Animal Learning & Behavior
1993, 21 (2), 159-167

The influence of brief stimuli uncorrelated with reinforcement on choice between variable-ratio schedules

PHIL REED and VAL SZCZUDLO
University College, London, England

and

ALAN WILLIS and GEOFFREY HALL
University of York, York, England

Experiment 1 investigated the behavior of rats trained to leverpress on a concurrent variable ratio (VR) 30 VR-30 schedule with a brief, 500-msec, light occurring at the midpoint of the ratio on one of the levers. Higher response rates were recorded on the lever associated with this stimulus, a finding that paralleled the effect produced by inserting primary reinforcement at the midpoint (i.e., by training on a concurrent VR-30 VR-15 schedule). Similar results were found in Experiment 2 using a concurrent VR-20 VR-20 schedule with a 2-sec visual stimulus presented midway through one of the components. In addition, a brief stimulus inserted midway through the VR-20 component of a concurrent VR-20 VR-10 schedule retarded the development of a difference in response rates between the components relative to a VR-20 VR-10 group lacking the signal. In Experiment 3, multiple VR VR schedules were used. Again, the response rate was higher in the component that had the added stimulus or, for a second group of subjects, on the component with the smaller response requirement. Probe-choice trials revealed a preference for the component that generated the higher rate in both groups. Presenting a stimulus partway through a ratio appears to reduce the effect on response rate and choice of a large ratio value.

In a study of performance on variable-ratio (VR) schedules, Reed and Hall (1989) compared response rates shown by rats trained on a simple VR-30 schedule with response rates shown on a schedule that differed only in that a brief, response-contingent stimulus (a tone) was presented midway through each ratio. The latter procedure produced a much lower rate of responding, and one almost identical to that recorded for subjects trained on a simple VR-15 schedule. Reed and Hall interpreted this result as being an instance of quasi-reinforcement (Neuringer & Chung, 1967). This notion suggests that presenting the brief stimulus midway through the ratio effectively creates a second-order schedule with two VR-15 components, with completion of the first resulting in the presentation of the tone and completion of the second resulting in primary reinforcement. In the Reed and Hall study, presentation of the tone midway through the ratio produced much the same behavior as would be expected from presenting primary reinforcement in this position. Similar effects have been reported for second-order fixed-ratio (FR) schedules (e.g., Cohen & Calisto, 1981) and for second-order interval schedules (e.g., Squires, Norborg, & Fantino, 1975).

This research was supported in part by a United Kingdom Science and Engineering Research Council grant. Correspondence should be addressed to P. Reed, Department of Psychology, University College, Gower Street, London WC1E 6BT, England.

Whatever mechanism is responsible for this effect (and several have been suggested; e.g., Kelleher, 1966; Lieberman, Davidson, & Thomas, 1985; Neuringer & Chung, 1967; Staddon & Innis, 1969), presenting a brief stimulus in this way effectively diminishes the effect on response rate and choice of a schedule with a large ratio (or interval) requirement and produces behavior more similar to that of a schedule with a smaller ratio (or interval) requirement. The experiments reported here were designed to assess and extend the generality of this assertion.

Although rats exposed to a VR schedule having a low ratio requirement (e.g., VR-15) will respond at a lower rate than other subjects given a somewhat larger ratio, such as a VR-30 (see Reed & Hall, 1989), the same may not be true when subjects experience both schedules concurrently. Studies of concurrent VR VR schedules (see de Villiers, 1977, for a review) suggest that more responses will be made on the manipulandum associated with the smaller ratio value, and, when given a choice, animals will behave so as to gain access to the schedule having the lower response requirement. Whatever the source of these effects (and, again, several possibilities have been suggested; Baum, 1981; Lea, 1979; Rachlin, 1978), they provide a further means of testing the proposition that a brief stimulus presented midway through a VR schedule may reduce the effect of a large ratio and produce behavior similar to that generated by an orthodox VR schedule with a lower ratio value.

EXPERIMENT 1

In the first experiment, rats were exposed to concurrent VR VR schedules. For subjects in the critical experimental condition, each lever in a two-lever conditioning chamber was associated with a VR-30 schedule. One of these levers, however, was also associated with the presentation of a brief, salient stimulus midway through the ratio. If such a stimulus reduces the effect of a large ratio schedule and makes this component function as a smaller ratio, then the rate of response should be higher on the lever having that stimulus than on the lever that does not have that stimulus. A second group of rats received a concurrent VR-30 VR-15 schedule to allow confirmation that, with these procedures, the lower ratio value does indeed generate a higher rate of response than the larger ratio value when both are concurrently operative.

Method

Subjects. Sixteen male hooded Lister rats served as subjects. They were 4-6 months old at the start of the experiment, ranged in free-feeding weights from 430 to 590 g, and were maintained at 80% of these weights throughout the study. The subjects had previously served in an appetitive classical conditioning experiment in which they experienced food reinforcement, a tone, and a clicker. The subjects were naive, however, with respect to leverpressing and the visual stimulus used in the present experiment. The rats were housed in pairs and had constant access to water in the home cage.

