in conditions, the bar-press is presumably reinforced immediately by the new stimulus situation (our "darkness"), which is at once an S^{Δ} for bar-pressing and an S^{D} for the occurrence of the mediating behavior (our "dipper contacts").

In connection with a recent discussion of conditioned reinforcement (Kelleher and Gollub, 1962), it may be noted that the darkness stimulation associated with reinforcement in the present study may qualify as discriminative in two conceivable ways. It may be, as suggested above, an S^{D} for (unrecorded) operant behavior; or it may also qualify as a conditioned (hence discriminative) stimulus within a delayed-reflex paradigm.

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