VARYING TEMPORAL PLACEMENT OF AN ADDED STIMULUS IN A FIXED-INTERVAL SCHEDULE[1]

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One paradigm for exploring stimulus effects on behavior is defined for steady state experiments. The paradigm is illustrated by a 60-sec fixed-interval reinforcement schedule wherein a 6-sec light is introduced into each interval. The temporal relation of this stimulus to the reinforcer is the independent variable that is systematically explored. Two experiments studied this temporal relation under two parametric conditions: (a) when the 6-sec light occurs once in each 60-sec interval, (b) when the 6-sec light occurs twice in each interval, the second time always during the 6 sec immediately preceding the reinforcer. Functions are presented showing the effect of the 6-sec light on responding at all points in the fixed-interval.

Given a chain of responses composing a behavior stream, one paradigm for behavioral analysis is provided by intruding a new or extraneous stimulus into that chain. When that intrusion is experimentally specified, and repeated, some fundamental laws of behavior appear respecting stimulus control (Skinner, 1938, pp. 14ff.) and the terms or conditions of the experiment define parameters for systematic study. Pavlov's experiment regarded the intruding stimulus as the conditioned stimulus (CS) being paired with the reinforcing stimulus or US. Skinner's experiment offers another case in its treatment of the S^D, an initially neutral stimulus which, intruding into the behavioral stream, is experimentally paired with a response-contingent reinforcer (S^R). For both cases, the temporal parameters were among the early and widely recognized ones of the pairing. The present studies are concerned with certain temporal relations in a particular operant schedule of reinforcement. They employ a free operant brought to a steady state at each value of the independent variable, and data are reported from individual organisms.

In the first experiment, the reinforcement schedule was a 60-sec fixed-interval into which the added stimulus was a 6-sec light (hereafter called S_1) inserted at specified and systematically varied temporal relations to S^R. The occurrence of S_1 was under the experimenter's control and not contingent on a response. In the second experiment, the same procedure was used except that S_1 occurred twice in each 60-sec cycle, the first time in the systematically varied temporal position as described, the second time always in a fixed close position to S^R with the two occurrences again under the experimenter's control and not response contingent. Each experimental design—variants of the paradigm of the intruding paired stimulus —encompasses a number of problem areas which customarily appear under different names.

METHOD

Subjects

Two white Carneaux hen pigeons, 6 to 8 years old, were maintained at 80% of free feeding body weight throughout the experiment.

Apparatus

The experimental chamber was a Lehigh Valley Electronics pigeon chamber Model No. 1519C, containing a key as operandum. A minimum of 25 g of force on this key was required to close the microswitch. Transistorized digital logic components programmed stimulus changes and S^R delivery. Data were recorded on Sodeco counters.

Procedure

Experiment I. After shaping the key-pecking operant (with S^R being 3-sec access to mixed grain) to the key transilluminated with a 1.8 log foot lamberts white diffused light, two pigeons (#467, #486) were exposed for approximately 60 hr (or 60 daily sessions, each of which terminated after 61 S^Rs) to a 60-sec fixed-interval (FI 60) reinforcement schedule. The intervals were timed from the end of the preceding 3-sec S^R. Beginning on day 61, transillumination of the key was changed (not contingent on the bird's response) from a white to a green light (S_1) of 0.1 log foot lamberts for 6 sec out of each 60-sec FI cycle, the key continuing to be white for the remaining 54 sec of each interval. This schedule is of the type called "multiple EXT FI" (Ferster and Skinner, 1957). More usually, it has been employed with a continuing stimulus in each component (analogous to delay conditioning) rather than the present use of only a 6-sec exteroceptive stimulus for the second component (analogous to trace conditioning) and no exteroceptive stimulus in the first component. The temporal position of the 6-sec green key light within each 60-sec interval was systematically varied during days 61 through 144, with 1-hr training sessions at each position for seven days. For the first seven days of this phase, S_1 occupied the last 6 sec of each interval, that is, the 6 sec from the 55th to the 60th sec inclusive in the fixed interval cycle. The change from green back to white coincided with the completion of that 60-sec interval. S^R occurred with the next response. Thereafter, on every eighth day, the temporal placement of S_1 was shifted 6 sec earlier in the interval towards the preceding S^R. By the end of the experiment, 10 temporal positions covering the whole fixed interval cycle were used, and behaviors were redetermined at two of those positions. The 10 positions were specified as time from the preceding S^R. The order in which they were introduced was 54-59.99 sec, then 48-53.99 sec, and so on in successive 6-sec intervals. Two redeterminations were made, the first at 48-53.99 sec, immediately after the end of the above series of 10, the second at 42-47.99 sec, after Exp II below was completed. All reported data and calculations are means of performances for the last days (days 55-60) of the 60-day exposure to FI 60 (when only white