Apparatus. Two identical operant conditioning chambers (Campden Instruments Ltd.) were used. Each chamber was housed inside a light- and sound-attenuating case. A ventilating fan provided a 65-dB(A) background masking noise. Each chamber was equipped with two retractable levers, one on each side of a centrally located, recessed food tray. Reinforcement consisted of the delivery of a single 45-mg food pellet. The ceiling of the chamber was white Perspex, which allowed diffuse illumination via a 30-W strip light. The chamber was not otherwise illuminated during the course of conditioning. The apparatus was controlled by BBC computer.

Procedure. The subjects were magazine trained in two 40-min sessions during which the levers were removed from the chambers and reinforcement was delivered according to a variable-time 60-sec schedule (range: 6-180 sec). For the first session, the flap covering the magazine tray was taped open to allow easy access to the food pellets; during the second session, the flap was lowered to its standard resting position. For the next four sessions, one lever was inserted into the chamber, and the subjects were taught to leverpress (two sessions with the left lever present, and two sessions with the right lever). Each session lasted until the subject had obtained 75 reinforcers on a continuous reinforcement (CRF) schedule. All the subjects then received, on each lever, one session of VR-5 (range 1-9) training, one session of VR-10 (range 2-18) training, and two sessions of VR-20 (range 4-36) training. Each of these sessions lasted until the subject earned 30 reinforcers. The subjects were then exposed to a concurrent VR-20 VR-20 schedule for two 40-min sessions. There was no changeover delay in operation during exposure to the concurrent schedule for either group during this pretraining or any subsequent phase of the experiment. After pretraining, the subjects were divided into two groups (n = 8) matched for response rate on each lever during the last session of the concurrent schedule.

During Phase 1, one group of subjects responded on a concurrent VR-30 (range 6-64) VR-15 (range 3-27) schedule. For all subjects in this group, the VR-15 component was presented on the left lever. In Phase 2, the ratio values associated with each lever were reversed so that the lever previously associated with the VR-30 schedule became associated with the VR-15 schedule and the lever that was previously VR-15 became VR-30. For a second group of subjects, Phase 1 consisted of concurrent VR-30 VR-30 training. In addition, a 500-msec, response-contingent flash of light was presented halfway through the programmed ratio value on one lever; there were no stimulus presentations on the other lever. The component with the brief stimulus was presented on the left lever for all subjects in this group (VR-30+S VR-30). In Phase 2, the brief-stimulus condition was switched to the right lever for all subjects (VR-30 VR-30+S). For both groups, each phase consisted of 24 40-min sessions.

Results and Discussion

The mean response rates on each lever during both phases of the experiment are displayed for each group over three-session blocks in Figure 1. The subjects given the concurrent VR-30 VR-15 schedule (left panel) began Phase 1 with similar response rates on the two levers. With training, however, responding on the VR-15 lever increased above that observed on the VR-30 lever. During Phase 2, when the contingencies were reversed, the response rates initially converged and eventually reversed from the terminal levels in Phase 1.

This description of the results was confirmed by statistical analysis. An analysis of variance (ANOVA) conducted on the Phase 1 data with component (VR-30 vs. VR-15) and block as factors revealed a significant main effect of component [$F(1,7) = 19.23, p < .01$] and block [$F(7,49) = 7.32, p < .01$] and a significant interaction between the two [$F(7,49) = 47.32, p < .001$]. A t test conducted on the last block of Phase 1 training revealed that response rates were higher on the lever associated with the VR-15 schedule than the VR-30 schedule [$t(7) = 4.98, p < .01$]. A two-factor ANOVA (component × block) conducted on the data from Phase 2 also revealed a significant interaction of component and block [$F(7,49) = 73.21, p < .001$], but no significant main effects ($ps < .20$). A t test conducted on the last block revealed a marginally significant difference between components, with subjects responding faster on average in the VR-15 than in the VR-30 component [$t(7) = 2.01, .07 > p > .06$].

The subjects trained on the concurrent VR-30 VR-30+S schedule (right panel of Figure 1) responded at similar rates on the two levers at the start of the experiment. Over the course of Phase 1, rates of response on the lever with the brief stimulus (i.e., VR-30+S) became slightly higher than rates emitted on the other lever. During Phase 2, when the contingencies were reversed, the response rate for the VR-30+S component was markedly higher than for the other component. A two-factor ANOVA (component × block) conducted on the Phase 1 data demonstrated no significant main effects and no interaction between the two factors ($ps > .30$). A two-factor ANOVA (component × block) conducted on the Phase 2 data revealed a main effect of component [$F(1,7) = 6.31, p < .05$] and an interaction between component and block [$F(7,49) = 13.32, p < .01$], but no main effect of block ($p > .20$).

