THE EFFECT OF ACCELERATION ON FOOD-REINFORCED DRL AND FR¹

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Performance on DRL 10 sec and FR 5 was studied after exposure to acceleration. After four rats, two on each of the above schedules, had stabilized they were exposed to 5 hr of acceleration at 5 G immediately before daily experimental sessions. Food intake was also studied in rats given access to food daily in their home cages and exposed to acceleration immediately before the free-feeding session. Weight gain of free-feeding animals and reinforcement intake of experimental animals dropped after acceleration. Over-all response rate on the FR was depressed markedly by acceleration but local response rates did not appear to be affected. IRT distributions of DRL sessions after acceleration were markedly shifted toward the long intervals. A sequential plot of IRTs on acceleration days showed an altered, but relatively stable, temporal patterning of responses followed by an abrupt return to the normal baseline toward the end of the session.

Animals can survive in a wide range of gravitational environments, but possible behavioral changes under these conditions have been only sparsely documented (*e.g.*, Briney and Wunder, 1926; Smith, Winget, and Kelly, 1959; Wunder, 1961; Wunder, Lutherer, and Dodge, 1963). Because modifications of behavioral patterns basic to the animal's maintenance are of particular importance, the effect of acceleration on two food-reinforced schedules, an FR and a DRL, was investigated.

A fixed-ratio schedule is known to produce highly stable and consistent response rates (Ferster and Skinner, 1957; Sidman, 1960). It was thus hoped that, even after acceleration, behavior could be maintained at a measurable level with this schedule. Low-rate responding on a DRL schedule has been related by some investigators to proprioceptive, or response-produced, feedback (*e.g.*, Berryman, Wagman, and Keller, 1960; Brady and Conrad, 1960; Taber, Homme, and Csanyi, 1961). Such response-produced stimuli purportedly allow the organism to discriminate the appropriate in-

terresponse period. Experimental manipulations which could disrupt or modify this feedback, such as administration of drugs, have produced alterations in performance consistent with this explanation (*e.g.*, Berryman *et al.*, 1960; Dews and Morse, 1958; Schuster and Zimmerman, 1961; Weiss and Laties, 1961). Since an altered gravitational environment might be expected to affect the proprioceptive system, the stability of such behavior after acceleration was examined.

METHOD

Subjects

Eight, 6- to 7-month-old male Long-Evans rats, experimentally naive, and averaging between 300 and 370 g at the start of the experiment were used.

Apparatus

Sessions were conducted in two Grason-Stadler rat chambers model no. 3125A. Interior dimensions were 7½ in. deep, with a floor 11⅜ by 9½ in. Access was through a side-opening door. Food was obtained through a hopper centered on one wall 5⅝ in. from each end and ¼ in. from the floor. For the DRL sessions, the animals had access to a lever, 2 in. wide and ½ in. thick, mounted on the same wall as the hopper. The lever protruded ½ in. into the cage midway between the hopper and adjacent wall at a height of 3⅛ in. The FR

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animals had access to a 1-in. diameter translucent modified Gerbrands pigeon key, mounted on the same wall as the hopper and centered between the hopper and the adjacent wall, 1½ in. from the floor. A stimulus light was approximately 1½ in. above the food hopper and response key.

Standard relay-type behavioral equipment programmed the experiments. For the FR schedule, total responses and reinforcements were recorded on counters. For the DRL schedule, IRTs were recorded on a Grason-Stadler print-out, transferred to IBM cards, and analyzed on an IBM 7090 computer.

Problems in scheduling use of the centrifuge required some animals to be accelerated on an 8-ft radius centrifuge, receiving approximately 5 G at 40 rpm, and others on a 2-ft radius centrifuge receiving 5 G at 85.5 rpm. While on the centrifuge, subjects were individually confined in small chambers, 8 in. long by 6 in. wide, covered by a perforated plastic dome 3⅝ in. high. The centrifuge cage was allowed to swing freely, enabling an automatic readjustment of position relative to the resultant G force.

