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Operant and alternative buttonpressing by college students on DRL and RR schedules of points reinforcement

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Male and female college students were given differential reinforcement of low rate (DRL) 5-sec and random-ratio (RR) 6 schedules of points reinforcement. Operant buttonpressing increased over six 4-min blocks of training under the RR schedule, but not under the DRL schedule. IRT/*N* distributions shifted toward shorter values under the RR schedule and toward longer values under the DRL schedule. Beyond these changes in operant behavior, subjects' responding on four identical, but inoperative, buttons was differentially affected by the operant reinforcement schedules. Alternative buttonpressing decreased over training blocks under the RR schedule, but not under the DRL schedule. Furthermore, under the RR schedule, responding was greater on alternative buttons that were adjacent to the operant button; however, under the DRL schedule, responding was greater on nonadjacent buttons.

A schedule of reinforcement specifies how reinforcers are to be given following responses of a certain class—the operant. Different schedules of reinforcement, of course, support different patterns of operant behavior. Less certainly, schedules of reinforcement may affect behaviors other than those explicitly required. These unnecessary responses have been variously called schedule-induced, adjunctive, superstitious, collateral, and mediating behaviors (Bruner & Revusky, 1961; Laties, Weiss, & Weiss, 1969; Skinner, 1948; Staddon, 1977). Whatever label one chooses, however, these alternative behaviors have defied ready interpretation.

The point of departure for our research was the incidence of unnecessary responding on interresponse time schedules (IRT $> t$, or, more commonly, differential reinforcement of low rates, DRL). Thus, even though pressing only one telegraph key was effective in producing monetary reinforcers on a DRL schedule, Bruner and Revusky (1961) reported that teenage boys often pressed one or more other available, but ineffective, keys. This result was replicated by Stein and Landis (1973), who also showed that the performance of these other behaviors had a felicitous, but unscheduled, effect on the delivery of points reinforcers; namely, reinforcers were more frequently delivered when female college students were allowed to press the ineffective keys than when they were prevented from doing so. These findings suggest that alternative behaviors may serve a mediating function, by ensuring that operant responses are spaced sufficiently far apart in time to meet the interresponse time requirement.

If this analysis is correct, then frequent alternative responding should not inevitably accompany any and all schedules of reinforcement. High rates of unnecessary responding are to be expected under a DRL schedule, because subjects must refrain from impetuous operant responding until the IRT requirement has elapsed. However, low or zero rates of unnecessary responding are to be expected under a ratio schedule, because reinforcers are based only on the number of times the subject performs the operant response; indeed, if subjects on ratio schedules make alternative responses, they are wasting valuable opportunities to make operant responses, those that truly count (Kelly, 1974).

To test this analysis, we compared the behavior of college students given DRL and random-ratio (RR) schedules of points reinforcement. The five buttons we provided were circularly arrayed. Thus, we did not expect preferential responding on any particular button due to middle or end effects, which might have occurred had the buttons been linearly arrayed as in prior research (Bruner & Revusky, 1961; Stein & Landis, 1973). Also, we wanted to see whether the two buttons adjacent to the operant button were more or less likely to be pressed than were the two nonadjacent buttons. Finally, both male and female college students were studied. Because the largest investigation of human responding under DRL schedules (Stein & Landis, 1973) had involved only women, we compared the behavior of men and women to see if any notable sex differences emerged.

METHOD

Subjects

Thirty-two undergraduates (16 males and 16 females) in introductory psychology classes participated.

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Apparatus

Each subject was seated in a standard experimental room, before a panel containing five large buttons in a circular arrangement and two lights (one green and one yellow) above the array of buttons. The buttons were equally spaced, 72° apart, on an imaginary circle with a 41.28-mm radius, with one button at the top of the circle. A force of 400 g activated a microswitch attached to each button. A DEC PDP 8/L laboratory computer, equipped with a relay interface and the SKED software system, was housed in a separate room and controlled stimulus presentations and recorded subjects' responses. Each subject was tested individually for a total of 28 min. The following instructions were provided for subjects to read at the beginning of the session:

> On the panel in front of you are five buttons, a green light, and a yellow light. This apparatus is connected to a computer in another room. The computer will turn the green light on. While the green light is on, your task is to accumulate as many points as you can by pressing the buttons. However, you may only press one button at a time, using only one hand at a time. In addition, you may only press buttons if the green light is on. If the green light is off, it is impossible for you to accumulate points by pressing buttons. When you have earned a point, the yellow light will flash and a point will be counted by the computer. The green light will turn on and turn off several times during the experiment. For the first several minutes, you will not be able to earn points. During this period, familiarize yourself with the apparatus by pressing the buttons. I shall return to notify you when you can obtain points. Try to get as many points as you can.

