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PREFERENCE FOR AND EFFECTS OF VARIABLE- AS OPPOSED TO FIXED-REINFORCER DURATION[1]

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Pigeons were trained on multiple schedules in which a fixed number of pecks produced either a fixed or a variable period of access to food, the average variable-duration reinforcement equalling the fixed. Pecking rates were generally higher during the variable-duration component. Subsequent performance on concurrent schedules revealed an initial preference for variable-duration reinforcement for all subjects; for most subjects, this preference was sustained. For one subject, the average variable duration was gradually reduced to half the fixed duration: continued preference for the variable component resulted in a loss of up to 30% of available reinforcement time. A return to multiple schedules with unequal pay-off shifted the preference to the greater fixed duration, and this preference was maintained even when the variable duration was again raised to equal the fixed duration. For the remaining subjects, the initial variable-duration preference on concurrent schedules was gradually replaced by a side preference. When the range of variable durations was varied, keeping the average variable duration equal to the fixed, the occasional longer reinforcers sustained a preference for variable-reinforcer durations for three of the four subjects.

When investigating the effects of schedules, the experimenter usually employs a fixed duration or amount of reinforcement: the reinforcer is available for a fixed duration of time (*e.g.*, a pigeon had access to grain for 3 sec), or a fixed amount of the reinforcer is delivered (*e.g.*, a 45-mg food pellet). Although it is also possible to employ variable durations or amounts of reinforcement, there has been little research in this area. This is odd in view of the extensive investigations of variable schedules of reinforcement, such as variable-interval and variable-ratio schedules. Investigators have compared fixed and variable schedules of reinforcement in choice situations, and variable schedules have generally been preferred to fixed (Herrnstein, 1964; Fantino, 1967; Killeen, 1968; Davison, 1969, 1972). However, little seems to be known about the effects of fixed- compared to variable-reinforcer magnitude. Given the option between constant- and variable-reinforcer magnitudes, will a subject prefer one to the other? If fixed- and variable-reinforcer magnitudes are scheduled in different components of multiple schedules, will there be a differential effect upon performance? The present study explored these questions.

METHOD

Subjects

Three adult Roller pigeons and two adult Nun[3] pigeons had brief experimental histories including conditioning of pecking and turning and color discrimination. The birds were maintained at 80% of their free-feeding weights.

Apparatus

A 31 cm by 33 cm Lehigh Valley pigeon chamber with a two-key panel was wired so that each pecking key could be illuminated from behind by a green or a red light or could be unlit. The keys were 2.5 cm in diameter, 14 cm apart, and 20.5 cm from the floor. A houselight centered at the top of the panel was lit except during reinforcement and timeout, and a light inside the feeder was lit during reinforcement.

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[2] Reprints may be obtained from Susan Essock, Psychology Department, Brown University, Providence, R.I. 02912.

[3] Nun and Roller pigeons are small varieties that generally have free-feeding weights of 350 to 400 g. The subjects used in this experiment were hatched and raised in flyways at Mount Holyoke College.

Variable-duration reinforcement (VS^R) was arranged by a combination of six timers, each one of which was attached to five positions on a 30-step stepper. Each time a VS^R was delivered, the stepper advanced one position. The stepper could be set to any one of the 30 positions at the beginning of each session. Relay circuitry, electromechanical counters, and a Gerbrands six-channel event marker were used for scheduling and data recording.

Procedure

Variable-duration reinforcement followed completion of a fixed-ratio requirement during one key color, and fixed-duration reinforcement (FS^R) followed completion of the same fixed-ratio (FR) requirement during the other key color. During multiple sessions, one key was lit, and reinforcement could be obtained only by completing the ratio requirement on that key. During concurrent (*conc*) scheduling, both keys were lit and VS^R could be obtained by pecking one key, and FS^R could be obtained by pecking the other. In each session, unless otherwise noted, red and green stimuli each appeared the same number of times, the frequencies with which they appeared on the right and left sides were equalized, and the side and order of stimulus presentations were determined using Fellow's (1967) sequences.

For Subjects 1, 2, and 3, VS^R followed an FR 30 on a red key and FS^R followed an FR 30 on a green key. For Subjects 4 and 5, the colors were reversed. Subjects 1, 2, and 3 were studied every other day; Subjects 4 and 5 were studied daily.

