

*FIXED VERSUS VARIABLE SEQUENCES OF  
FOOD AND STIMULUS PRESENTATION IN  
SECOND-ORDER SCHEDULES<sup>1</sup>*

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Three pigeons were exposed to a second-order schedule in which the behavior specified by a fixed-interval component schedule was reinforced according to a ratio overall schedule. The completion of components not followed by food was signalled by a brief stimulus never paired with food. Food and the stimulus occurred in a random sequence or in fixed alternation, but the overall schedules (variable ratio 2 or fixed ratio 2) ensured that an equal number of food and brief-stimulus presentations occurred in each session. The control exerted by the food and by the brief stimulus was measured by overall response rates, mean pauses, frequency distributions of pauses, and response patterning across components. In general, the stimulus controlled patterns of behavior more similar to those controlled by food when food and the stimulus occurred in a random sequence than when they occurred in fixed alternation.

*Key words:* second-order schedules, fixed-interval components, nonpaired brief stimuli, schedule control, conditioned reinforcement, omission effect, key peck, pigeons

Kelleher (1966*b*) defined a second-order schedule as one in which the behavior specified by a schedule is treated as a unit that is itself reinforced according to some schedule of primary reinforcement. A second-order schedule in which a fixed-interval (FI) component is reinforced by a fixed-ratio (FR) overall schedule is conventionally designated FR (FI) (Kelleher, 1966*b*). In brief stimulus second-order schedules, completion of the component schedule is accompanied by the delivery of a reinforcer such as food or by the delivery of a brief stimulus, such as a flash of light, which may or may not also be delivered when food is presented.

Stimuli paired with food may control response rates and patterning in a manner similar to food (*e.g.*, Byrd and Marr, 1969; de Lorge, 1967, 1969; Kelleher, 1966*b*; Marr, 1969; Thomas and Blackman, 1974; Zeiler,

1972). The study of second-order schedules with these brief stimuli is important in the investigation of conditioned reinforcement, because this procedure enables a clear demonstration that a previously neutral stimulus can acquire the power to act like a primary reinforcer in maintaining appropriate schedule-controlled patterns of responding over long periods of time. The effects of brief nonpaired stimuli in second-order schedules are more equivocal, however. Although several reports have suggested that nonpaired stimuli do not control behavior similar to that controlled by food (*e.g.*, Byrd and Marr, 1969; de Lorge, 1967, 1969, 1971; Kelleher, 1966*b*; Malagodi, DeWeese, and Johnston, 1973; Marr, 1969), demonstrations of such control have appeared (*e.g.*, Cohen and Stubbs, 1976; Kelleher, 1966*b*; Squires, Norborg, and Fantino, 1975; Stubbs, 1971; Stubbs and Cohen, 1972; Stubbs and Silverman, 1972). The findings that nonpaired stimuli can exert such effects is important because of the long-standing assumption that stimuli must be paired with primary reinforcers to become conditioned reinforcers.

The present experiment therefore attempted to provide detailed and quantitative data to show the acquisition of control by a nonpaired brief stimulus and the session-to-session stability of these effects, data which have been lacking in most previous reports of the effects of nonpaired stimuli, and indeed, of paired

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stimuli. Typically, the schedule control exerted by stimuli is assessed with general reference to the effects of food usually observed in simple schedules (e.g., with reference to Ferster and Skinner, 1957), and is not compared directly with that exerted by food within subjects and within the sessions in which the stimulus is presented. For example, fixed-interval components have been the most widely investigated in second-order schedules, yet only one report (Thomas and Blackman, 1974) (in which paired stimuli were used) has provided any quantitative comparisons of pausing, which is characteristic of fixed-interval responding. Similarly, only one report (Stubbs, 1971) has included any quantitative comparisons of response patterning after food with that after the stimulus.

Examination of the available data reveals that the behavior controlled by a stimulus (whether paired or nonpaired) tends to be more similar to that controlled by food when variable rather than fixed overall schedules are used (e.g., see Kelleher, 1966a; Stubbs, 1971). Similarly, Boren (1973) in a second-order schedule of matching-to-sample found that the effects of the same *paired* stimulus were different according to the nature of the overall schedule; behavior was maintained when the stimulus and food were arranged in a variable order, but broke down when they were arranged in a fixed sequence. The present experiment therefore attempted a direct comparison between random scheduling of a nonpaired stimulus with fixed scheduling while keeping the overall frequency of food and stimuli equal in both conditions, i.e., VR 2 (FI 1-min:Sn) *versus* FR 2 (FI 1-min:Sn) (see Stubbs, 1971). An ABA reversal design was incorporated.