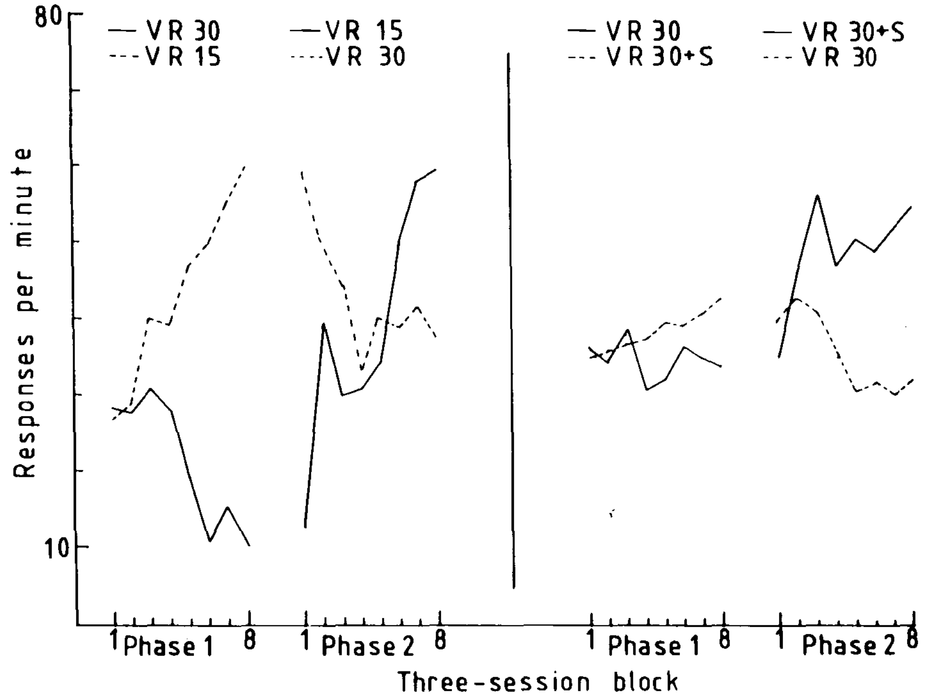

Figure 1. Mean rates of response over three-session blocks for both groups in both phases of Experiment 1. Left panel: The subjects receiving the concurrent VR-30 VR-15 schedule in Phase 1, which reversed in Phase 2. Right panel: The subjects receiving the concurrent VR-30 VR-30+S schedule in Phase 1, which was reversed in Phase 2 (S = brief stimulus presented midway through the ratio).

A *t* test conducted on the last block of Phase 2 training revealed that the subjects responded at a higher rate on the VR-30+S lever than on the lever lacking this stimulus [$t(7) = 3.21$, $p < .05$].

The results from the group experiencing the concurrent VR-30 VR-30+S schedule could have arisen if the subjects exhibited a right-lever preference that interacted with the effect of the contingencies. Such a preference may have acted in opposition to the contingencies in Phase 1 to produce no difference in response rate between the levers, but in conjunction with the contingencies in Phase 2 to produce a large difference in response rate. To examine the possible contribution of lever preferences, the results from the last block of training in Phase 1 and Phase 2 were collapsed so that each subject had one response rate score for the VR-30 component and one response rate score for the VR-30+S component. If the subjects merely exhibited a right-lever bias, then there should be no statistically significant difference in these scores since the right lever would be associated with both components over the course of the two phases. The mean response rate for the VR-30 component was 29 responses per minute, and for the VR-30+S component it was 51 responses per minute. A *t* test revealed a statistically significant difference between these scores [$t(7) = 2.81$, $p < .05$]. This suggests that any right-lever preference that did exist cannot account for the entire pattern of results in this experiment.

The results also confirm that on a concurrent VR VR schedule, animals will respond at a higher rate on the manipulandum associated with the smaller ratio value. Such a finding has been taken to indicate a preference for the smaller ratio (de Villiers, 1977), the source of which may be a greater frequency of reinforcement (Baum, 1981), less response effort per reinforcer (Lea, 1979), or a combination of these factors (Rachlin, 1978).

Whatever the source, the point at issue for the present study was whether inserting a brief stimulus in a VR-30 schedule would engender a preference similar to that produced by a smaller ratio requirement. The results from Phase 1 provided no supporting evidence for this view: the subjects given the concurrent VR-30 VR-30+S schedules showed no reliable preference for the lever associated with the brief stimulus. However, the results from Phase 2 *did* provide some evidence that a brief stimulus influences concurrent ratio schedule performance. Although the effect of presenting a brief stimulus midway through a ratio was not as pronounced as presenting primary reinforcement in the same position, the brief stimulus did increase preference for the schedule with which it was associated.

EXPERIMENT 2

Experiment 2 attempted to replicate the results obtained after the reversal of contingencies in Phase 2 of Experiment 1. Three groups of subjects were employed: one group responded on a concurrent VR-20 VR-20 schedule with a brief stimulus presented midway through one of the components, a second group responded on a standard VR-20 VR-10 schedule, and a third group responded on a VR-20 VR-10 schedule with the brief stimulus presented midway through the VR-20 component. Should the results from Experiment 1 be confirmed, the brief stimulus presented midway through a ratio schedule should reduce the difference in response rate produced between the large and small ratio schedules in the latter group (i.e., it should reduce preference for the VR-10 schedule). It should also produce a preference for the component containing it for the VR-20 VR-20 group.

Method

Subjects. Thirty experimentally naive, male hooded Lister rats served as subjects. They were 3-4 months old at the start of the experiment, had free-feeding weights ranging from 260 to 290 g, and were maintained at 85% of these weights throughout the study. The rats were housed in groups of 4 (except for 2 animals housed in a pair) and had constant access to water in the home cage.