During the first 4 min of the session, no points could be obtained. During this baseline period and the six subsequent 4-min acquisition blocks, the green session light was illuminated to signal the subject to press buttons. After the baseline period, the experimenter returned to the testing room to notify the subject that points could be earned the next time the green session light came on. When the experimenter left the room, the first 4-min block of the acquisition phase started. Approximately 30 sec elapsed between the end of each block in the acquisition phase and the beginning of the next block. Both lights remained off between blocks. Reinforcers, in the form of 0.5-sec flashes of the yellow light, were delivered to subjects, contingent on their performance.

The button to the subject's lower left was programmed to produce reinforcers on a DRL 5-sec schedule for half of the subjects and on a RR 6 schedule for the other half of the subjects. The DRL schedule required that the subject wait a minimum of 5 sec between presses on the operant button; operant presses that occurred before the required time interval had elapsed were not reinforced and restarted the timing of the interval. Under the RR 6 schedule, each operant press had a .167 chance of producing a reinforcer. Responses on the other four buttons had no scheduled effect on the production of points reinforcers under either schedule. All response requirements were reset at the beginning of each block.

RESULTS

Response Rate

Baseline. During the baseline period, the subjects responded on the five buttons at similar rates. Across both DRL and RR groups and both male and female subjects, the mean rate of response on the operant button (Button 0) was 19.94 presses per min; mean response rate one button clockwise (Button −1) was 18.47 presses per min and one button counterclockwise (Button +1) was 17.50 presses per min; mean response rate two buttons clockwise (Button −2) was 18.93 presses per min and two buttons counterclockwise (Button +2) was 18.06 presses per min. An analysis of variance (ANOVA) failed to disclose any reliable differences ($p > .05$) in overall response rate among the five buttons. Nor were there reliable differences in overall response rate per button between subjects in the DRL group (19.43 presses per min) and subjects in the RR group (17.73 presses per min) or between males (17.81 presses per min) and females (19.35 presses per min). These data are shown in Figure 1.

Acquisition. From baseline to the first block of acquisition, there was a general rise in responding to all buttons in the DRL group (Figure 1, left) and a selective increase in responding to the operant button in the RR group (Figure 1, right). The course of acquisition for response rate (and for other dependent variables) was more rigorously evaluated by examining block-by-block changes while points reinforcers were available.

During the six blocks of acquisition, responding on the five buttons changed differentially as a function of the schedule and the sex of the subject. This conclusion is supported by a reliable four-way interaction [$F(20,560) = 1.63, p < .05$] and by numerous reliable lower order interactions and main effects obtained from a block × button × schedule × sex ANOVA. In order to clarify these statistical findings, separate ANOVAs were conducted on operant and alternative buttonpressing.

Turning first to operant responding, overall pressing increased during the six blocks of training [$F(5,140) = 3.42, p < .01$]; subjects in the RR group pressed more than subjects in the DRL group [$F(1,28) = 39.22, p < .001$], and males pressed more than females [$F(1,28) = 5.50, p < .05$]. These reliable main effects are conditionalized by two reliable two-way interactions. First, there was a reliable block × schedule interaction [$F(5,140) = 5.20, p < .001$]. This finding plus the results shown in Figure 1 suggest that operant buttonpressing increased over blocks of training only under the RR schedule; under the DRL schedule, responding remained relatively constant. Of the RR subjects, 87.50% increased operant buttonpressing from Block 1 to Block 6 of acquisition, whereas only 31.25% of the DRL subjects did so. Second, there was a reliable schedule × sex interaction [$F(1,28) = 4.69, p < .05$]. This finding plus the results shown in Figure 1 suggest that males responded more than females, but only under the RR schedule (males, 227.49 presses per min; females, 122.42 presses per min); under the DRL schedule, males and females responded at similar low rates (males, 31.19 presses per min; females, 26.98 presses per min).