## METHOD

### *Subjects*

Three experimentally naive male pigeons, approximately 3-yr old at the start of the experiment, were maintained at 80% of their free-feeding weights. They were housed individually, water and grit being freely available in the home cages.

### *Apparatus*

Three operant-conditioning chambers consisting of three-key panels (Lehigh Valley Electronics, model 141/10) mounted in a model

1417C sound-attenuating chamber were used. Only the center key was operative and could be transilluminated by red or yellow light; the side keys were always dark. General illumination was provided by a houselight located above the center key. Programming and recording was achieved by an on-line computer (Digital Equipment Corporation, PDP-9). Responses and stimulus presentations were also recorded on cumulative recorders and counters.

### *Procedure*

The center response key was always red, except during reinforcement or stimulus presentations. Reinforcement consisted of 3-sec access to mixed grain, with the response key darkened and the food magazine illuminated by white light. After preliminary key-peck training and three sessions with each response producing food, the schedule was changed. In Phase 1 the first peck after the illumination of the houselight at the start of the session produced 3-sec access to grain. When the food cycle ended, the response key was lit again and thereafter the first peck after 1 min was followed by food (FI 1-min schedule). Daily sessions terminated after 60 fixed intervals. Training continued for a minimum of 30 days and until the difference between the mean response rate of three successive days and that of the immediately preceding three days was less than 5% (Schoenfeld, Cumming, and Hearst, 1956). Total sessions were 51 for P1, 40 for P2, and 44 for P3.

In Phase 2 (50 sessions) food presentations were omitted following 50% of the FI 1-min components. Responses that completed fixed intervals but did not produce food changed the key color from red to yellow for 0.5 sec. Intervals ended with food or the stimulus with an equal probability of 0.5 as determined by a random-number generator. The schedule was thus a VR 2 (FI 1-min:Sn) second-order schedule.

In Phase 3 (35 sessions), 50% of the fixed-interval components continued to end with food, and components that did not end with food still ended with the stimulus. However, food and stimulus presentations now occurred in fixed alternation, intervals ending with food always being followed by intervals ending with the stimulus, and *vice versa*. This was therefore an FR 2 (FI 1-min:Sn) schedule.

In Phase 4 (25 sessions) the VR 2 (FI 1-min:Sn) schedule was re-imposed. Finally, the simple FI 1-min schedule was re-established for 25 sessions (Phase 5).

### RESULTS

Figure 1 shows the daily overall response rates in fixed intervals after food and after the stimulus. The response rates after the stimulus were usually higher than after food, but this difference was greatest in Phase 3 (FR 2 overall schedule). With P1 in Phases 2 and 4, response rates after food and after the stimulus were very similar.

Figure 2 shows the mean pauses (time to the first response) after food and after the stimulus

for each session of Phases 2, 3, 4, and 5 and the last 10 sessions of Phase 1. With P1 and P2, pauses after the brief stimulus were initially very short in Phase 2 (VR 2 overall schedule) but developed with continued training. This pausing decreased in Phase 3 (FR 2 overall schedule), but developed again on the return to the VR 2 overall schedule in Phase 4. Post-stimulus pausing developed with P3, but only in Phase 4.

Figure 3 shows frequency distributions of the individual pauses that contributed to the means presented in Figure 2. Performance was characterized by a high percentage of 0- to 4-sec pauses after the stimulus during the first five days of Phase 2 (Row B). By the last five days of Phase 2, the percentage of short pauses after