light transilluminated the key) and for the last two of each block of seven days at each temporal position of S_1.

Experiment II. Birds #467 and #486 (those used in Exp I) were used on a basic FI 60 schedule with the white key light again chang-
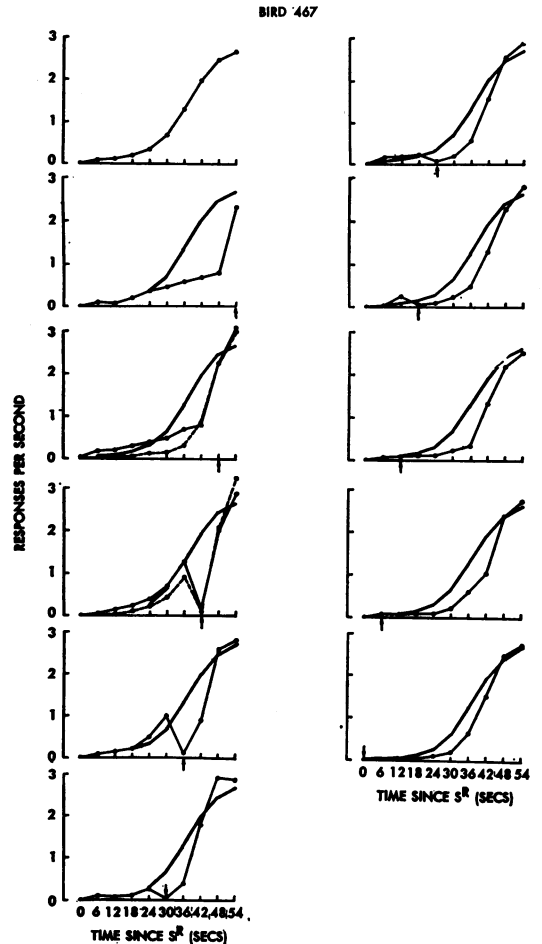

Fig. 1. Performance of Bird #467 in Exp 1. In each panel, the temporal position of 6-sec S_1 onset is indicated by an arrow on the abscissa. The upper left panel (without arrow) is baseline performance on the 60-sec FI schedule before introduction of S_1; each datum point here represents the rate for each successive 6 sec in the FI interval averaged across 300 intervals (the last five sessions taken as criterion performances from 60 approximately 1-hr daily sessions of training). This baseline function form, with data points not plotted, is retraced in all succeeding panels for comparison purposes. Data points in all other panels are averages of 120 intervals (the last two sessions taken as criterion performances from seven approximately 1-hr daily sessions). The numbers on the abscissae mark the beginning of each of the 10 successive 6-sec intervals. The dotted graphs in the panels for S_1 positions of 42 and 48 sec are redeterminations of the functions (see text).

