GROUP BEHAVIOR OF RATS UNDER SCHEDULES OF REINFORCEMENT¹

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Groups of three rats were placed in a chamber containing one response lever and one water dispenser. A variety of schedule conditions were explored including fixed ratio, extinction, satiation, fixed interval, fixed time, differential reinforcement of low rates, and discrimination learning. Each group was treated as a single unit, with the collective lever responses emitted by the three rats being the main dependent variable. Group responding was found to be controlled by the reinforcement schedules in an orderly and consistent manner. However, the groups often paused less and responded faster than individual rats working under identical conditions.

Whereas the experimental analysis of behavior has emphasized isolated organisms, in nonlaboratory environments animals often interact. The present study attempted to extend operant conditioning methods and analysis to the behavior of groups. Most experiments on group performance have been concerned with the behavior of one individual as a function of variables related to the presence of others (*e.g.*, Husband, 1931; Wheeler and Davis, 1967). When interaction was involved, it was the nature of the within-group interactions that was typically of primary interest (*e.g.*, Baron and Littman, 1961; Mowrer, 1960; Oldfield-Box, 1967). A few experiments have examined groups as units, using the collective performance of the group as the dependent variable (*e.g.*, Abel, 1937; Ader and Tatum, 1963; Allee and Masure, 1936; Antonitis and Barnes, 1961; Gates and Allee, 1933; Harless, 1972; Klopfer, 1958; Miller and Murphy, 1955). But there are no major studies in which the operant behavior of a group of co-acting

organisms has been studied as a function of basic schedules of reinforcement.

In the present study, three rats were placed together in an operant chamber containing one lever and one water dispenser. The collective operant behavior of the group, defined by lever responses, was the main dependent variable. The groups were also monitored visually. To compare group performances with the more extensively studied individual operant performances, individual rats were presented with schedules identical to those given the groups.

EXPERIMENT 1: FIXED RATIO, EXTINCTION, AND SATIATION

METHOD

Subjects

Twelve experimentally naive female Long-Evans rats, approximately 18 months old at the start, were individually housed and maintained on a 20.5- to 23-hr water deprivation schedule, with 20 to 30 min of access to water in their home cages after each session. Food pellets were always available in the home chamber.

Apparatus

Two identical wire-mesh experimental chambers 38 by 23 by 23 cm were used. A wire-mesh tunnel, 10 by 10 by 14.5 cm, extending from the center of one side of the chamber,

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contained a Gerbrands water dipper and, to the right of the dipper, a 5- by 1.5-cm response lever that required 41 g of force (0.4N) to operate. Each chamber was housed in a sound-attenuating box that contained a 15-W house-light, a buzzer, and an exhaust fan.

Procedure

Fixed ratio. Each subject was trained to press the lever for water reinforcers consisting of 2.5 sec of access to 0.1 cc of water from the dipper. At the end of the 2.5-sec period, the dipper cup was removed, whether or not the water had been drunk. A buzzer sounded during reinforcement. Each subject was then given six sessions alone in the chamber with the schedule increasing from fixed ratio 1 (FR 1) to FR 5, under which every fifth response produced water. When all subjects were responding steadily, they were divided into four sets of three, with the composition of the sets matched according to rates of responding under FR 5. Three of the sets were designated as Groups, and the fourth was divided into three Individuals. All animals continued to be housed separately and members of the Groups were together only in the operant chamber. Two Groups and one Individual were assigned to one experimental chamber, and two Individuals and the third Group to the other. No differences in responding attributable to the chambers were found. Sessions were conducted daily. This standard procedure was in effect throughout this and each of the other experiments described.

When the three rats in each Group were placed together in the experimental chamber for the first time, the reinforcement schedule remained an FR 5: five responses made by the Group as a whole resulted in a single 2.5-sec reinforcement. It did not matter whether one or more members of the Group contributed to the five responses nor, since more than one rat could squeeze into the tunnel, did the responding member necessarily drink the reinforcer. Thus, with respect to the schedule dependencies and equipment, the Group was treated as a single unit. The Individuals were placed on an FR 5 schedule identical in all respects to that of the Groups. Eleven 60-min sessions were given under FR 5. These sessions were not consecutive, as phases of extinction and satiation were interpolated (see below). Fifteen consecutive sessions under FR 50, each

120 min in duration, were then given and were followed by fourteen 180-min sessions under the same ratio. The ratio requirement was then increased to FR 150 for 31 consecutive 180-min sessions.