Procedure

All subjects were given 2 hr access to food at the same time daily until baseline data had been collected. They were weighed before and after each 2-hr session. In all cases feeding was scheduled so that, on centrifuge days, it occurred immediately after acceleration. Food was available *ad lib* only on weekends and removed 22 hr before Monday's sessions. Subjects had continuous access to water except during acceleration.

Four animals were arbitrarily assigned to Group 1, a free-feeding group, and fed for 2 hr daily in their home cages. Their weight gains during feeding periods were collected for three weeks before acceleration as baseline data.

Two animals, C11 and C12, were assigned to Group 2 and run on DRL 10 sec. They were shaped on gradually increasing IRT requirements, from CRF to DRL 6 sec to DRL 8 sec and finally to DRL 10 sec. They continued on DRL 10 until performance was stable for five consecutive days (determined visually): 42 sessions for C11, 51 sessions for C12.

Group 3 animals, C13 and C14, were run on FR 5. They were shaped one day on CRF and then moved to FR 5 for 39 and 52 sessions,

respectively. In both Groups 2 and 3, responses were reinforced with 0.045-g Noyes' pellets.

All animals were then given eight, 5-hr sessions of acceleration at 5 G. An acceleration session occurred one day a week (referred to as centrifuge day) immediately before the daily free-feeding or experimental sessions. It was originally planned to present the acceleration sessions at one-week intervals, but sessions 3 and 7 occurred after two-week intervals for C11 and C13. All of the animals in Group 1 were accelerated on the 8-ft. radius centrifuge; Groups 2 and 3 on the 2-ft. radius centrifuge.

On each centrifuge day the animals were weighed, placed in transfer cages, and taken to the centrifuge in another building. They were then placed in centrifuge cages and slowly brought up to the 5 G level within approximately 5 min, using step increases of 1 G. Deceleration, after 5 hr, varied from 1 to 3 min. Room illumination during acceleration was normal and no extreme variation in noise level or temperature was observed. After acceleration the animals were returned to the laboratory, weighed, and given their 2-hr free-feeding or experimental sessions.

All animals received 2-hr feeding sessions for from four to six weeks after the eight acceleration exposures in order to assess their recovery.

RESULTS

Group 1

The mean weight gain of free-feeding animals for daily sessions during the eight weeks of acceleration is shown in Fig. 1. Weight gain on centrifuge days was significantly lower than on control days ($p < 0.0001$, Wilcoxin, 1949). This finding was consistent both for individual animals and for separate weeks during the acceleration phase. The mean weight gain on one day post acceleration was still significantly lower than the control day level ($p < 0.0001$, Wilcoxin, 1949). By two days post acceleration, the group had apparently returned to the normal baseline since no difference between that day and the control day was observed.

Groups 2 and 3

Figure 2 indicates the mean number of reinforcements obtained in the daily FR and DRL sessions during the eight weeks of acceleration.

Fig. 1. Mean weight gain in grams of the free-feeding group during the weeks of acceleration. Weight gain was determined by the weight gained from the beginning to the end of the daily 2-hr feeding period. The day preceding acceleration sessions is designated as a control day on the figure.

Systematically fewer reinforcements were obtained on the centrifuge day than on the control day for all animals, and also on the first and second day post acceleration for all animals except C12. Thus, with the exception of C12, all the animals appeared to have recovered within one day after acceleration.

Performance on FR 5 remained stable in one respect but changed markedly in another. Representative segments of early portions of the cumulative record for C13 on a characteristic day are shown in Fig. 3. Rate of respond-

Fig. 2. Mean number of reinforcements taken in sessions during the weeks of acceleration shown separately for the four animals in Groups 2 and 3. C11 and C12 were on DRL 10 sec, C13 and C14 were on FR 5.

Fig. 3. Initial segment of cumulative records on FR 5 for C13 from representative control and centrifuge days.

ing dropped noticeably in the session after 5 hr of acceleration as compared to the control day session. The control and centrifuge data for the other animal on this schedule paralleled the data in Fig. 3 in almost every respect.