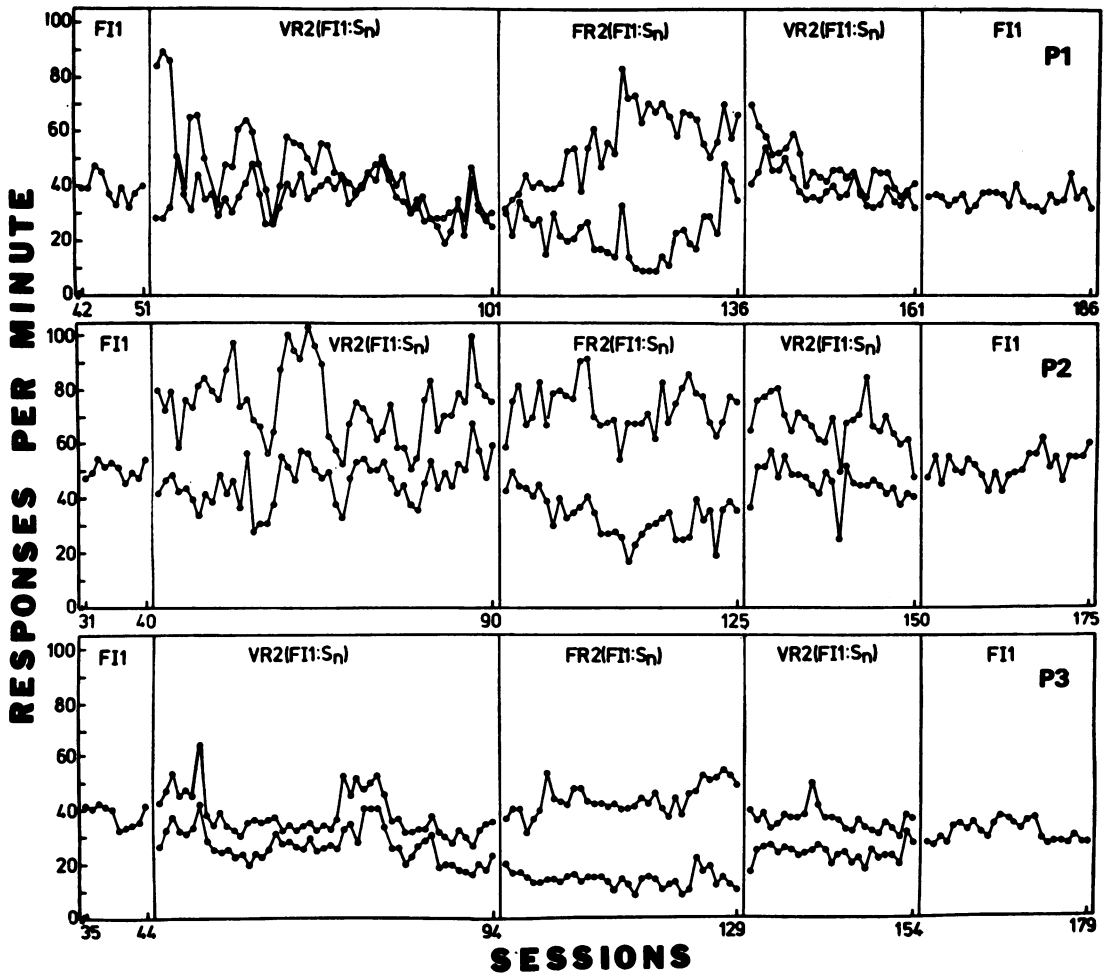


Fig. 1. Mean daily response rates (responses per minute) in intervals following food (filled circles) and following the brief stimulus (open circles) for each subject. For Phase 1 (FI 1-min) the data from only the last 10 sessions are presented.