Extinction. After the first five sessions of FR 5, five 60-min sessions were given in which the dipper and buzzer operated as usual on the FR 5 but water was not present in the dipper reservoir. A second period of extinction was given after the FR 150 sessions and consisted of eight 180-min sessions during which there was water in the reservoir but the dipper and buzzer were never operated. Individual 3, which had stopped responding under the FR 150 conditions, was not included in the second extinction test.

Satiation. After the eighth session of FR 5 training, three 8-hr sessions under FR 5 were given to study the effects of satiation. Each session occurred approximately 48 hr after the start of the previous session. The subjects received 30 min of access to water in their home cages between sessions so that they were water deprived for approximately 24 hr before each session. Unlike regular sessions, food pellets were available in the experimental chambers.

RESULTS

Fixed ratio. Representative cumulative records of terminal performances of the Groups and Individuals show that, at the beginning of most sessions, Groups and Individuals responded similarly, with short and irregular postreinforcement pauses followed by rapid response rates (Figure 1a). However, whereas the Groups responded at high and fairly steady rates throughout the session, the Individuals' rates usually decreased during the latter portion of the sessions, presumably because an Individual could obtain approximately three times as many reinforcers as each Group member, thereby becoming satiated.

Table 1

Terminal response rates for each group and individual during the FR schedules.

(Means of Last Three Sessions at Each Value)

Condition	G-1	G-2	G-3	I-1	I-2	I-3
FR 5	25.8	24.6	32.2	13.5	18.9	23.5
FR 50 (2 hr)	29.9	44.4	57.2	41.3	43.4	44.9
FR 50 (3 hr)	50.3	63.3	62.4	45.3	47.1	47.1
FR 150	50.3	75.3	42.8	14.3	81.1	2.9

For this reason, rates of responding of the Individuals were calculated using data from only the first third of each session. Table 1 shows whole-session rates of responding for the Groups and one-third session rates for the Individuals, averaged over the last three sessions at each ratio value. The three Groups responded faster than the three Individuals under FR 5 and FR 50 (3 hr) conditions. Under

FR 50 (2 hr), there was little difference between Groups and Individuals. Under FR 150, one of the Individuals (#3) practically stopped responding. In general, during the first few sessions after a ratio requirement was increased, there was a greater decrement in individual than in group responding.

Regular direct observation of the Groups showed much interaction among the animals.

Fig. 1. Representative cumulative records of Group and Individual terminal performances under: (a) FR 50, Experiment 1; (b) FI 2-min, Experiment 2; and (c) FT 2-min, Experiment 2. Full sessions are shown.

Fig. 2. Total numbers of responses emitted by the Groups and Individuals during each session before, during, and after the first extinction test (top), and before and during the second extinction test (bottom). The ordinate scale is logarithmic.

Scrambling and fighting were often observed near the dipper, especially at the start of each session, with the three rats sometimes squeezed into the tunnel at the same time. A round-robin pattern of responding was frequently observed. At other times, one of the subjects was alone in the tunnel for several minutes while the other two engaged in exploratory, fighting, or grooming behaviors in the main cage area. Often when a reinforcer was delivered, animals outside the tunnel would quickly enter it. By the end of the 3-hr sessions especially, the alternations decreased in frequency and one animal often responded alone for several minutes while the others remained outside the tunnel. All Group members responded and obtained reinforcements during every session observed.

Extinction. Figure 2 presents total numbers of responses emitted each session by Groups and Individuals during the two extinction tests. The ordinate is logarithmic and equal proportional changes in rate are thus represented by equal distances along the ordinate, regardless of absolute values. Responding of the three Groups decreased more slowly than that of the three Individuals during extinction after both FR 5 and FR 150.