Apparatus. Four identical operant conditioning chambers (Campden Instruments Ltd.) were used. Each chamber was housed inside a light- and sound-attenuating case. A ventilating fan provided a 65-dB(A) background masking noise. Each chamber was equipped with two levers, one on each side of a centrally located, recessed food tray. Each lever was made of clear Perspex, which allowed the levers to be illuminated from behind by a bulb located outside the chamber. The chamber was not otherwise illuminated during the course of conditioning. Reinforcement consisted of the delivery of a single 45-mg food pellet.

Procedure. The subjects were magazine trained as described in Experiment 1. For the next two sessions, a concurrent CRF CRF schedule was in operation. Each press to either lever produced reinforcement. Each session of CRF training, and each subsequent session, lasted for 20 min. In an attempt to neutralize any lever preferences prior to introduction of the experimental contingencies, the subjects were then pretrained on a concurrent variable interval (VI) VI schedule with equal interval values in both components. Initially, the rats received two sessions of training on a concurrent VI 30-sec (range 1-60 sec) VI 30-sec schedule. Following this, all subjects received two sessions of concurrent VI 60-sec (range 1-120 sec) VI 60-sec training. Such schedules typically produce approximately equal rates of response in each component (cf. de Villiers, 1977). There was no changeover delay in these concurrent schedules or during the critical experimental phase of the study. The subjects were divided into three groups (n = 10) matched for response rate on each lever during the last concurrent VI 60-sec VI 60-sec session.

For the critical experimental phase, one group of subjects was trained on a concurrent VR-20 (range 1-40) VR-10 (range 1-20) schedule. The VR-10 schedule was associated with the lever that generated the lower response rate on the last session of pretraining. The second group of subjects also received concurrent VR-20 VR-10 training, but with a 2,000-msec, response-contingent illumination of the response lever presented halfway through the programmed ratio on the VR-20 lever. There were no stimulus presentations on the other lever. The VR-20 schedule was associated with the lever that generated the lower response rate on the last pretraining session. For the third group, a concurrent VR-20 VR-20 schedule was in operation. A 2,000-msec illumination of the response lever was presented exactly halfway through the programmed ratio on one of the levers; there were no stimulus presentations on the other lever. The VR-20 schedule containing the stimulus presentation was associated with the lever that generated the lower response rate on the last pretraining session. Training in all groups continued for 20 sessions.

Results and Discussion

Figure 2 displays the mean response rates on each lever for each group over two-session blocks. Response rates of the group given the standard concurrent VR-20 VR-

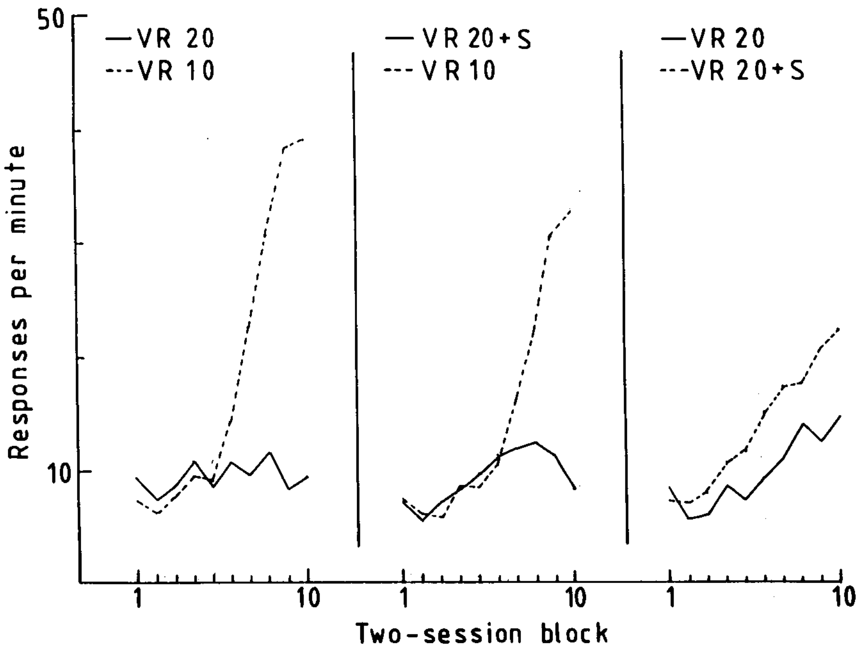

Figure 2. Mean rates of response over two-session blocks for the three groups in Experiment 2. Left panel: The subjects receiving the concurrent VR-20 VR-10 schedule. Middle panel: The subjects receiving the VR-20+S VR-10 schedule (S = brief stimulus presented midway through the ratio). Right panel: The subjects receiving the concurrent VR-20 VR-20+S schedule.

10 schedule are shown in the left panel. These subjects began training with similar response rates on the two levers, but, over blocks, responding on the VR-10 lever increased above that observed on the VR-20 lever. A two-factor ANOVA (component × block) revealed significant main effects of component [$F(1,9) = 106.20, p < .001$] and block [$F(9,81) = 23.74, p < .001$] and a significant interaction between the two factors [$F(9,81) = 22.41, p < .001$]. A t test conducted on the last block of training revealed a significantly higher response rate for the VR-10 component [$t(9) = 6.38, p < .001$].