Turning to alternative responding, overall pressing per button was reliably higher under the DRL schedule (left panel of Figure 1) than under the RR schedule (right panel of Figure 1) [$F(1,28) = 33.57, p < .001$]. This reliable main effect is conditionalized by two reliable two-way interactions. First, there was a reliable block × schedule interaction [$F(5,140) = 4.12, p < .01$]. This finding plus the results shown in Figure 1 suggest that alternative buttonpressing generally fell for RR subjects (81.25% showed this trend); DRL subjects, however, evidenced no general tendency for alternative responding to decrease (43.75% showed this trend). Second, there was a reliable schedule × sex interaction [$F(1,28) = 10.01, p < .01$]. This finding plus the results shown in Figure 1 suggest that males showed a greater difference in alter-

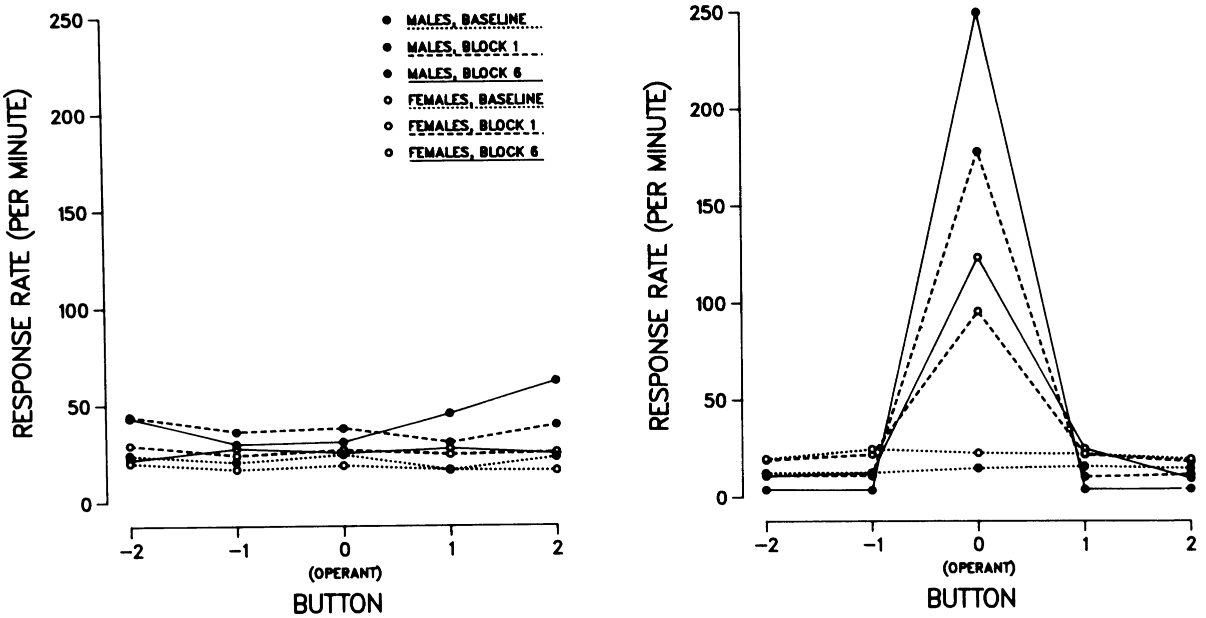

Figure 1. Mean rate of responding to the five available buttons during baseline and Blocks 1 and 6 of acquisition. The behaviors of male and female subjects are separately depicted under both differential reinforcement of low rate (left panel) and random-ratio (right panel) schedules of reinforcement.

native responding under the two different schedules (DRL, 42.17 presses per button per min; RR, 5.75 presses per min) than did females (DRL, 26.60 presses per button per min; RR, 15.91 presses per min).

Although difficult to see in Figure 1, spatial proximity to the operant button had an effect on responding. In Block 1, DRL subjects tended to respond more on far (+2 and −2) than on near (+1 and −1) alternative buttons (80% or $^{12}/_{15}$ subjects with untied scores showed this trend), whereas RR subjects tended to respond more on near than on far alternative buttons (68.75% or $^{11}/_{16}$ subjects showed this trend). In Block 6, also, DRL subjects tended to respond more on far than on near alternative buttons (60% or $^{9}/_{15}$ subjects with untied scores showed this trend), and RR subjects tended to respond more on near than on far alternative buttons (70% or $^{7}/_{10}$ subjects with untied scores showed this trend).

IRT Distribution

In order to gain a better understanding of the temporal structure of operant responding, IRT distributions were examined. These distributions were created for individual subjects by dividing the number of IRTs falling between x and $x+1$ sec by the total number of IRTs during a 4-min period (IRT/N). Figure 2 shows the mean IRT distributions.