The first session for each subject was multiple (continuous reinforcement, variable-duration reinforcement 5-sec) (continuous reinforcement, fixed-duration reinforcement 5-sec) or *mult* (CRF, VS^R 5) (CRF, FS^R 5)—every response produced either fixed- or variable-duration reinforcement. The FR requirement was gradually increased until the sixth session was *mult* (FR 30, VS^R 5) (FR 30, FS^R 5). Data from these sessions were not analyzed, and session numbers given in Table 1 and the figures omit these initial sessions. The ratio requirement for all remaining trials was kept at FR 30. A 4-sec timeout followed each reinforcement on a multiple schedule. Subsequent multiple-schedule sessions alternated six stimulus presentations of one color and six stimulus presentations of the other color, until there were 36 stimulus presentations. Time in seconds from the onset of the key light to completion of the FR was recorded for each color on each side during the final 24 presentations of each session.

After five to nine sessions on these multiple schedules, preference was measured during *conc* (FR 30, VS^R 5) (FR 30, FS^R 5) presentations. A session then consisted of 12 multiple presentations followed by a 12-sec timeout and then 24 concurrent presentations. A 4-sec timeout followed reinforcement when a multiple schedule was in effect; there was no timeout after reinforcements following concurrent presentations.

Range of VS^R Duration

Initially, all multiple and concurrent sessions were studied with FS^R 5-sec and with various combinations of the following VS^R durations arranged to average 5 sec: 2, 3, 4, 6, 7, 8 sec. When performance stabilized as a given subject showed either a consistent tendency to respond to FS^R or VS^R on the concurrent schedule or else perseverated on one side or the other irrespective of color, the durations of the VS^R were systematically changed. The number of concurrent and multiple schedule sessions at each VS^R range for Subjects 2 to 5 are given in Table 1. Six weeks after the original experiment had ended, all subjects were returned to the concurrent schedule with a VS^R range of 4 to 10 sec. These additional sessions were conducted without "training sessions" on multiple schedules, and without multiple presentations preceding the daily exposures to the concurrent schedule.

VS^R Reduction

After Subject 1 demonstrated a consistent preference for the VS^R component of a concurrent schedule, the average duration of the VS^R was gradually reduced from 5 sec to 2.6 sec, while the duration for the FS^R remained at 5 sec. The increments by which the VS^R was reduced can be read from Figure 4b. Following this period of VS^R reduction on concurrent schedules, the subject was given six sessions on multiple schedules in which the average VS^R was approximately half that of FS^R: *mult* (FR 30, VS^R 2.7) (FR 30, FS^R 5). For the remaining multiple and concurrent

Table 1

Number of concurrent and multiple schedule sessions at each VS^R range for Subjects 2, 3, 4, and 5.*

Schedule VS^R Range (in sec)	*mult 2-8*	*conc 2-8*	*mult 2-8*	*conc 2-8*	*mult 2-10*	*conc 2-10*	*mult 3-10*	*conc 3-10*	*mult 4-10*	*conc 4-10*	*conc 4-10*
Subject 2	1-6	7-12	13-15	16-18	19-24	25-33	—	34-39	40-45	46-51	52-58
Subject 4	1-9	10-17	—	—	—	—	18-23	24-27	28-32	33-43	44-56
Subject 5	1-9	10-14	—	—	—	—	15-19	20-29	30-35	36-41	42-49
Subject 3	1-5	6-10	11-13	14-15	16-21	22-38	—	—	39-43	44-48	49-57

*Each concurrent schedule session was preceded by 12 multiple presentations except those to the right of the double line, which began directly with concurrent presentations. The double line indicates a six-week period during which the subjects were not exposed to the apparatus. The VS^R durations at each range were: 2-8: 2, 3, 4, 6, 7, 8 sec; 2-10: 2, 3, 4, 4, 7, 10 sec; 3-10: 3, 3, 4, 4, 6, 10 sec; 4-10: 4, 4, 4, 4, 4, 10 sec.

sessions, the average VS^R was again equal to the FS^R of 5 sec; but the range for VS^R was 4 to 10 sec.

RESULTS

Figure 1 gives the percentage of fixed-ratio trials completed on the VS^R color during concurrent schedule sessions for Subjects 2, 3, 4, and 5. While the range of VS^R durations was 2 to 8 sec, each subject initially preferred variable- to fixed-duration reinforcement, but the percentage of trials completed on the VS^R color gradually decreased. Percentages near 50% indicate sessions with much side perseveration, rather than sessions in which the subject switched randomly from one side to the other. Perseveration requires the least amount of effort and would be expected if the two alternative reinforcer durations controlled nearly equal response probabilities.

In any one session, there were 11 occasions when a subject would have to switch keys to follow a given color. The cross-overs, which also illustrate the progression of reinforcer preference, were termed "follows" and are graphed in Figure 2. This measure shows that three of the four subjects followed the VS^R color more often than the FS^R color, and that Subject 3 again preferred FS^R during most sessions.