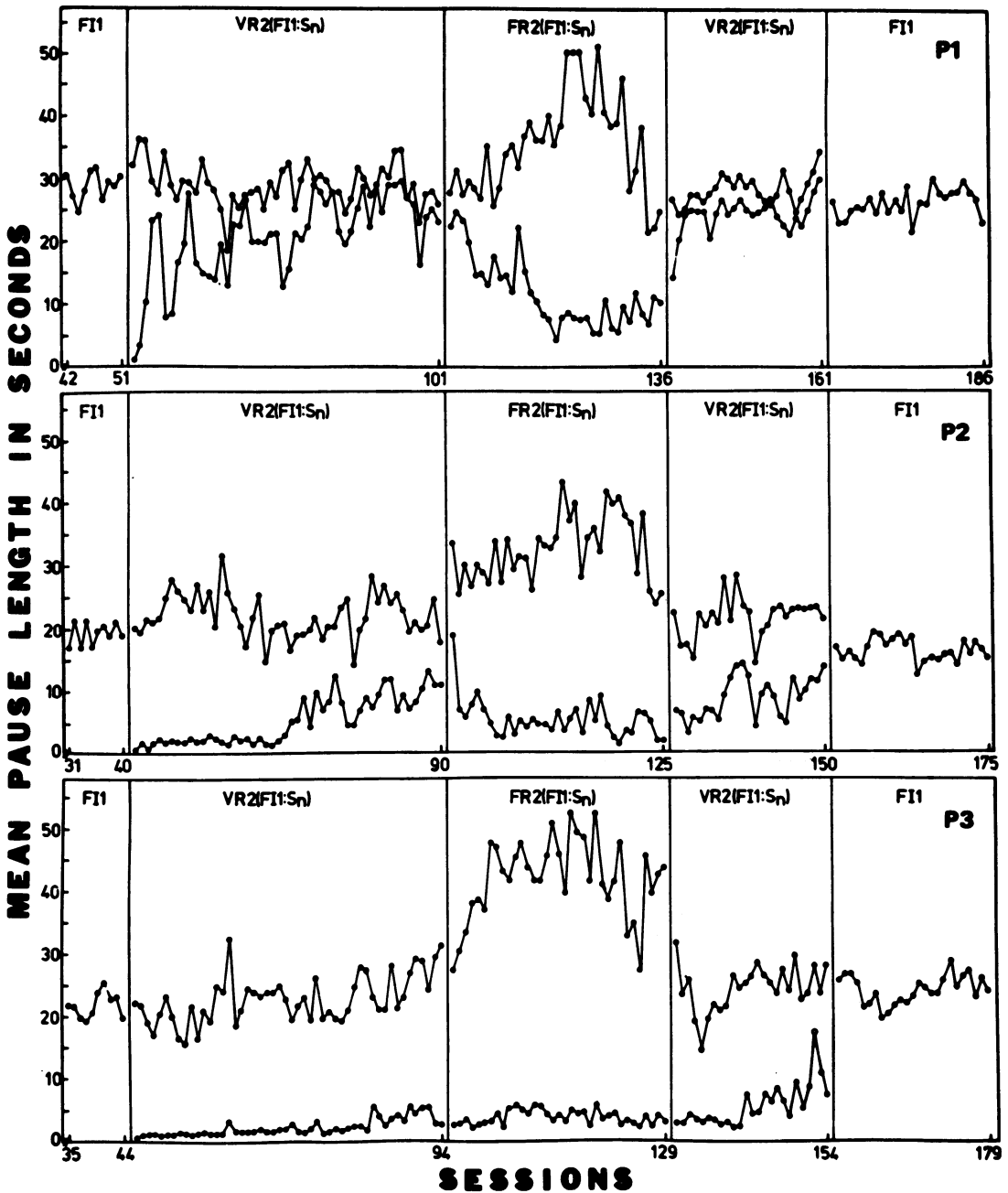


Fig. 2. Mean pause length in seconds in intervals following food (filled circles) and following the brief stimulus (open circles). Data shown are for each daily session except that only the last 10 sessions of Phase 1 (FI 1-min) are included.

the stimulus fell for all animals (from 53% to 7% with P1; 97% to 43% with P2; 100% to 75% with P3) and the distribution for P1 was very similar to that after food (Row C). Under the FR 2 overall schedule, the percentage of short poststimulus pauses increased (to 29%

with P1, 63% with P2, and 77% with P3) (Row D). During the last five days of the return to the VR 2 overall schedule (Row E), the percentage of short poststimulus pauses fell again (to 0% with P1, 39% with P2, and 55% with P3) and the remainder of the distributions be-