The data for the group given the concurrent VR-20+S VR-10 schedule are shown in the middle panel. These subjects also began training with similar response rates on the two levers. Over sessions, responding on the VR-10 lever also increased above that observed on the VR-20+S lever. A two-factor ANOVA (component × block) revealed significant main effects of component [$F(1,9) = 33.13, p < .001$] and block [$F(9,81) = 14.03, p < .001$] and a significant interaction between the two factors [$F(9,81) = 9.11, p < .001$]. A t test conducted on the last block of training revealed a significantly higher response rate for the VR-10 component [$t(9) = 3.75, p < .01$].

The subjects trained on the concurrent VR-20 VR-20+S schedule (right panel) also began the experiment with equal response rates on the two levers. Over the course of training, response rates on the lever with the brief stimulus became higher than those emitted on the other lever. A two-factor ANOVA (component × block) demonstrated a significant main effect of component [$F(1,9) = 30.67, p < .001$] and a main effect of block [$F(9,81) = 14.03, p < .001$], but no interaction between these factors ($p > .20$).

Figure 3 replots the response-rate data in Figure 2 as discrimination ratios (number of responses emitted in one component divided by the total number of responses emitted). For the VR-20 VR-10 group, this ratio was calculated by dividing the number of responses emitted during the VR-10 component in a block by the total number of responses emitted to both levers in that block. Inspection of the data for this group reveals that the subjects emitted an increasingly greater proportion of their responses to the VR-10 lever as training progressed. For the VR-20+S VR-10 group, the discrimination ratio was also calculated by dividing the number of VR-10 component responses in a block by the total number of responses emitted to both levers in that block. Over training, the subjects in this group also emitted a higher proportion of their responses to the VR-10 lever. However, the rate at which this ratio increased over the course of training was retarded compared to that of the VR-20 VR-10 group. For the VR-20+S VR-20 group, the ratio was calculated by dividing the number of responses emitted during the VR-20+S component in a block by the total number of responses emitted to both levers in that block. The subjects emitted an increasingly greater proportion of their responses to the VR-20+S lever as training progressed. By the end of training, however, the ratio in this group was not as high as in the other two groups. A two-factor ANOVA (group × block) conducted on these data revealed no main effect of group ($F < 1$), but a main effect of block [$F(9,243) = 25.43, p < .001$] and an interaction between the two factors [$F(18,243) = 6.02, p < .001$]. Analysis of the simple main effect of group on each block revealed a statistically significant difference on Blocks 3 and 5-10 [smallest $F(2,243) = 5.00$, all $ps < .01$]. Subsequent Tukey's *HSD* tests revealed that on all blocks where a significant main effect of group was found, all group differences were statistically significant (all $ps < .01$).

These results confirm the findings established in Experiment 1. First, on a concurrent VR VR schedule, animals respond at a higher rate on the manipulandum as-

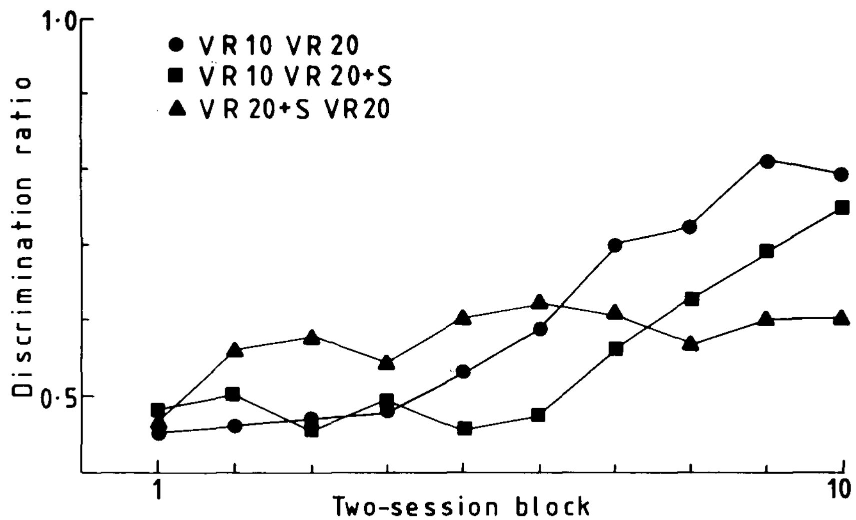

Figure 3. Mean discrimination ratios over two-session blocks for the three groups in Experiment 2.

sociated with the smaller ratio value. Second, inserting a brief stimulus midway through a VR-20 schedule engendered a preference for this schedule with respect to a VR-20 schedule lacking the stimulus (albeit less pronounced than one for a VR-10 schedule). That this preference was established in an initial phase of training, as opposed to after a contingency reversal as in Experiment 1, indicates that the pretraining of the present experiment may have successfully neutralized any lever preferences prior to the introduction of the experimental contingencies.

In the VR-20+S VR-10 group, the presence of a stimulus midway through the larger ratio reduced the relative rate of response on the lever associated with the smaller ratio value and retarded the development of a preference for the latter lever. Taken together, these findings are consistent with the notion that a brief stimulus presented midway through a ratio requirement will act to attenuate the effect of a large ratio requirement on response rate and choice.