Whenever the data for an entire session indicate a marked preference for either reinforcement contingency, the subjects generally followed the preferred key color as soon as the color of the keys changed. Where the data indicate only slight preference, subjects tended to remain on one side of the apparatus. During sessions with persistent side perseveration, when facing the non-preferred key color, the subjects frequently turned their heads toward the preferred key color and sometimes switched to the preferred key color after a few pecks on the non-preferred color. However, when the preferred color appeared on the key in front of them, subjects seldom turned their heads in the direction of the other key, nor did they switch to that key. Switching never occurred when a bird had emitted more than six pecks on a given key.

When the range of VS^R was changed to extend from 2 to 10 or 3 to 10 sec, three of the four subjects generally exhibited a moderate but persistent preference for VS^R, but much side perseveration still occurred. The other subject (Subject 3) showed a marked preference for the FS^R when the VS^R range was 2 to 10 sec. When the VS^R range was changed to 4 to 10 sec, this FS^R preference disappeared and side perseveration recurred in the next series of concurrent sessions, suggesting a preference change in the same direction as the other subjects despite an overall bias for FS^R.

When the subjects were removed from the experimental situation for six weeks and then returned to concurrent schedules (which were not prefaced with multiple presentations as before), their performance was essentially the same as during the previous sessions when the VS^R range was 4 to 10 sec (Figures 1, 2). The preferences thus appear to be quite stable.

Figure 3 shows the average pecking rates for trials terminating in VS^R and FS^R on multiple schedules. These data reflect rates for the final 24 presentations of each multiple session. Rates were not computed for the initial 12 multiple schedule presentations nor for