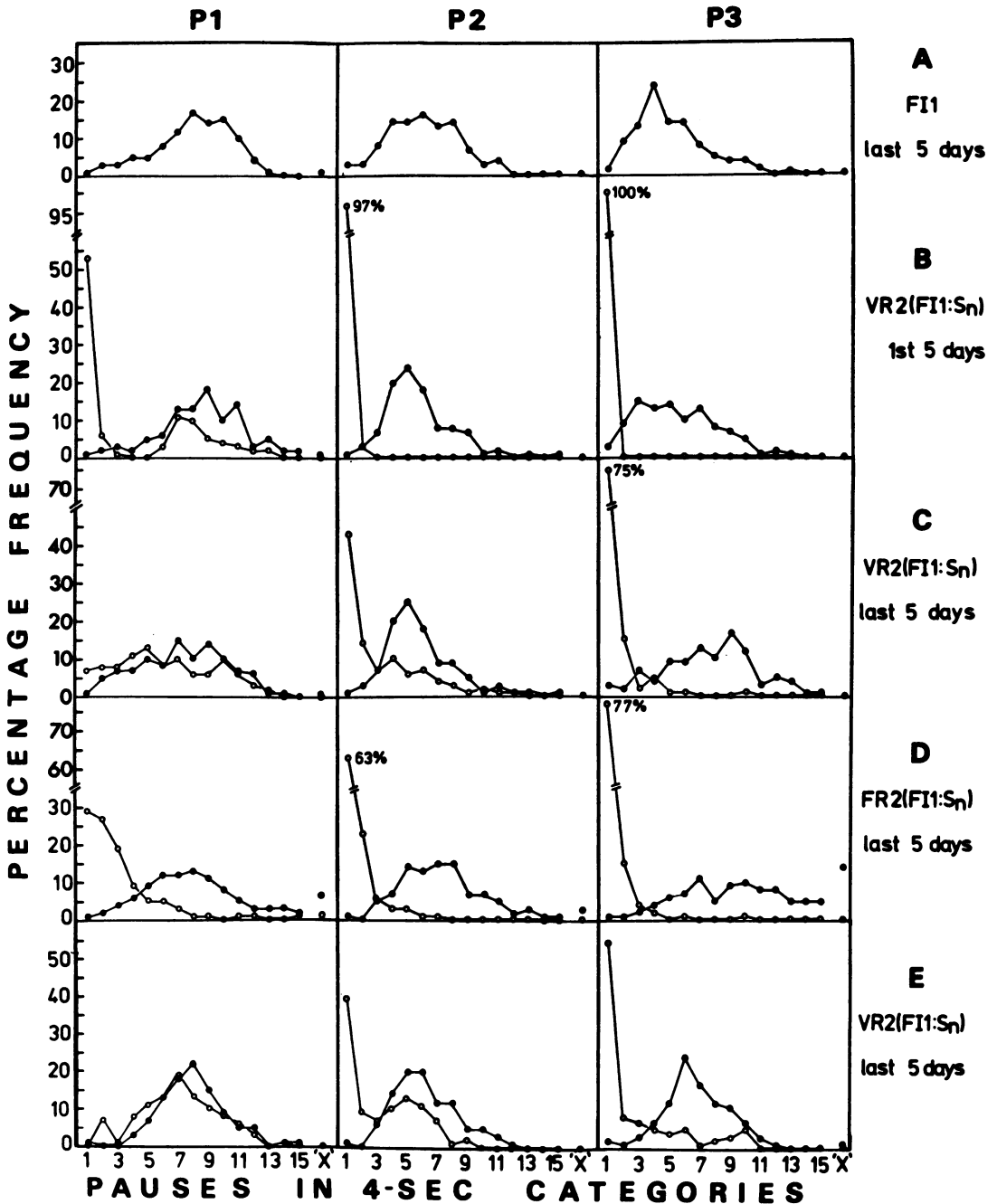


Fig. 3. Percentage frequency distributions of pauses in intervals following food (filled circles) and following the brief stimulus (open circles). Data are presented in 4-sec class intervals ('X' includes pauses greater than 60 sec) to summarize five selected consecutive sessions.

came more similar to those after food, especially with P1 and P2.

Figures 4, 5, and 6 show response patterning during the fixed intervals following food and following the stimulus for each animal. Each

60-sec fixed interval was divided into six successive 10-sec periods for recording purposes. Data are presented in five-session blocks except in Figure 4b, which includes the first day only of Phase 2 for P1 since the stimulus quickly

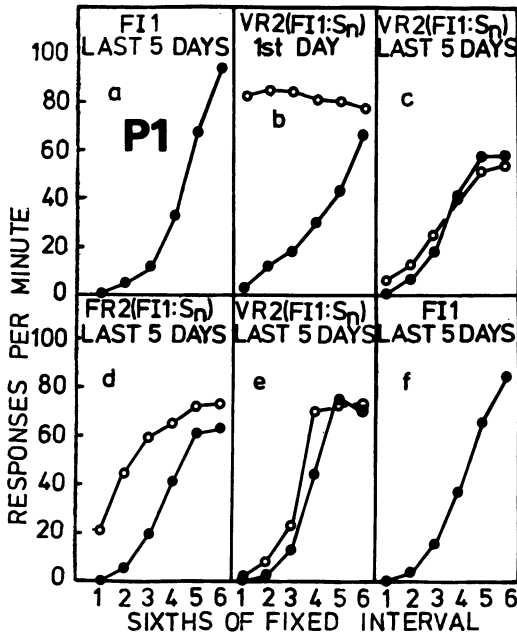


Fig. 4. Mean response rates (responses per minute) in successive sixths of fixed intervals following food (filled circles) and following the brief stimulus (open circles) for P1. Data summarize five-session blocks of the schedules, except in segment b which includes only the first session.