Satiation. Figure 3 shows the numbers of responses emitted during consecutive 30-min portions of the 8-hr satiation sessions. The means of the three sessions are shown. Most responses were emitted during the first 2 hr and, as time in the chamber increased, responding decreased for both Groups and Individuals. None of the Groups satiated completely: responding per 30-min period remained above zero throughout most of the session. On the other hand, all Individuals approached and often reached zero levels of responding.

EXPERIMENT 2: FIXED INTERVAL AND FIXED TIME

METHOD

Subjects and Apparatus

The same subjects and apparatus were used as in Experiment 1.

Procedure

Fixed interval. An FI 2-min schedule was instituted in which the first response to occur

2 min after a reinforcement produced another reinforcement. The three Groups and three Individuals were given thirty-one 180-min sessions, except for Individual 1, which became ill after 26 sessions and was removed from the experiment.

Fixed time. The session length was reduced to 60 min for all subjects while the FI 2-min schedule was maintained. After three sessions the schedule was changed to an FT 2-min under which water reinforcers were given every 2 min, independently of the subjects' behaviors. Twenty 60-min sessions were given. One of the members of Group 1 became ill and was not used in the last 10 sessions.

RESULTS

Fixed interval. Representative cumulative records of terminal performances of Groups and Individuals are shown in Figure 1b. The Groups failed to establish a consistent pattern of pausing and responding under the FI contingencies. Their postreinforcement pauses were relatively short and often did not occur; responding within an interval was often interrupted by pauses. On the other hand, within approximately seven sessions, the Individuals established patterns of responding characteristic of a fixed-interval schedule: long postreinforcement pauses were followed by rapid and steady response rates.

Figure 4 shows frequency distributions of postreinforcement pause durations, defined as the time to the fifth response in an interval. The fixed interval is divided into 10-sec segments and the number of pauses ending in each segment is presented as a percentage of the total number of pauses. Pause data were recorded on alternate days and the curves show the means for three of the last six sessions. Due to the illness of Individual 1, data from only one of its sessions were available. As under the FR schedule, the Individuals' response rates commonly decreased before the end of the sessions, resulting in an increase in pause length (see Figure 1b). Therefore, only the data from the first third of each session were used in computing the distribution of pause durations for the Individuals. The Groups' modal pause length was approximately 25 sec and the Individuals' was approximately 95 sec. Largely due to the difference in pause lengths, overall rates of responding were higher for Groups than for

Fig. 3. The number of responses emitted by the Groups and Individuals during successive 30-min portions of the 8-hr satiation sessions. Each point represents the mean of three sessions.

Individuals (again using one-third sessions for the Individuals and full sessions for the Groups). Mean responses per minute over the last three sessions for the three Groups were 47.1, 41.0, and 34.9; for the Individuals they were 16.5, 30.4, and 24.4.

Fixed time. Under the FT 2-min schedule, performances of both the Groups and Individuals remained very similar to those under the FI 2-min schedule. Representative cumulative records of terminal performances, shown in Figure 1c, were similar to those produced under the FI schedule: the Groups' post-reinforcement pauses remained short and irregular while the Individuals continued to emit long postreinforcement pauses followed by rapid, steady responding. After the change from FI to FT there was an initial small decrease in response rates, but the rates soon stabilized at a relatively high level and after 20 sessions there was no indication that rates

would decline further. Average rates of responding over the last three sessions for the Groups were 44.4, 26.0, and 25.1 responses per minute and for the Individuals were 23.7 and 20.1 (again using one-third sessions for the Individuals and full sessions for the Groups).

EXPERIMENT 3: DIFFERENTIAL REINFORCEMENT OF LOW RATES

METHOD

Subjects and Apparatus

Twelve 60-day-old female Long-Evans rats, not previously used in any experiment, served as subjects. The apparatus and maintenance regime were the same as described above.

Procedure

DRL. After the subjects were trained to press the lever and were responding steadily

on FR 1, they were divided into four sets of three—three Groups and three Individuals—with the composition of the sets matched according to response rates during training. The subjects were given DRL (differential-reinforcement-of-low-response-rate) training under which a response produced water only if it was preceded by a pause of specified minimum duration. If the response occurred before the required pause interval was completed, water was not given and the timing began again. The DRL interval began with the end of water delivery. Groups and Individuals were exposed to a DRL 1-sec schedule for three sessions, DRL 2-sec for 10 sessions, and DRL 4-sec for 22 sessions. Sessions were terminated after 60 reinforcements to remove the prob-

lem of satiation in the Individuals. Therefore, complete session data were used for both the Groups and Individuals in this and the following experiments.