ing at some point in the interval (independently of responding) to green and remaining green for 6 sec. In this experiment, however, S_1 always reappeared a second time in each fixed interval cycle during the last 6 sec. The temporal placement of the first occurrence of S_1 was varied. (The stimulus S_1 may be depicted as S_1^0 when presented in the temporal position
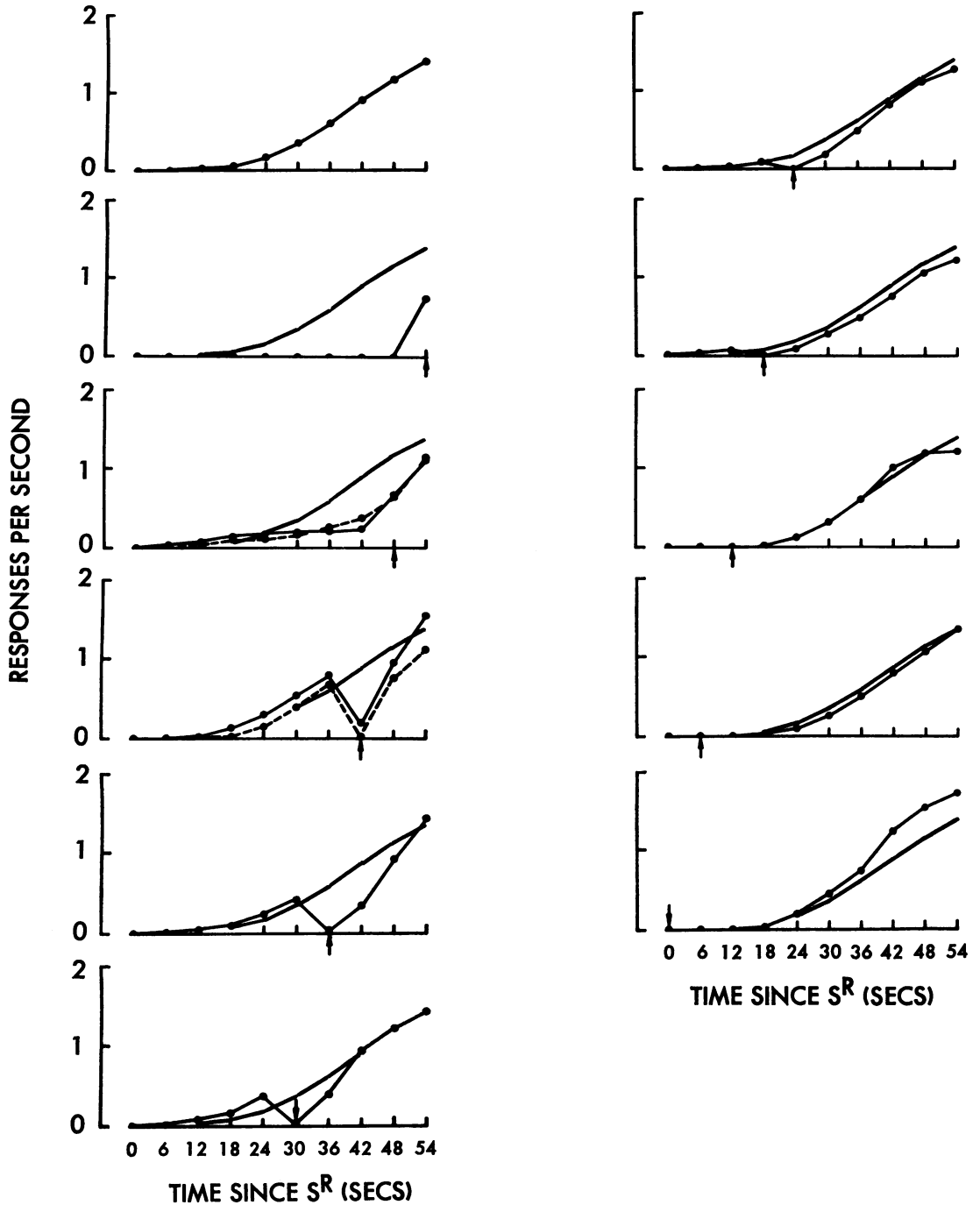
BIRD 486

Fig. 2. Performance of Bird #486. The legend for Fig. 1 is applicable here.

just before S^R, and S_1^1 when presented in any of the temporally removed positions.) All the temporal placements of Exp I were not repeated and only four placements of S_1^1 were used: 42-47.99 sec, 30-35.99 sec, 18-23.99 sec, and 6-11.99 sec, in that order. As in Exp I, birds were exposed for seven days at each of these S_1^1 placements, and the reported data and calculations are based on the last two of each seven-day block.