EXPERIMENT 3

In this experiment, essentially the same procedures as used in Experiments 1 and 2 were adopted, except that the schedules were presented successively, not concurrently (i.e., a multiple schedule was used). The nature of the contingency in force in a given component was signaled by which lever was inserted into the chamber. There is some evidence (at least for FR schedules) that response rates on multiple schedules tend to be higher in the component associated with the lower ratio requirement (Henton & Iversen, 1978, pp. 224-227).

A measure of the subjects' preferences for the alternative schedules was achieved in Experiment 3 by inserting choice trials with both levers simultaneously available (cf. Logan, 1965). Choice of one lever caused the other to be retracted from the chamber, and the subject then completed the ratio on the chosen lever. On the next component of the multiple schedule, the subject was exposed to the alternative not chosen on the free-choice trial in order to ensure equal exposure to both alternatives.

For one group of subjects, equal VR schedules were presented in both components of the multiple schedule, and a brief stimulus was presented midway through the ratio value of one component. A second group of subjects received a multiple schedule with different ratio values in the two components. It was assumed that the subjects would respond at a higher rate in the smaller ratio component and would choose that component in a free-choice trial. The question of interest was whether the brief stimulus would produce a similar effect on the subjects' behavior in the first group.

Method

Subjects and Apparatus. The subjects were 14 male hooded Lister rats, 5-6 months old, with free-feeding weights ranging from 320 to 360 g and maintained as in Experiment 1. The animals had all previously served in an appetitive classical conditioning experiment in which they had experienced food reinforcement, a clicker, and a tone. The subjects were naive, however, with respect to leverpressing and the light stimulus used in the present experiment. The apparatus was the same as that used in Experiment 1.

Procedure. The subjects needed no magazine training and were taught to leverpress during two sessions of CRF, one on each lever. Each session lasted until the subject obtained 75 reinforcements. All subjects then received two sessions of multiple VR-5 VR-5 training, two sessions of multiple VR-10 VR-10 training, and three sessions of multiple VR-20 VR-20 training. During each of these sessions, one lever was inserted into the chamber and the programmed schedule completed. Reinforcement was then delivered, and the lever was retracted. After an intercomponent interval of 3 sec, the other lever was inserted into the chamber. Each session lasted until the subject had earned 30 reinforcers (i.e., 15 reinforcers on each lever). The subjects were then divided into two groups (n = 7) matched for response rate in each component on the last session of multiple VR-20 training.

One group of rats earned reinforcement on a multiple VR-30 VR-15 schedule. For the first four "trials" of each session, the components alternated, two trials of each schedule type being presented to the subject. On the fifth trial, both levers were inserted into the chamber and the subject was allowed a free choice between them. A response to one lever retracted the other lever, and the selected component was then completed for reinforcement. Following the choice trial, the nonpreferred component was presented to the subject. The components were separated by 3 sec. This sequence of six component presentations was repeated five times during a session; that is, the subjects earned 30 reinforcers and experienced five free-choice trials. The second group of subjects experienced the same treatment, except that the multiple schedule consisted of two VR-30 components, one of which had a stimulus presented halfway through the response requirement. The stimulus was a 500-msec flash of light delivered from the overhead strip light. Training lasted for 24 sessions.

Results and Discussion

The mean response rates for both groups over three-session blocks are displayed in Figure 4. Inspection of these data for the group receiving the multiple VR-30 VR-15 schedule (left panel) reveals that the subjects responded faster during the VR-15 than during the VR-30 component of the schedule. A two-factor ANOVA (component × block) revealed a main effect of component [$F(1,6) = 17.70$, $p < .05$], but not of block or their interaction ($ps > .10$). In the group experiencing brief stimulus presentations during one of the VR-30 components (right panel), the subjects responded faster on the lever associated with the brief stimulus. A two-factor ANOVA (component × block) on these data revealed marginally significant effects of component [$F(1,6) = 5.50$, $.07 > p > .06$] and block [$F(5,30) = 2.32$, $.07 > p > .06$], but no significant interaction ($p > .30$).

The results displayed in Figure 4 demonstrate that rats trained on a multiple VR VR schedule respond at higher rates in the component having the smaller ratio value. In addition, the insertion of a brief stimulus on a multiple VR VR schedule midway through a ratio when the two ratios have equal values produces differences in behavior between the two components. Response rates were greater for the component with the stimulus and followed a similar qualitative trend to that generated by having a smaller ratio size for one of the components.

The mean percentage of choices of the component with the smaller VR value, or of the component that produced