Cued DRL. To determine whether an exteroceptive cue would improve performance under the DRL schedules, the DRL value was increased to 6 sec and, whenever reinforcement became available, the houselight went out and two 7.5-W bulbs, housed behind a translucent glass plate above the tunnel, were lighted. At the end of 2.5 sec of access to water, the tunnel light went out and the houselight was lighted until another interval was completed. Thus, availability of reinforcement was cued by the tunnel light. Twenty-one sessions were given, followed by six sessions without cue (*i.e.*, the houselight was always on and tunnel light always off), five more sessions with cue, and another six sessions without cue.

RESULTS

DRL. The Groups responded at stable and relatively high rates under the three DRL values. The Individuals' response rates were also stable but much lower than the Groups under the 2- and 4-sec values. Figure 5a shows the mean number of responses per reinforcement for each Group and each Individual averaged over the last three sessions of each DRL condition. All Groups emitted many more responses per reinforcement than did any Individual. Shown in Figure 5b are rates of responding for the Groups and Individuals, again averaged over the last three sessions of each condition. The results parallel those of the responses-per-reinforcement data. Because the Groups responded at relatively higher rates, they obtained reinforcements at lower rates than the Individuals.

Cued DRL. Figure 5c shows that when the cue signalling availability of reinforcement was present, Group responses per reinforcement were much lower than when the cue was absent. On the other hand, presence of an external cue had very little effect on the Individuals' performances, probably because they were already responding at a near optimal level without the cue. Figure 5d shows a small decrease in Group rates of responding produced by the cue while, again, the Individuals' rates were not affected. Throughout, Groups consistently responded faster than did Individuals.

Fig. 4. Frequency distributions for the Groups and Individuals of postreinforcement pause durations during the final sessions under the FI 2-min schedule. The fixed interval is divided into 10-sec segments and the number of pauses ending in each segment is presented as a percentage of the total number of pauses. Each point represents the mean of three sessions.

Fig. 5 (a) The mean number of responses per reinforcement emitted by each Group (open bars) and Individual (shaded bars) during the last three sessions of the regular DRL conditions. (b) Mean rates of responding during the last three sessions of the regular DRL conditions. (c) Mean numbers of responses per reinforcement during the last three sessions of the cued and noncued DRL 6-sec conditions. (d) Mean rates of responding during the last three sessions of the cued and noncued DRL 6-sec conditions.

EXPERIMENT 4: DISCRIMINATION

METHOD

Subjects and Apparatus

Twelve mature female Fisher rats, not previously used in the present study, served as subjects. They had all received brief prior experience in a shock-avoidance (shuttle-box) experiment. The apparatus and maintenance regime were the same as used in Experiment 3.

Procedure

The same preliminary training procedure was followed as described under Experiment 3 except that both houselights and tunnel lights were on during the early training. Three sessions were given during which the ratio requirement was increased to 10, followed by six more sessions at FR 10. During these last nine training sessions, and throughout the remainder of the experiment, the stimulus lights were alternated according to a VT 30-sec schedule: the houselight was on and the tunnel light off for an average of 30 sec, after which the houselight was off and the tunnel light on, again for an average of 30 sec, *etc.* Discrimination training was then instituted under which responses occurring while the tunnel light was on (and houselight off) were reinforced on an FR 10 schedule (S^D period). Responses occurring when the houselight was on (tunnel light off) were never reinforced, and, in addition, prevented onset of S^D for at least 10 sec after the last response (S^A period). Sessions terminated after 60 reinforcements or 60 min, whichever came first. These conditions were in effect for 14 sessions, after which the stimulus conditions were reversed: the tunnel light now signified the S^A period while the houselight signified the S^D . Twenty-two additional sessions were given.