RESULTS

Experiment I

The baseline fixed interval functions illustrated in Fig. 1 and 2 (top left panels) exhibit several typically reported features such as low response rates immediately following S^R which increase as the interval elapses. The intrusion of S_1, and the systematic lengthening of the $S_1 - S^R$ interval, produces clearly visible behavioral effects centering on S_1. The control exercised by S_1 is seen in the fact that rate changes during the fixed interval cycle become correlated with the presence or absence of S_1 as well as the passage of time since the last S^R. At short $S_1 - S^R$ (≤ 12 sec) intervals, responding is low throughout most of the interval, then picks up sharply in the presence of S_1. At longer $S_1 - S^R$ intervals (from 18 to 30 sec), high rates develop before S_1 onset (but not appreciably higher than those of the baseline fixed interval functions), while the rates during S_1's 6-sec presence, instead of remaining high, drop to low or zero levels. After S_1 termination, high rates comparable to the original baseline levels terminate in S^R delivery. This response patterning in the fixed interval cycle, and the way in which it changes as the $S_1 - S^R$ interval is increased, is further illustrated in the sample cumulative records of Bird 467 in Fig. 3. An estimate of data recoverability is given in Fig. 1 and 2 (dotted line plots) at $S_1 - S^R$ intervals of 12 and 18 sec. The extent of recoverability of the original baseline fixed interval function is indicated in the lowest right panels of Fig. 1 and 2, where S_1 occurs at the beginning of the 60-sec FI.

Discussion

Skinner's (1938) categories of stimulus function were aimed at highlighting the operationally distinguishable ways in which stimulus control over behavior could be exercised by an experimenter or be detected by an observer. In those terms, the present S_1, which divides the fixed interval cycle into two portions, can be said to have a conditioned reinforcing (S^r) function for responses in the portion preceding it, and a discriminative (S^D or S^Δ) function for responses in the portion during or following it. Looked at in this way, the S^D function displayed in Fig. 1 and 2 is prominent at short temporal separations of S_1 and S^R, while the S^Δ and perhaps also an S^r function becomes more visible as the separation between these stimuli is increased. These types of control assumed by S_1 over antecedent, concurrent, and following responses, and the balance between these types of control, are apparently dependent on the temporal parameters of the experimental procedure. From the general $S_1 - S^R$ paradigm, the more conventional operation for establishing the S^D function of the stimulus (*e.g.*, Skinner, 1938) emerges as a special case as the temporal separation between S_1 and S^R approaches zero. At no separation (not studied here) S_1 and S^R coincide in time, at which point S_1 is the conventionally defined S^D in that reinforcements are delivered in its presence.

In fixed interval schedules there is, except during the post-reinforcement pause, high probability that a response will occur shortly
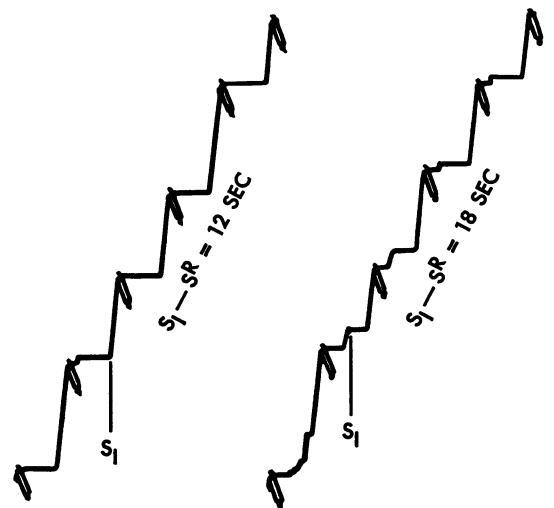