In considering the DRL data, behavior was examined, first, by plotting proportional IRT distributions. Figure 4 shows representative normalized IRT distributions for C12 on three centrifuge days and three control days. The differences are marked. Distributions after acceleration are noticeably flattened with an increased proportion of IRTs in the last interval (20 sec or more). The data for C11 are not shown as they reveal the same effect, although the shift to the right is not as great.

Fig. 4. IRT distributions for three centrifuge and three control days for C12.

In view of this marked change in IRT distributions, the sequential characteristics of the behavior were examined. These sequential properties, obscured in frequency distributions, can be examined if IRTs are plotted consecutively. This was accomplished with the aid of an EAI data plotter to produce the sequential plots in Fig. 5, which presents consecutive IRTs on three control days for animal C12. As shown, most of the IRTs oscillated about the 10-sec value on control days, interspersed somewhat irregularly with IRTs of 40 sec and longer. Figure 6 shows sequential plots for the acceleration day sessions which followed the control day sessions of Fig. 5. The data on acceleration days differ in at least two respects from the data on control days. First, on acceleration days there was a greater frequency of IRTs at the 20-30 sec level, around which they vacillated fairly regularly. Second, there appeared to be an abrupt recovery in performance indicated by the sharp drop to

Fig. 5. Consecutive IRTs for three control days for C12. The abscissa represents consecutive responses while the ordinate indicates interresponse latency in seconds. The upper limit is 40 sec and all responses in excess of that were pooled at 40. The black line at 10 sec indicates the time above which a response was reinforced and below which it was not reinforced.

Fig. 6. Consecutive IRTs for three centrifuge days for C12.

the normal mean IRT of 10 sec toward the end of the session in Fig. 6. A similar effect was shown by C11 and consistently observed in all acceleration session data analyzed in this form.

Weight loss by each animal during acceleration sessions varied considerably. Inspection of the data failed to reveal any ordering with respect to the number of centrifuge sessions received.

DISCUSSION

The results in Fig. 1, for the free-feeding animals, are evidence that the comparable decrement in food intake shown by the experimental animals (Fig. 2) was not simply attributable to the response requirements of their reinforcement schedules.

The data for the animals on FR 5 indicate that acceleration depressed over-all response rate. Reduction in over-all rate appears to be due primarily to an increase in pauses after reinforcements. These pauses tend to be of characteristic length as indicated by Fig. 3. However, there is no indication that acceleration disrupted the integrity or rate of the five-

response unit. The detail of the cumulative response records of Fig. 3 suggests that very similar local response rates were maintained through both control and acceleration days. This suggests that local response rate on an FR 5 is not visibly altered by confining and accelerating the animal for 5 hr. Between-reinforcement pausing was apparently altered by acceleration. It resembled the effect produced from satiation on an FR schedule (Sidman and Stebbins, 1954) with the exception that, with acceleration, pauses ensue from the beginning of the session. The relationship of these pauses to the accompanying reduction in reinforcement intake should be investigated further.

An important advantage of the sequential analysis of IRTs is the amount of information to be gained on DRL behavior. While the IRT distributions on centrifuge days (see typical examples upper row in Fig. 4) show that the highest percentage of IRTs was 20 sec or longer, they also show that many responses occurred at or near the reinforcement criterion. The sequential plots (Fig. 6) reveal that this portion of the IRT distribution, at or near the reinforcement criterion, occurred mainly at the end of the session. They also show that when the normal response level was regained, variability around that value was low. Furthermore, while the IRT distributions shown in the upper row of Fig. 4 adequately indicate the higher modal response interval on acceleration days, they fail to show the orderly temporal pattern indicated in Fig. 6. Much of the performance, even though distributed about a higher-than-normal mode, is quite orderly. The variability of the early portion of the sessions is primarily due to the extremely long pauses which were a prominent feature of acceleration day sessions.

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