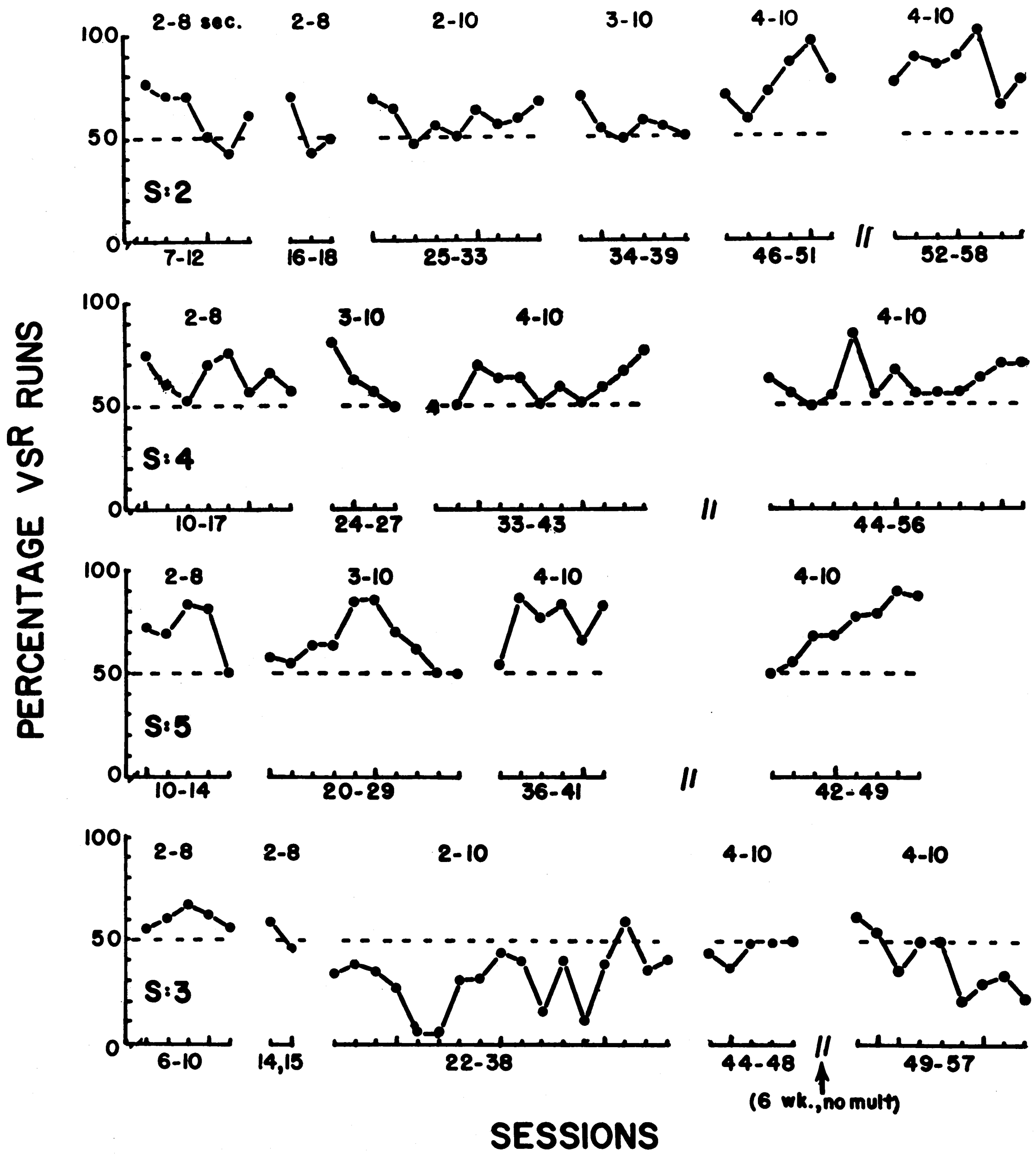

Fig. 1. Percentage of trials per session completed on VS^R component of concurrent schedule for Subjects 2, 3, 4, and 5. Points below 50% indicate FS^R preference. Range of VS^R values for each group of sessions is given above the data for those sessions. Breaks between groups of sessions indicate shifts to multiple-schedule sessions.

the 128 multiple presentations that preceded each concurrent schedule session. For each of the four subjects, the pecking rate was slightly, but quite consistently higher on the VS^R color than on the FS^R color. Even Subject 3 responded more rapidly on the VS^R color during 16 of the 18 sessions on multiple schedules. However, the difference in its response rate was greater during the first five sessions that preceded concurrent sessions in which FS^R was preferred. There appear to be no systematic changes in the differences *between* VS^R and FS^R rates attributable to changes in the range of VS^R durations.

The data from all subjects show an initial preference for variable-duration reinforce-