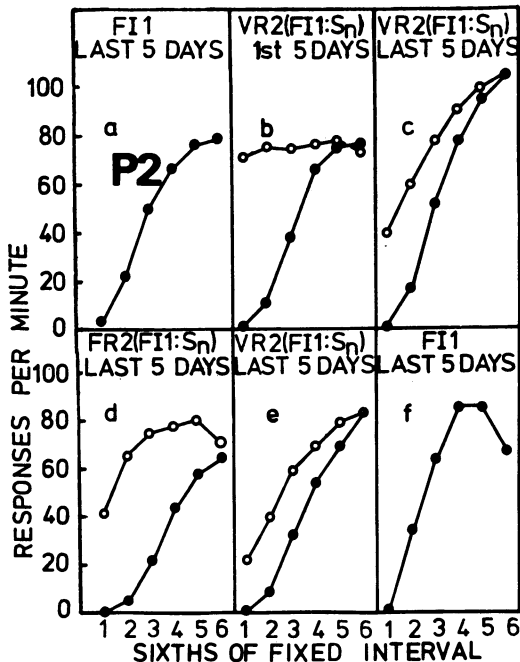


Fig. 5. Mean response rates (responses per minute) in successive sixths of fixed intervals following food (filled circles) and following the brief stimulus (open circles) for P2. Data summarize five-session blocks of the schedules.

gained control over its behavior (see Figures 1 and 2) and thus patterning for the first five days would have masked the initial effects of the stimulus. It can be seen that poststimulus patterning was not evident when the stimulus was first introduced, but developed by the end of Phase 2 with P1 and P2, although response rates were usually higher than after food with P2 (Figures 4c and 5c). Poststimulus patterning was disrupted when the FR 2 overall schedule was introduced (Figures 4d and 5d) but reappeared on return to the VR 2 overall schedule (Figures 4e and 5e). Poststimulus patterning also developed with P3 on the second exposure to the VR 2 overall schedule (Figure 6e).

Sequential analyses of response rates (after Byrd and Marr, 1969) and pauses (after Starr and Staddon, 1974) revealed no systematic trends toward higher or lower response rates or pauses during runs of successive food or stimulus presentations, apart from a tendency toward slightly lower response rates in the first component after food with P2 and P3.

DISCUSSION

The patterns of positively accelerated responding in the intervals after the stimulus

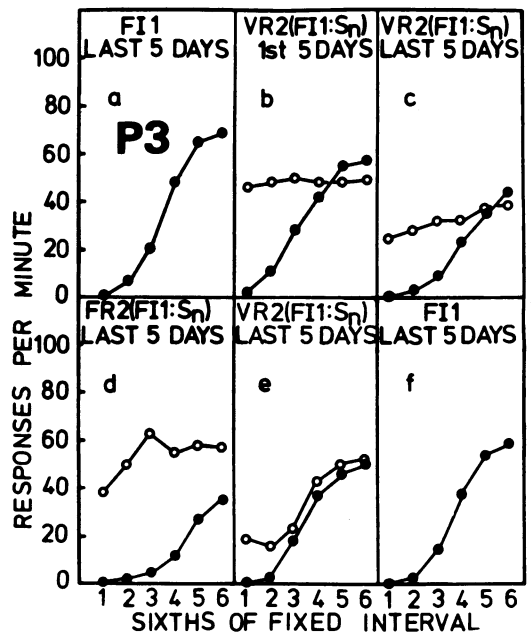


Fig. 6. Mean response rates (responses per minute) in successive sixths of fixed intervals following food (filled circles) and following the brief stimulus (open circles) for P2. Data summarize five-session blocks of the schedules.

(Figures 4, 5, and 6), when it was presented according to the VR 2 overall schedule, were appropriate to fixed-interval schedules and confirmed in general terms previous suggestions in the literature that appropriate schedule control can be maintained by a stimulus never associated with food (*e.g.*, see Stubbs, 1971; Figure 3). However, the results extend previous analyses by showing that the similarity of behavioral control exerted by food and the stimulus was greater with the random than with the fixed scheduling of events. Furthermore, the greater range of dependent variables reveals that even with the VR 2 overall schedule, almost identical control was exerted only in one animal (P1). Such differences may also have emerged from previous reports, both with paired as well as nonpaired stimuli, had previous investigators presented more detailed quantitative data. Until further data become available, general statements about the extent to which stimuli, whether paired or nonpaired, can exert appropriate schedule control cannot be made. Some general statements that have been made in the literature appear to be overstated and important factors that determine whether a stimulus will gain control over behavior have not been sufficiently emphasized. For example, Stubbs (1971), in one experiment (p. 294) compared VR 2 and FR 2 overall schedules with an FI 1-min component, but made no mention of any differences between the effects of VR 2 and FR 2 overall schedules. This appears surprising in view of the large and consistent differences observed in the present experiment.