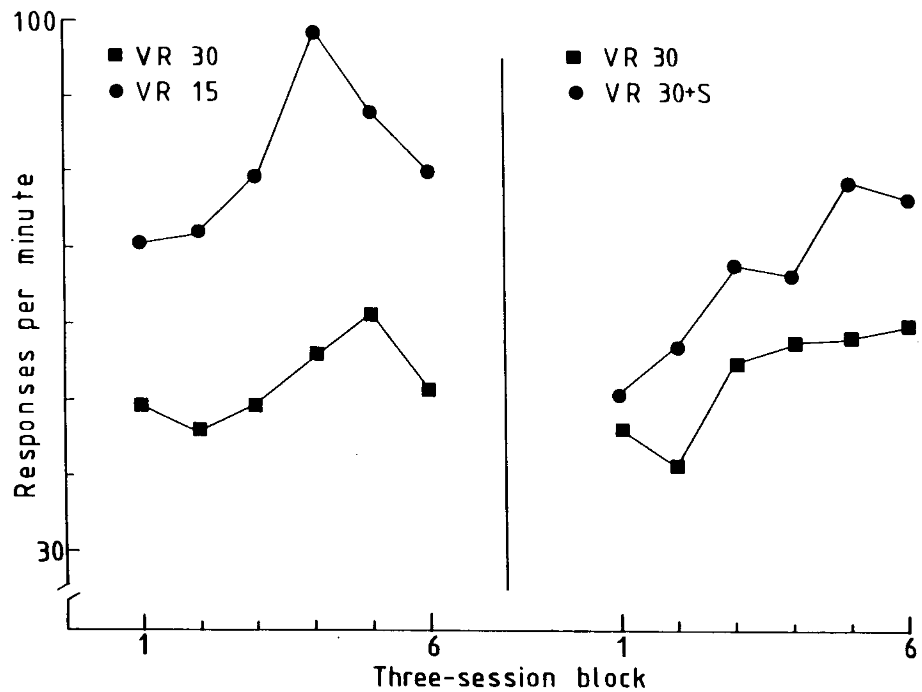

Figure 4. Mean rates of response over three-session blocks for both groups in Experiment 3. Left panel: The subjects receiving the multiple VR-30 VR-15 schedule. Right panel: The subjects receiving the multiple VR-30 VR-30+S schedule (S = brief stimulus presented midway through the ratio).

the brief stimulus, were calculated for the final three-session block. The group receiving the VR-30 VR-15 schedule in Phase 1 chose the VR-15 component on 76% of all probe-choice trials. Matched t tests revealed a statistically significant preference for the lower ratio component [$t(6) = 5.70, p < .001$]. For the group receiving a brief stimulus presented midway through the ratio requirement of one of the components, the subjects chose that component on 66% of all choice trials. This preference for the brief-stimulus component was also statistically significant [$t(6) = 3.33, p < .05$]. To directly compare the two groups, a difference score for each subject was calculated by subtracting the number of choices for the VR-30 component in each of the two multiple schedules from (1) the choices of the VR-15 component in the group experiencing a multiple VR-30 VR-15 schedule or (2) the choices of the VR-30+S component in the group experiencing the multiple VR-30 VR-30+S schedule. The mean difference score for the former group was 7.75; for the latter group, it was 4.75. A t test conducted on these scores revealed no significant difference between them ($p > .10$).

These results, in general, reveal a preference for the component associated with the smaller ratio, or that associated with a brief stimulus presented midway through the ratio. That is, a component associated with a brief stimulus presented midway through the ratio of a multiple VR VR schedule engendered performance similar to the component of a multiple VR VR schedule associated with a smaller ratio value.

GENERAL DISCUSSION

Experiments 1 and 2 demonstrated that rats trained on a concurrent VR VR schedule showed higher rates of response on a lever associated with a lower ratio value. In addition, greater levels of instrumental performance were observed in the component of a multiple VR VR schedule that likewise had a smaller ratio requirement (Experiment 3). In Experiment 2, it was further shown that presenting a brief stimulus midway through the larger ratio component of a concurrent VR-20 VR-10 schedule slowed the development of a difference in the behavior produced between the two components of this schedule. When equal ratio values were associated with each lever on the concurrent VR VR schedule, presenting a brief stimulus midway through one ratio component produced higher rates of responding on that lever than on a lever lacking the stimulus (Experiments 1 and 2). Similarly, when the same ratio requirement was used in both components of a multiple schedule (Experiment 3), presenting a brief stimulus midway through one ratio component generated higher rates than were seen in the other component. Probe-choice trials inserted into the multiple schedule sessions of Experiment 3 revealed that when both components were simultaneously available, rats preferred the smaller ratio schedule. Similarly, a component yielding the brief stimulus was also generally that chosen on probe-choice trials.

The effect of a brief stimulus presented midway through a ratio schedule in the concurrent- and multiple-schedule procedures is qualitatively similar to that produced by using a ratio schedule with a smaller response requirement. That is, such a stimulus appears to reduce the influence of the larger ratio requirement on response rate and choice. The effect of the brief stimulus uncorrelated with reinforcement on these schedules parallels that previously reported by Reed and Hall (1989) for the effects of such a stimulus on simple VR schedules. Reed and Hall found that a simple VR schedule with a stimulus presented partway through the ratio generated much the same response rates as those seen on a simple VR schedule having a response requirement only half as large. This result was taken to be an instance of a quasi-reinforcement effect (see Neuringer & Chung, 1967).