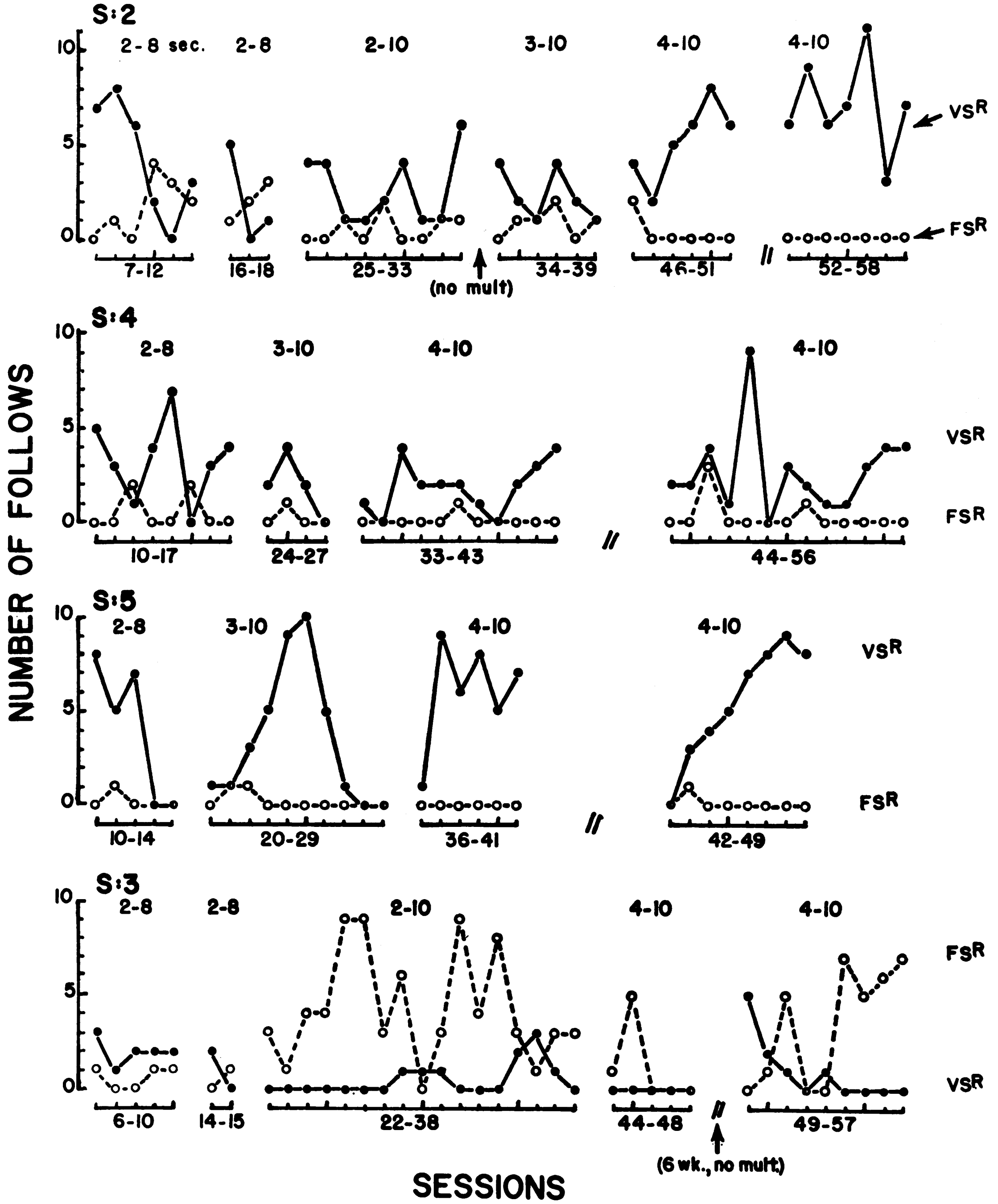

Fig. 2. Number of Follows of VS^R or FS^R when key colors changed during concurrent schedules for Subjects 2, 3, 4, and 5. (Eleven possible follows per session.) Range of VS^R for each group of sessions is given above the plot of the data for those sessions. Breaks between groups of sessions indicate shifts to multiple-schedule sessions.

ment, and for one subject (Subject 1) this VS^R preference was maintained for 19 sessions (Figure 4a). In an attempt to offset this preference, the average duration of VS^R for this subject was lowered while that of FS^R was maintained at 5 sec (Figure 4b, Sessions 20 to 52). At the end of this period the average VS^R duration was 2.6 sec, or about half the FS^R

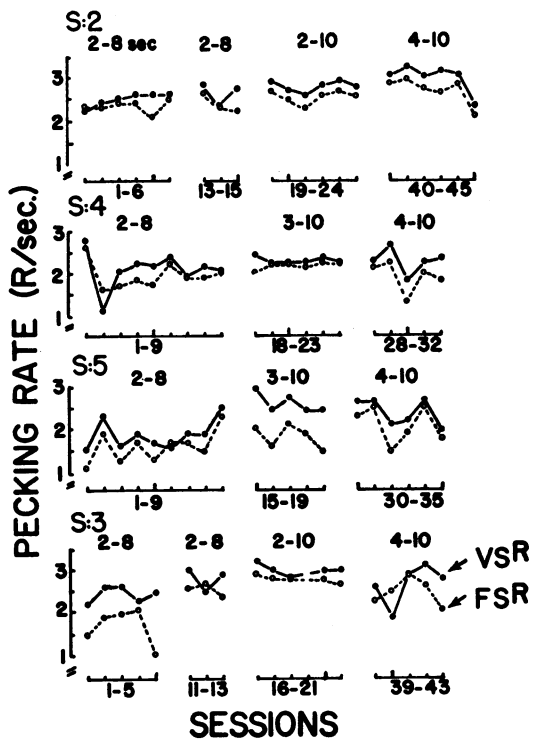

Fig. 3. VS^R and FS^R rates of responding during multiple schedule presentations for Subjects 2, 3, 4, and 5. Range of VS^R values for each group of sessions is given above the data for those sessions. Breaks between groups of sessions indicate shifts to concurrent-schedule sessions.

duration, and the subject was perseverating on one key (Figure 4b). The number of follows on VS^R had decreased from 11 (the maximum possible) to zero, resulting in considerable reinforcement loss (Figure 4c). When the VS^R duration was 2.6 sec, side perseveration produced a 24% reduction in the maximum possible feeding time from the concurrent schedule.

The increase in pecking rate during *mult* (FR 30, VS^R 2.7) (FR 30, FS^R 5) indicated a shift in preference, which was demonstrated when the bird was returned to *conc* (FR 30, VS^R 2.9) (FR 30, FS^R 5) (Figure 4). Whereas the subject might eventually have shifted to a FS^R preference with further sessions on concurrent schedules, the performance changed almost immediately on the multiple schedule. It would seem that the multiple schedule provided a more favorable situation for discriminating the discrepancy in VS^R and FS^R average durations than did the concurrent schedule.