Baseline. During the baseline period, most IRTs were between 0 and 3 sec, with decreasing numbers of responses occurring at longer IRTs. The overall IRT distribution was reliably nonrectangular [$F(19,532) = 21.55$, $p < .001$]. There were no reliable differences in the shapes of the IRT distributions between subjects in the DRL group and subjects in the RR group, or between male and female subjects.

Acquisition. From the first to the last block of acquisition, the IRT distributions changed differentially as a function of the schedule of reinforcement. This conclusion is supported by a reliable block × bin × schedule interaction [$F(19,532) = 5.15, p < .001$] and by numerous reliable lower order interactions and main effects obtained from a block × bin × schedule × sex ANOVA. In order to clarify these statistical findings, separate ANOVAS were conducted on DRL and RR performance.

Considering DRL performance first, the overall IRT distribution was nonrectangular [$F(19,266) = 18.02$, $p < .001$]. In addition, there was a rightward shift in the IRT distribution from Block 1 to Block 6 of acquisition [$F(19,266) = 6.22$, $p < .001$]. Finally, this rightward shift in the IRT distribution was more pronounced for male than for female subjects [$F(19,266) = 1.70$, $p < .05$]; thus, although both men and women increased the percentage of IRTs that qualified for reinforcement from Block 1 to Block 6, the increase was larger for males. Of the 7 males who increased the percentage of reinforced IRTs from Block 1 to Block 6, 5 showed increases in excess of 20%; of the 7 females who increased the percentage of reinforced IRTs, only 3 showed increases in excess of 20%. Furthermore, although the mean IRT distributions of both men and women in Block 6 rose immediately after the 5-sec criterion (Figure 2), 62.50% of the males had modal IRTs greater than criterion, whereas only 25% of the females had modal IRTs greater than 5 sec.

Considering RR performance, the overall IRT distribution was nonrectangular [$F(19,266) = 77.27$,

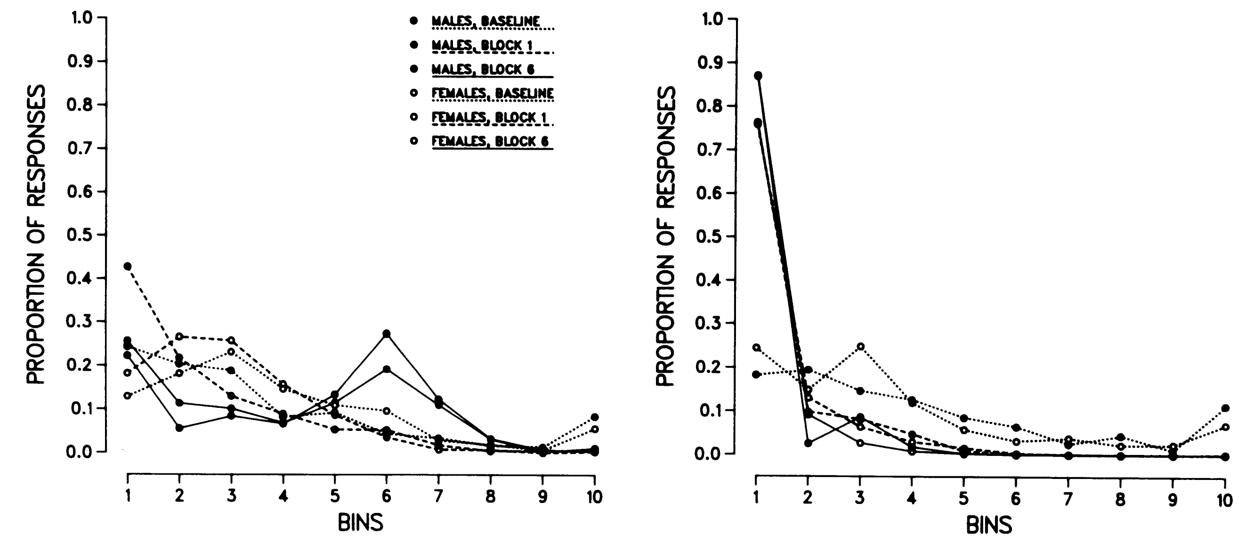

Figure 2. Mean IRT/*N* distributions of operant buttonpressing during baseline and Blocks 1 and 6 of acquisition. The behaviors of male and female subjects are separately depicted under both differential reinforcement of low rate (left panel) and random-ratio (right panel) schedules of reinforcement. In each panel, successive 1-sec bins are shown along the abscissa; Bin 10 represents IRTs greater than or equal to 9 sec.