A number of explanations have been offered for the quasi-reinforcement effect. One interpretation is that brief stimuli influence behavior via their conditioned reinforcing properties (Kelleher, 1966). There are, however, several experiments showing that the brief stimuli need not be paired with reinforcement to be effective (Neuringer & Chung, 1967; Squires et al., 1975). The results reported here support this observation: the brief stimulus was presented midway through the ratio schedule and produced its effects on choice behavior despite not being differentially associated with reinforcement. It is possible that a stimulus that is not temporally contiguous with primary reinforcement will acquire some secondary reinforcing properties, perhaps by signaling a reduction in time to the delivery of primary reinforcement (e.g., Fantino, 1981). Although there is nothing in the present data that would discount such a hypothesis, it is worth noting that Reed and Hall (1989) have demonstrated that a stimulus presented midway through a ratio schedule tends to acquire Pavlovian conditioned inhibitory properties. This finding, coupled with others that have established that the hedonic properties of the brief stimulus appear to have little influence on its function (e.g., Keenan & Leslie, 1981), suggests that brief stimuli imposed midway through a schedule requirement do not exert their influence through a mechanism of conditioned reinforcement.

An alternative interpretation is that the brief stimuli acquire discriminative properties and come to signal the operation of the schedule on which they were presented. In the present experiments, presenting a stimulus midway through a ratio schedule might have served the purpose of signaling that a smaller ratio requirement was now in operation. For example, presenting a brief stimulus midway through one component of a concurrent VR-30 VR-30 schedule might effectively signal to the subject that the choice after the stimulus occurred was between a VR-30 and a VR-15 schedule. This implies that immediately following reinforcement the subject would respond equally often to the two components until a brief stimulus is presented. Only after the brief stimulus was presented should a preference for one of the components develop. Unfortunately, no data were collected that might address this question.

The discrimination view is similar to that proposed as an explanation of the quasi-reinforcement effect by Neuringer and Chung (1967) and Squires et al. (1975). This view suggests that the presentation of a brief stimulus midway through a schedule would effectively alter the nature of that schedule. In the present case, a brief stimulus presented midway through a ratio schedule would produce two ratio schedules, each of which would possess a lower response criterion. In the limiting case, a VR-30 schedule would become a second-order FR-2 (VR-15) schedule. The results from the present experiments, though, demonstrate that the effects on response rate and choice behavior of presenting a brief stimulus midway through a ratio schedule are not as dramatic as halving the ratio criterion. However, the present results did demonstrate that a brief stimulus would produce a preference for the component of a concurrent or multiple schedule in which it was presented when the components had equal VR values (Experiments 1, 2, and 3) and would also retard the development of preferences between a large and a small ratio schedule when presented midway through the large ratio criterion (Experiment 2). The brief stimulus appears to at least partially reduce the deleterious effects of a large ratio schedule on response rate. This finding is consistent with the interpretation offered by Reed and Hall (1989).

REFERENCES

Baum, W. M. (1981). Optimization and the matching law as accounts of instrumental behavior. *Journal of the Experimental Analysis of Behavior*, **36**, 387-403.

Cohen, S. L., & Calisto, G. (1981). The effect of brief-stimulus presentation on fixed-ratio second-order schedules. *Journal of the Experimental Analysis of Behavior*, **36**, 329-342.

de Villiers, P. A. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 233-287). Englewood Cliffs, NJ: Prentice-Hall.

Fantino, E. (1981). Contiguity, response strength, and the delay reduction hypothesis. In P. Harzem & M. D. Zeiler (Eds.), *Advances in analysis of behaviour: Vol. 2. Predictability, correlation, and contiguity* (pp. 169-201). Chichester: Wiley.

Henton, W. W., & Iversen, I. H. (1978). *Classical conditioning and operant conditioning: A response pattern analysis*. New York: Springer-Verlag.

Keenan, M., & Leslie, J. C. (1981). Effects of fixed-time shocks and brief stimuli on food-maintained behavior of rats. *Journal of the Experimental Analysis of Behavior*, **36**, 353-361.

Kelleher, R. T. (1966). Conditioned reinforcement in second-order schedules. *Journal of the Experimental Analysis of Behavior*, **9**, 475-485.

Lea, S. E. G. (1979). Foraging and reinforcement schedules in the pigeon: Optimal and non-optimal aspects of choice. *Animal Behavior*, **27**, 875-886.

Lieberman, D. A., Davidson, F. H., & Thomas, G. V. (1985). Marking in pigeons: The role of memory in delayed reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes*, **11**, 611-624.

Logan, F. A. (1965). Decision-making by rats: Delay versus amount of reward. *Journal of Comparative & Physiological Psychology*, **59**, 1-12.

NEURINGER, A. J., & CHUNG, S. H. (1967). Quasi-reinforcement: Control of responding by a percentage-reinforcement schedule. *Journal of the Experimental Analysis of Behavior*, **10**, 45-54.

RACHLIN, H. (1978). A molar theory of reinforcement schedules. *Journal of the Experimental Analysis of Behavior*, **30**, 345-360.

REED, P., & HALL, G. (1989). The quasi-reinforcement effect: The influence of brief stimuli uncorrelated with reinforcement on variable ratio schedules. *Learning & Motivation*, **20**, 242-261.

SQUIRES, N., NORBORG, J., & FANTINO, E. (1975). Second-order schedules: Discrimination of components. *Journal of the Experimental Analysis of Behavior*, **24**, 157-171.

STADDON, J. E. R., & INNIS, N. K. (1969). Reinforcement omission on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, **12**, 689-700.

(Manuscript received January 10, 1991;
revision accepted for publication August 17, 1992.)