When average VS^R and FS^R reinforcer durations were again equalized, Subject 1 showed no clear differences in response rate during multiple-schedule sessions (Figure 4d). When Subject 1 was then returned to concurrent schedules with a VS^R range of 4 to 10 sec, the preference for FS^R was maintained, even though the VS^R range of 4 to 10 sec had produced the greatest preference for VS^R for Subjects 2 and 5 (Figures 1, 2). The final sessions after the six-week break, however, show a fairly consistent preference for VS^R, indicating that prolonged exposure in the apparatus may have partially compensated for the effect of the period of unequal VS^R and allowed for a return to the original VS^R preference.

DISCUSSION

Higher rates of responding were maintained by VS^R than by FS^R during multiple schedules, and VS^R tended to control more responding during concurrent schedules. Each subject showed at least an initial preference for VS^R during concurrent schedules, although one subject later developed a FS^R preference even when the average VS^R duration was equal to FS^R. Subjects apparently tended to opt for the occasionally longer VS^R rather than for the constant FS^R. With a 4- to 10-sec VS^R range the VS^R preference was more pronounced, suggesting that the magnitude of the potential reinforcer may be a greater determinant of preference than variability *per se* (Figures 1, 2).

In this study, relative response rates during the two components of the multiple schedule were usually, but not always, related to subsequent performance on the comparable concurrent schedule. During the initial sessions with multiple schedules, the VS^R rate exceeded the FS^R rate for four of the five subjects, and for all subjects the VS^R color controlled more responding during the concurrent schedules that followed. However, the later preference for FS^R demonstrated by Subject 3 on concurrent schedules was not signalled by higher FS^R rates on the multiple schedules that preceded them. If preference is defined in terms of choice behavior, then relative pecking rates on multiple schedules generally, but not always, predicted subsequent preferences demonstrated on concurrent schedules. Hence, rate measures from