$p < .001$]. In addition, there was a leftward shift in the IRT distribution from Block 1 to Block 6 [$F(19,266) = 3.47, p < .001$]. This leftward shift was not significantly different for male and female subjects. Both men and women equivalently increased the mean percentage of IRTs between 0 and 1 sec from Block 1 to Block 6 of training (Figure 2), a trend also seen in the data of individual subjects (7 of the 8 women increased the percentage of IRTs in Bin 1 from Block 1 to Block 6 and 6 of the 7 men with untied scores did so).

DISCUSSION

Within the span of only 24 min of training with points reinforcers, male and female college students evidenced notable changes in operant buttonpressing on RR and DRL schedules. From the first to the sixth and final 4-min block of training, operant responding increased under the RR schedule. Accompanying this increase in response rate was a tendency for subjects to emit proportionately shorter IRTs. Although the rate of operant responding did not change from Block 1 to Block 6 under the DRL schedule, proportionately longer IRTs were emitted in Block 6 of training than in Block 1.

The acquired operant behavior patterns controlled by the RR and DRL schedules were quite different. The subjects responded on the operant button at much higher rates under the RR schedule than under the DRL schedule. Furthermore, in Block 6 of training, 87.50% of the RR subjects produced a modal IRT between 0 and 1 sec, whereas 43.75% of the DRL subjects produced a modal IRT in excess of the 5-sec criterion for reinforcement. Not only did operant behavior differ, but by the end of training, subjects responded on the alternative buttons at higher rates under the DRL schedule than under the RR schedule. Although alternative responding under the DRL schedule remained relatively constant, it decreased under the RR schedule as training progressed from the first to the sixth block.

This pattern of results confirms prior speculation that alternative responding is a function of the schedule of reinforcement (Kelly, 1974). Alternative buttonpressing continued undiminished when the operant button was under a DRL schedule; however, when the operant button was under a RR schedule, alternative buttonpressing almost ceased by the end of training. These results are understandable if subjects are sensitive to the rates of reinforcement that are produced by different patterns of operant and alternative behavior. Alternative behavior should continue under the DRL schedule because its occurrence can help to prevent impetuous operant behavior, whose too-frequent occurrence costs reinforcers; however, alternative behaviors should stop under the RR schedule because their occurrence can only cost reinforcers.

Not only did the schedule of reinforcement affect operant and alternative behaviors, the sex of the subject was also an important factor. Males pressed the operant button at a higher rate than did females, but only on the RR schedule; on the DRL schedule, the rate of operant responding was about the same. Although both men and women responded at higher rates to the alternative buttons under the DRL schedule than under the RR schedule, the difference in rate was larger for men than for women. Furthermore, males showed a greater rightward shift in their IRT distributions under the DRL schedule than did females; both sexes showed similar leftward shifts in their IRT distributions under the RR schedule.

Finally, spatial proximity to the operant had an influence on the incidence of alternative behavior. Alternative responding tended to be greater to adjacent than to nonadjacent buttons under the RR schedule; however, alternative responding tended to be greater to nonadjacent than to adjacent buttons under the DRL schedule.

REFERENCES

Bruner, A., & Revusky, S. H. (1961). Collateral behavior in humans. *Journal of the Experimental Analysis of Behavior*, **4**, 349-350.

Kelly, D. D. (1974). Two unlike patterns of random-ratio responding associated with different eating habits in rhesus monkeys. *Journal of the Experimental Analysis of Behavior*, **22**, 169-177.

Laties, V. G., Weiss, B., & Weiss, A. B. (1969). Further observations on overt "mediating" behavior and the discrimination of time. *Journal of the Experimental Analysis of Behavior*, **12**, 43-57.

Skinner, B. F. (1948). "Superstition" in the pigeon. *Journal of Experimental Psychology*, **38**, 168-172.

Staddon, J. E. R. (1977). Schedule-induced behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 125-152). Englewood Cliffs, NJ: Prentice-Hall.

Stein, N., & Landis, R. (1973). Mediating role of human collateral behavior during a spaced-responding schedule of reinforcement. *Journal of Experimental Psychology*, **97**, 28-33.

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