Fig. 3. Sample cumulative records for Bird #467 taken from the middle portion of a criterion day recovery session at S_1-S^R of 12 and 18 sec. The temporal positioning of one of the intra-interval occurrences of S_1 is indicated by the vertical line labeled "S_1," to show its relation to local response patterning. Diagonal pips indicate S^R occurrence.

preceding, or coincident with, S_1 onset. In this sense, a sufficient condition for demonstrating an S^r effect of S_1 is approximately satisfied at most $S_1 - S^R$ intervals, even though S_1 occurrence is not response contingent. But if an S^r effect on responding is present, it is not readily distinguishable through any appreciable increase in pre-S_1 rates over baseline levels. But the drop in rate that follows the onset of S_1 at long $S_1 - S^R$ intervals may yet be thought of as analogous to a post-S^R pause.

One much-debated issue concerning these stimulus functions has revolved around their interrelations, or whether S_1 must be "discriminative" before it can "reinforce" (Schoenfeld, Antonitis, and Bersh, 1950; Kelleher and Gollub, 1962). An issue of this character, which arose historically from a group methodological context (wherein S_1 is established as discriminative under one set of conditions, and tested for its reinforcing effect under another set), does not appear to be engendered by the behavioral effects observed under the present single-organism, steady-state type of methodology. Instead, the control over behavior assumed by S_1 is visible, in both relative and absolute magnitude, at each point on either temporal side of S_1 and during S_1. This visibility appears to remove much of the analytical relevance of the special issue of the interrelations of stimulus functions.

In specific ways, the present data at short $S_1 - S^R$ intervals resemble the findings of Ferster and Skinner (1957) on long fixed interval with "added clock". Their procedure, involving as the clock "an external stimulus that varies uniformly in some dimension during the fixed interval" (p. 266), produced a fixed interval pattern in which responding was negligible through most of the interval but picked up sharply just before reinforcement. Similar patterns also develop when several discontinuous, rather than uniform, changes are made in the stimulus before S^R delivery, as in chain FIFI (*e.g.*, Kelleher and Fry, 1962; Segal, 1962). The foregoing studies agree in suggesting that organisms apparently tend to disregard the "clock" cues for much of the period until a critical "clock time" (stimulus value) is reached. At this particular point their behavior is affected in much the same way as by our single-valued, non-varying interpolated stimulus when at short separations from S^R delivery.

The overall effect at longer $S_1 - S^R$ intervals wherein two positive accelerations (scallops) emerge, one before and one after S_1, is similar to that obtained with schedules wherein several successive fixed interval scallops, associated with successive stimulus changes, have been reported. These multiple scallops seem especially likely to appear when the several stimuli preceding S^R are the same in physical value, as with Dews' (1962) "interruptions" of fixed interval responding by short S^A periods, or when the stimuli are indifferently related in time to S^R, as in the case of Kelleher and Fry's (1962) "variable chain" FIFIFI. These scallops, except for the one immediately preceding S^R, are, in the view of some investigators (*e.g.*, Kelleher and Fry, 1962) supported by the cycle-dividing stimulus acting as a conditioned reinforcer. An alternative description of multiple scalloping is made possible by Dews' finding that repeated interruptions of fixed interval responding by short S^A periods lowered rates during the S^A periods without disrupting the overall scalloped pattern. Thus, in terms of the present Exp I, the two scallops at long $S_1 - S^R$ intervals may be conceived as remnants of the original baseline fixed interval scallop remaining after the interpolation of S_1. From this viewpoint, explanation in terms of conditioned reinforcement is extraneous, since the baseline fixed interval schedule alone accounts for the extent of the scalloping before and after the "interrupting" S_1.