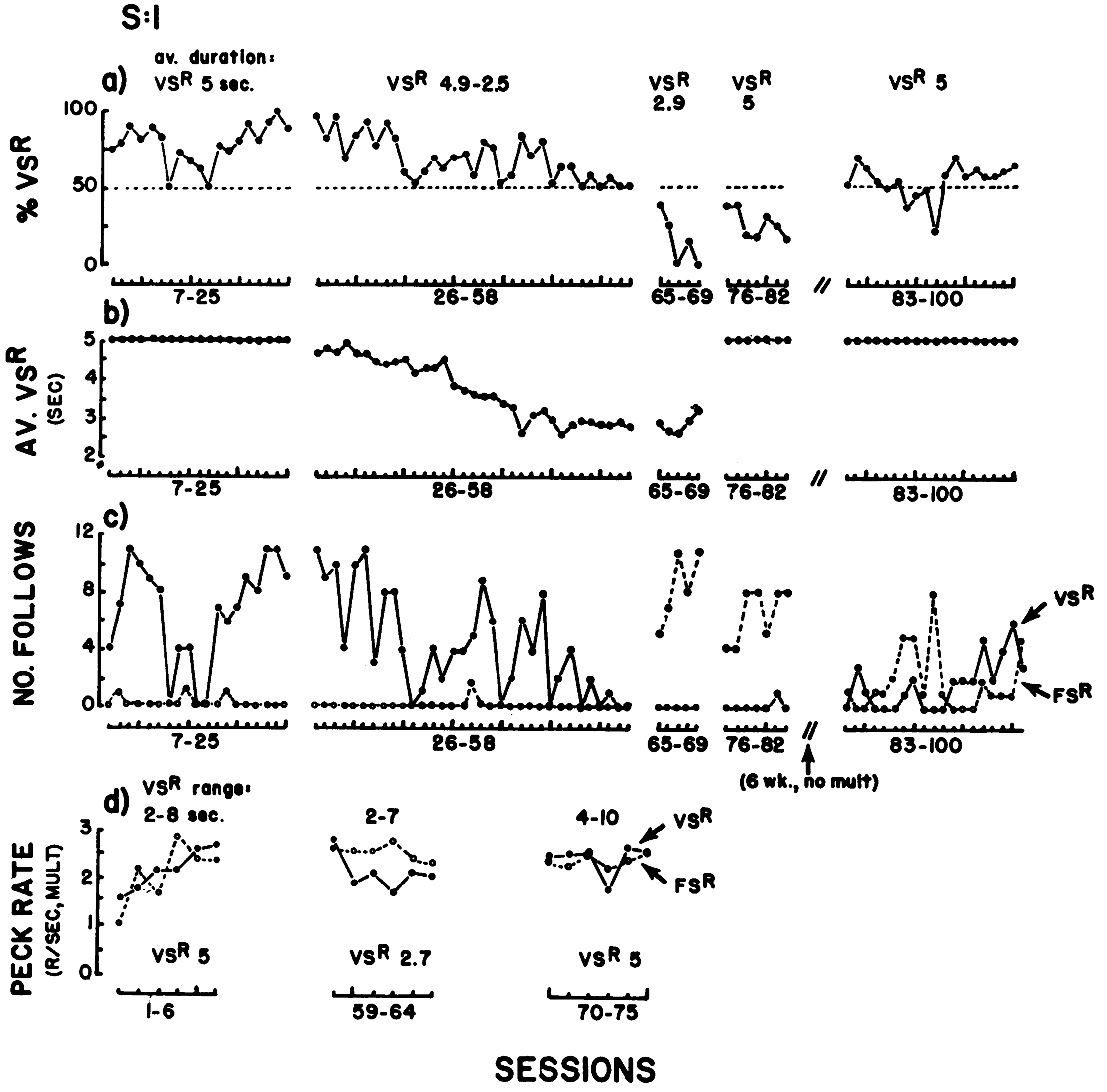

Fig. 4. Data from Subject 1. Range of VS^R values for each group of sessions is given above the data for those sessions. Concurrent schedule data-breaks between groups of data indicate shifts to multiple-schedule sessions.

4a. Percentage of trials per session completed on VS^R component of concurrent schedule. Points below 50% indicate FS^R preference.

4b. Average VS^R duration per session.

4c. Number of Follows of VS^R or FS^R when key color changed during concurrent schedules. (Eleven possible follows per session.)

Multiple-schedule data. Breaks between groups of data indicate shifts to concurrent-schedule sessions.

4d. VS^R and FS^R rates of responding during multiple-schedule presentations.

multiple schedules are not necessarily accurate gauges of preference in choice situations.

Herrnstein (1964) suggested that the higher response rate of pigeons on variable-interval (VI) schedules over comparable fixed-interval (FI) schedules is determined by the occasional short VI intervals: that the shorter intervals are weighted more heavily than the longer ones. If, in the present study, the short 2-sec access to food was a greater determinant of rate than the long 8-sec access, the subjects should have preferred the constant 5-sec FS^R. On the other hand, if the longer reinforcer durations were greater determinants than the shorter ones, then VS^R should have been preferred (if long and short VS^R intervals were weighted equally, no preference would be expected). Since all subjects showed an initial preference for VS^R, it seems as though the occasional long reinforcer durations were influencing the birds' performance. Our findings, like Herrnstein's, suggest that the assets more than balance the liabilities, whether they be longer access to reinforcement (present study) or shorter intervals between reinforcement (Herrnstein, 1964).

The present data conflict with those of Staddon and Innis (1966), which suggest that pigeons integrate amount of reinforcement linearly. Using concurrent VI schedules, they found no rate or preference differences for two pigeons choosing between fixed and variable amounts of reinforcement. Major differences between the Staddon and Innis study and the present one are that this study used a larger average reinforcer size (5 sec as compared to 3), and used FR schedule components rather than VI components. While no concise statements about effects of the range of VS^R can be made from the present data, there does appear to be a trend toward increasing VS^R preference (or decreasing FS^R preference for Subject 3) as the lower limit of the VS^R is raised. This suggests that the smaller reinforcer durations might not have been sufficiently reinforcing to sustain responding. Some of the present subjects wing-flapped after the delivery of 2-sec reinforcers, suggesting that these brief reinforcer durations, at least when longer duration have been available, may have had aversive qualities. Staddon and Innis used VS^R values of either 1, 2, 3, 4, and 5 sec or 1, 1, 1, and 9 sec. For the first VS^R range, all values were at or below the present mean value, and the second VS^R range consisted mainly of reinforcement durations that the present data suggest may have been too brief to sustain responding when the larger FS^R option was available. The brief reinforcer durations used by Staddon and Innis may have prevented the development of a VS^R preference.

A ratio schedule was used in the present study to try to minimize the potential for superstitious switching between keys during concurrent schedule performance. If variability in reinforcement duration has an effect on response rate (either incremental or decremental), this will in turn result in an increase or decrease in reinforcement rate on ratio schedules. Thus, either VS^R or FS^R preference could develop from variability of response rate, hence reinforcement density, on a ratio schedule. But if variability *per se* was the only factor initially increasing rate, the choice differential in favor of VS^R should have decreased as the amount of variability decreased. This was not the case. As already noted, the strongest VS^R preferences occurred when VS^R durations were 4, 4, 4, 4, 4, and 10 sec—the *least* variable of all the VS^R ranges used.