RESULTS

The discrimination ratios in Figure 6 (response rates in S^D divided by the sum of the rates in S^D and S^A), show that, during both acquisition of the original discrimination and acquisition of the reversal, the Individuals learned at a slightly faster rate than the Groups, but this difference was not large and the shapes of the curves were very similar. Absolute response rates are shown in Figure 7. Upon introduction of discrimination training,

rates of responding decreased during the S^A component for both Groups and Individuals. Response rates in S^D increased, indicating behavioral contrast (Reynolds, 1961), but the increase was much greater for Individuals than for Groups.

The members of each Group interacted extensively throughout this experiment. Their behaviors during the final sessions were characterized by much scrambling and fighting near the tunnel by all subjects during S^D periods, usually followed by sudden retreat from the tunnel at the onset of S^A . During S^A , the subjects often groomed, fought, or explored in the main cage area until the S^D re-appeared, at which time all three animals would again compete for access to the lever.

GENERAL DISCUSSION

Bar pressing by the Groups, taken as units, was generally orderly and consistent despite a high level of within-Group interaction. Groups often demonstrated less day-to-day variability than Individuals and the between-Group variability was generally not greater than, and sometimes less than, between-Individual variability. The present data therefore indicate that groups of animals can profitably be studied in much the same way as individuals, with the groups treated as units and their collective operant performance used as a dependent variable.

Under many of the schedule conditions, Groups paused less and responded more or faster than Individuals, *e.g.*, under the FI, FT, and DRL schedules, and in extinction and satiation. These results were similar to those often ascribed to social facilitation: when two or more animals are given access to food, each animal often eats more, or responds faster than when alone (Lepley, 1937; Scott and McCray, 1967; Stamm, 1961; Tolman, 1968; Zajonc, 1965). The present experiment differed from studies on social facilitation in that there was only one response lever and one reinforcement source; therefore, the Group members often competed for access to the lever and water dipper. Studies of competition have demonstrated an enhancement in the rates of responding of two rats working on two levers, side by side, when only the faster was rewarded (Church, 1961) and an enhancement in running speed in a runway when only the

Fig. 6. Discrimination ratios (response rate in S^D divided by the sum of the response rates in S^D and S^A) for Groups and Individuals during the original discrimination task and the discrimination reversal task.

faster of two rats was rewarded (Kanak and Davenport, 1967). In the present experiment, the animal responding was the one most likely to receive the water reinforcer. The competition that this situation produced, *i.e.*, for the opportunity to respond, may have engendered an increase in response rates.

When studying group operant behavior, it is important to consider the contingencies actually experienced by each animal. The reinforcement contingencies for both Individuals and Groups were, in part, a product of each Individual's or Group's interaction with the scheduling apparatus. In addition, within a Group, the behavior of each member influenced the contingencies for each of the other

members. The result was that, for Groups, the arranged schedule was often obfuscated. Under the fixed-ratio schedule, for example, one rat was often replaced at the lever by a second rat before the ratio requirement was completed, and the second rat would respond only a few times and receive reinforcement. Thus, for a given Group member, the schedule of reinforcement actually experienced was often a variable ratio. Similarly, under the fixed-interval and fixed-time conditions, the schedule of reinforcement experienced by a Group member was often variable interval and variable time, which may partially account for the shorter pauses and higher response rates emitted by Groups as compared

Fig. 7. Absolute rates of responding for the Groups and Individuals under the S^D and S^A conditions during the two discrimination tasks. Solid lines represent rates in S^D and dashed lines represent rates in S^A .

with Individuals (Ferster and Skinner, 1957). A marked case of schedule obfuscation occurred under the DRL schedules, where responses had to be spaced in time. One member of a Group might have paused for longer than the required interval, and still not receive reinforcement if another rat had just responded. Consequently, responding by the Groups was not well controlled by the DRL schedule. Providing the Groups with an exteroceptive cue led to immediately improved

performances: the cue for reinforcement could not be obscured by the behavior of Group members. The same analysis helps to explain why Groups quickly learned not to respond in S^A in Experiment 4. Each Group member could have learned individually to respond during the presence of the S^D stimulus and not to respond in S^A . While the S^A responses of other Group members might have caused delays in S^D onset, such responses would not have obfuscated the schedule contingencies.

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