If the present schedule is regarded as a two-ply multiple schedule in which the first component is extinction and the second component fixed interval, the literature (Ferster and Skinner, 1957) would lead to the expectation of, first, much lower response rates in the first or "extinction" component than presently obtained, and, second, little or no correlation between rate increases and time passage in the first component (*i.e.*, no scallop in the first component). The different behavioral result observed here is attributable, presumably, to the departure of the present schedule from the more commonly employed multiple schedules, namely, the trace character of S_1. In short, there are two variables to be considered as bridging chain and multiple schedule effects: the presence or absence of the response contingency for occurrence of the cycle-dividing S_1 stimulus, and the duration of that stimulus relative to the duration of the second compo-
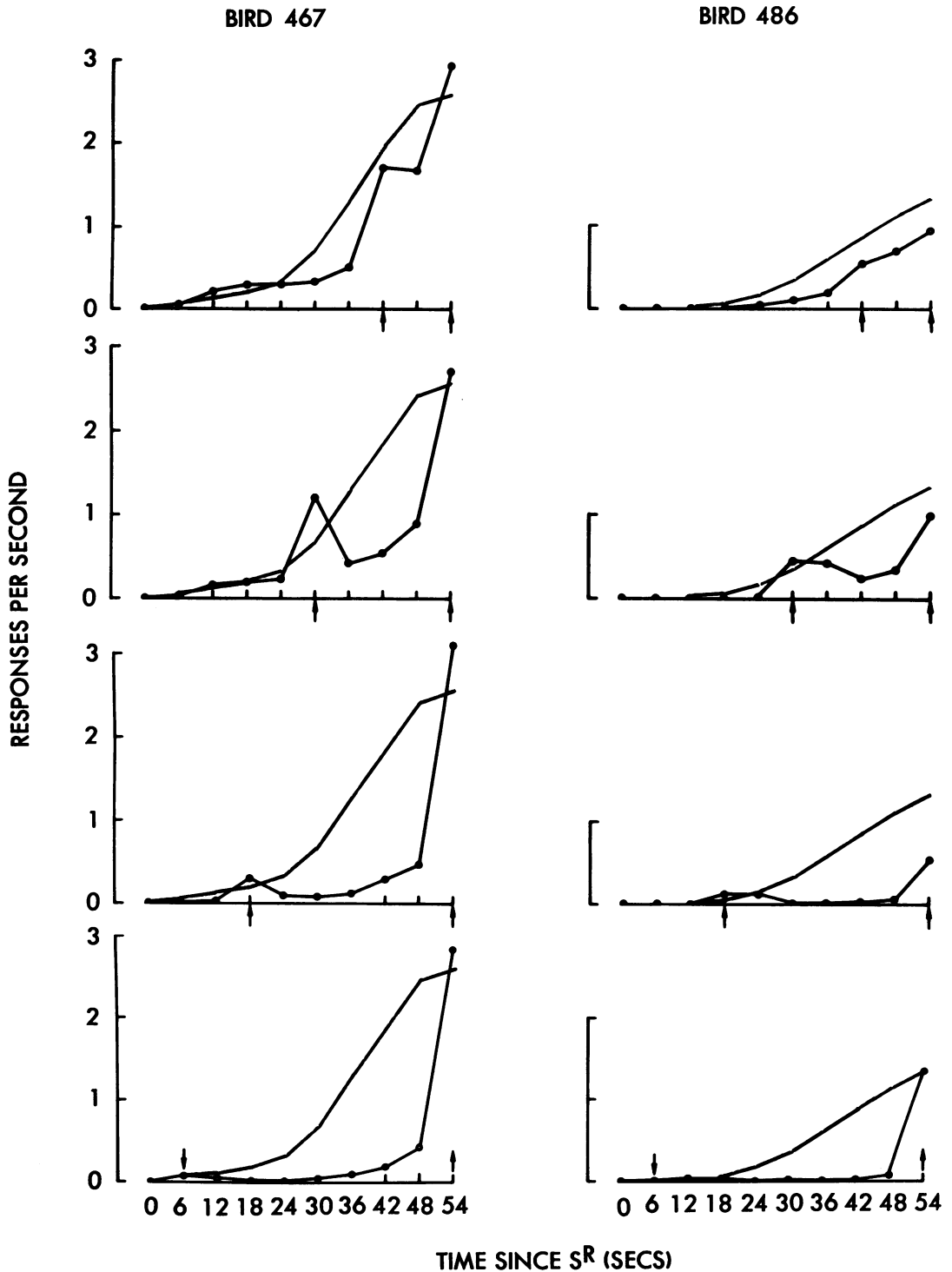
BIRD 467