The present experiment shows that the sequencing of food and stimuli may be a crucial determinant of the control exerted by a stimulus in second-order schedules. In previous experiments in which *fixed-interval* or *fixed-ratio overall* schedules have been used, prolonged pausing has often occurred in the first component after food and often in several subsequent components, followed by an abrupt or gradual shift to higher overall response rates within components. For example, sequence effects are clearly to be seen in the results reported by Kelleher (1966a) with an FI 10-min (FR 20) second-order schedule. Prolonged pausing occurred in the first fixed-ratio component but decreased following successive stimulus presentations. The data from an experiment by Stubbs (1971) also show sequence effects. Cum-

ulative records for an FI 600-sec (FI 64-sec) schedule (p. 295) show prolonged postfood pausing followed by a gradual decrease in pausing and increases in response rates in successive fixed-interval components as the fixed-interval of 600 sec, specified by the overall schedule elapsed, producing an approximation to an *overall* fixed-interval scallop. As Stubbs pointed out, the records ". . . indicate an interaction between component performance and performance generated by the FI 600-sec schedule. The FI 600-sec schedule generated a positively accelerated rate of responding over components. Under brief stimulus conditions, patterning occurred within components and rates within components tended to increase as the FI 600-sec period neared its end." When fixed overall schedules are used, clear sequence effects limit the development of schedule control by a brief stimulus, an effect similar to that observed in the early links of extended chain schedules (*e.g.*, Findley, 1962; Kelleher and Fry, 1962).

The importance of the overall schedule in determining behavioral control in component schedules is further emphasized by studies in which *variable overall* schedules have been used (*e.g.*, Byrd and Marr, 1969; Stubbs and Cohen, 1972). Byrd and Marr studied the effects of presenting brief stimuli in a second-order schedule with fixed-interval components maintained under a VR 12 overall schedule. When paired stimuli were used, an analysis of response rates in successive fixed-interval components in a run of 23 without food showed no trend toward higher rates at the end of a run or evidence of lower rates at the beginning of a run. Similarly, in the experiment reported by Stubbs and Cohen (1972), the cumulative records of responding on an FI 48-sec component schedule with a VI 4-min overall schedule showed that pauses were no longer after food than after brief stimulus presentations, and that response rates showed no consistent trend between food presentations. It may also be noted that in the three-component chain schedules investigated by Kelleher and Fry (1962) behavior was well-maintained in all three components when the stimuli occurred in a variable order.

Staddon and Innis (1969) examined the performance of animals on an FI 2-min schedule when a certain proportion of food presentations was omitted and replaced by a blackout.

A major finding of this report, and of other studies of reinforcement omission (e.g., Staddon and Innis, 1966), is that the behavior controlled by the stimulus in lieu of food is markedly different from that controlled by food itself; pauses are much shorter and response rates much higher after the stimulus than after food. The differing findings emanating from the essentially similar procedures of second-order schedules and reinforcement omission are puzzling and clearly in need of examination, because elaborate and opposing theories to predict and explain the effects of substituting stimuli in lieu of food have stemmed from them (cf. Staddon, 1970; Stubbs, 1971). The present findings may throw some light on this apparent anomaly in the literature.

In the experiment of Staddon and Innis (1969), fixed-interval components ended with food or the stimulus with a probability of 0.5 if food had occurred on completion of the preceding interval. Intervals following the stimulus, however, always ended with food with a probability of 1.0. A consistent finding in the present experiment was that pauses after the stimulus were shorter than after food, and response rates higher, with the FR 2 overall schedule (i.e., when food occurred with a probability of 1.0 at the end of intervals following a stimulus), but this effect diminished or disappeared with a VR 2 overall schedule. Thus, an "omission effect" measured in terms of response rates and pausing was transient and readily manipulated. It therefore seems that the omission effect reported by Staddon and Innis (1969) may in part have been an artifact of the scheduling arrangements used.

On the basis of the present findings it may also be suggested that the omission effect may be partly a transitional rather than a steady-state phenomenon. It is likely that too few sessions have been given in omission experiments for schedule control by the stimuli to develop. With two animals in the present experiment (P1 and P2), the differences between response rates and between pauses after food and after the stimulus were large when the stimulus was first introduced with the VR 2 overall schedule (Phase 2). These differences declined with continued training (see Figures 1 and 2), although more slowly with P2 than with P1. In addition, with P3, pauses after the stimulus developed only during the second

exposure to the VR 2 overall schedule (i.e., after more than 50 sessions of that schedule). In the omission phase of their experiment in 1969, Staddon and Innis carried out only 14 sessions with rats and seven with pigeons, and even in this short time it is clear that their omission effect was diminishing (see Staddon and Innis, 1969; Figure 2, p. 692), although this point was not emphasized by Staddon and Innis.