In a study that used pigeons on FI schedules with reinforcer durations comparable to those used in this study, Staddon (1970) demonstrated that response rate varied inversely with the duration of reinforcement preceding each FI. If Staddon's results can be applied to FR schedules (present study) as well as FI, then VS^R response rates in this study should have been greatest when the VS^R range was 2 to 8 sec and least when the range was 4 to 10 sec. Furthermore, the FS^R rate should have most nearly matched the VS^R rate when the VS^R range was 4 to 10 sec. The positive feedback produced by increased rates during ratio schedules should then produce a VS^R preference that should gradually vanish as the VS^R range is shifted from 2 to 8 sec to 4 to 10 sec. These predictions are contrary to the effects seen. VS^R preference tended to increase as the VS^R range was shifted from 2 to 8 sec to 4 to 10 sec. Furthermore, differences between the VS^R and FS^R response rates on multiple schedules were more disparate with a VS^R range of 4 to 10 sec than at other VS^R ranges. Again, it does not appear that VS^R or FS^R preference developed on the basis of reinforcement rate alone. Rather, the results seen here for variable- *versus* fixed-reinforcer durations seem to parallel Herrnstein's (1964) finding indicating non-linear magnitude integration—both suggest a preference for the occasional longer reinforcer duration or shorter interval between reinforcements.

The only period in which FS^R rates consistently exceeded VS^R rates occurred when the FS^R duration greatly exceeded the average VS^R duration (Subject 1, Figure 4d, Sessions 59 to 64). These sessions were preceded by a period during which Subject 1 demonstrated a persistent preference for VS^R even while the average VS^R duration was gradually decreased to half the available FS^R (Figure 4, Sessions 26 to 58). This preference may be in part attributable to the subject's extended (19 sessions) history on concurrent schedules in which the VS^R and FS^R were equal, in that non-linear integration of reinforcer duration might have been established or facilitated during this period. The occasional long VS^R duration was apparently sufficient to sustain the VS^R preference, even when the average VS^R duration was less than the FS^R alternative. Fantino (1967), Davison (1969, 1972), and Killeen (1968) give similar examples of apparent non-linear integration of reinforcer duration resulting in predictable reinforcement loss. In addition, Weiner (1965) showed that human subjects often sustain preventable reinforcement loss by continuing to respond at rates that become inappropriate when schedule contingencies are changed. Had the average VS^R duration on concurrent schedules been further reduced, the subject might have eventually opted for FS^R. But when the alternative "simultaneous choice" of the concurrent schedule was eliminated by returning the subject to a multiple schedule, the overall disparity between VS^R 2.7 and FS^R 5 produced higher pecking rates on the FS^R color. The subsequent preference for FS^R on concurrent schedules was not detrimental in terms of reinforcement loss because the average reinforcement during VS^R and FS^R was the same, but it seems reasonable to attribute the rather dramatic change in preference to this subject's history of reinforcement contingencies.

REFERENCES

Davison, M. C. Successive interresponse times in fixed-ratio and second-order fixed-ratio performance. *Journal of the Experimental Analysis of Behavior*, 1969, **12**, 385-389.

Davison, M. C. Preference for mixed-interval *versus* fixed-interval schedules: number of component intervals. *Journal of the Experimental Analysis of Behavior*, 1972, **17**, 169-176.

Fantino, E. Preference for mixed- *versus* fixed-ratio schedules. *Journal of the Experimental Analysis of Behavior*, 1967, **10**, 35-43.

Fellows, B. J. Chance stimulus sequences for discrimination tasks. *Psychological Bulletin*, 1967, **67**, 87-92.

Herrnstein, R. J. Aperiodicity as a factor in choice. *Journal of the Experimental Analysis of Behavior*, 1964, **7**, 179-182.

Killeen, P. On the measurement of reinforcement frequency in the study of preference. *Journal of the Experimental Analysis of Behavior*, 1968, **11**, 263-269.

Staddon, J. E. R. Effect of reinforcement duration on fixed-interval responding. *Journal of the Experimental Analysis of Behavior*, 1970, **13**, 9-11.

Staddon, J. E. R. and Innis, Nancy K. Preference for fixed *vs.* variable amounts of reward. *Psychonomic Science*, 1966, **4**, 193-194.

Weiner, H. Conditioning history and maladaptive human operant behavior. *Psychological Reports*, 1965, **17**, 935-942.

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