In the context of conditioned reinforcement, the present findings are in accord with previous suggestions that nonpaired stimuli can act as reinforcers in second-order schedules. However, the present study has shown that the manner of scheduling the stimulus may strongly influence the conditioned reinforcement process. With all three animals, the stimulus acted more like the food reinforcer with the VR 2 overall schedule than with the FR 2 overall schedule. The present findings may be incorporated with Boren's (1973) suggestion that "the current trend that emphasizes the schedule under which an event occurs does not discredit the notion of conditioned reinforcement. Rather, it shifts the emphasis away from the variables that involved pairing with primary reinforcement." However, further quantitative comparisons of the behavioral effects of food and stimuli in second-order schedules, as presented in the present study, are needed to provide some general guidelines as to what *degree* of schedule control is required for a stimulus to be termed a conditioned reinforcer if this concept is not to be degraded as an explanatory device.

## REFERENCES

- Boren, M. C. P. Fixed-ratio and variable-ratio schedules of brief stimuli in second-order schedules of matching-to-sample. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 219-233.
- Byrd, L. D. and Marr, M. J. Relations between patterns of responding and the presentation of stimuli under second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 713-722.
- Cohen, S. L. and Stubbs, D. A. Discriminative properties of briefly presented stimuli. *Journal of the Experimental Analysis of Behavior*, 1976, 25, 15-25.
- de Lorge, J. Fixed-interval behavior maintained by conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1967, 10, 271-276.
- de Lorge, J. The influence of pairing with primary reinforcement on the maintenance of conditioned reinforcement in second-order schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey Press, 1969. Pp. 61-76.



- de Lorge, J. The effects of brief stimuli presented under a multiple schedule of second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 19-25.
- Ferster, C. B. and Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.
- Findley, J. D. An experimental outline for building and exploring multi-operant behavior repertoires. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 113-166.
- Kelleher, R. T. Chaining and conditioned reinforcement. In W. K. Honig (Ed.), *Operant behavior: areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 160-212. (a)
- Kelleher, R. T. Conditioned reinforcement in second-order schedules. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 475-485. (b)
- Kelleher, R. T. and Fry, W. T. Stimulus functions in chained fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 167-173.
- Malagodi, E. F., DeWeese, J., and Johnston, J. M. Second-order schedules: a comparison of chained, brief-stimulus, and tandem procedures. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 447-460.
- Marr, M. J. Second-order schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey Press, 1969. Pp. 37-60.
- Schoenfeld, W. N., Cumming, W. W., and Hearst, E. On the classification of reinforcement schedules. *Proceedings of the National Academy of Sciences*, 1956, 42, 563-570.
- Squires, N., Norborg, J., and Fantino, E. Second-order schedules: discrimination of components. *Journal of the Experimental Analysis of Behavior*, 1975, 24, 157-171.
- Staddon, J. E. R. Temporal effects of reinforcement: a negative "frustration" effect. *Learning and Motivation*, 1970, 1, 227-247.
- Staddon, J. E. R. and Innis, N. K. An effect analogous to "frustration" on interval schedules of reinforcement. *Psychonomic Science*, 1966, 4, 287-288.
- Staddon, J. E. R. and Innis, N. K. Reinforcement omission on fixed-interval schedules. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 689-700.
- Starr, B. C. and Staddon, J. E. R. Temporal control of periodic schedules: signal properties of reinforcement and blackout. *Journal of the Experimental Analysis of Behavior*, 1974, 22, 535-545.
- Stubbs, D. A. Second-order schedules and the problem of conditioned reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 289-313.
- Stubbs, D. A. and Cohen, S. L. Second-order schedules: comparison of different procedures for scheduling paired and nonpaired stimuli. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 403-413.
- Stubbs, D. A. and Silverman, P. J. Second-order schedules: brief shock at the completion of each component. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 201-212.
- Thomas, G. and Blackman, D. Quasi reinforcement: control of behavior by second-order interval schedules. *Learning and Motivation*, 1974, 5, 92-105.
- Zeiler, M. D. Fixed interval behavior: effects of percentage reinforcement. *Journal of the Experimental Analysis of Behavior*, 1972, 17, 177-189.

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