BIRD 486

RESPONSES PER SECOND

TIME SINCE S^R (SECS)

Fig. 4. Performances of Birds #467 and #486 in Exp 2, where S_1 occurs twice (arrows) in each interval (see text). Each datum point is the average of 120 intervals (the last two sessions taken as criterion performances from seven approximately 1-hr daily sessions). The numbers on the abscissae mark the beginning of each of the 10 successive 6-sec intervals. The baseline function form, with data points not plotted, is retraced in all succeeding panels for comparison purposes.
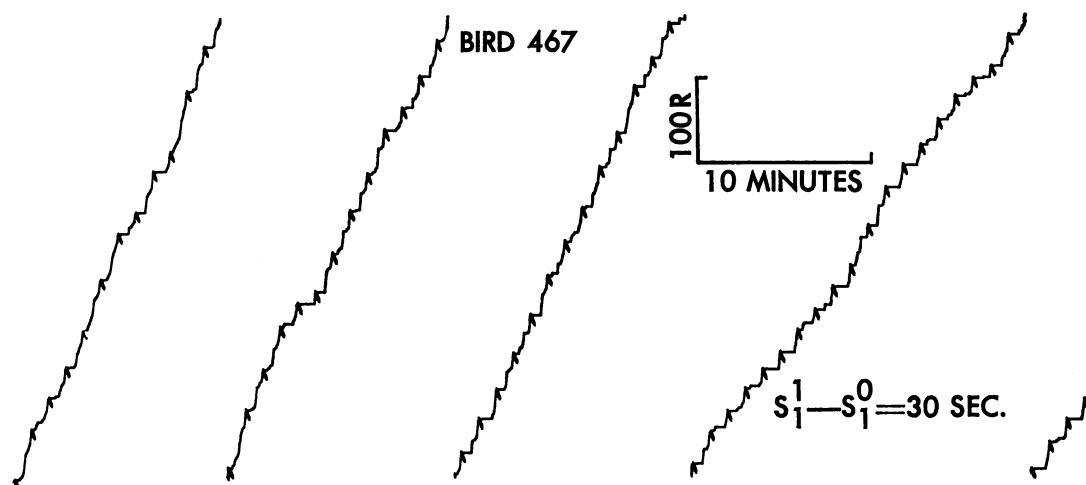
Fig. 5. One complete criterion day session's cumulative record for Bird #467 at $S_1^1 - S_1^0 = 30$ sec. Diagonal pips indicate S^R.

nent. The presence of the response contingency, regardless of S_1 duration, perhaps suffices to maintain time-correlated responding or scalloping in the first component. But, if response contingency is absent (as in the present case), then durations of S_1 become important in maintaining that scallop.

RESULTS AND DISCUSSION

Experiment II

This experiment undertook to examine the effects of lengthening the $S_1 - S^R$ interval when S_1 (here, notated S_1^1), in addition to being removed in time from S^R also continues to occur immediately preceding S^R (in this position, S_1^0). The incorporation into the present design of S_1^0 in this fixed and close relation to S^R, and the fact that S_1^0 and S_1^1 are physically the same in all properties save for temporal position, gives S_1^1 discriminative (S^D) control over responding even at long temporal separations from S^R (Fig. 4). This is in marked contrast with the finding in Exp I, which showed that S_1 acted as S^D only over a short range of $S_1 - S^R$ temporal separations. The double scallops that appear in the cumulative record between S^R (Fig. 5) further illustrate birds' tendency to respond during S_1^1 as well as during S_1^0 and to pause when neither stimulus was present. It may be seen that the absolute amount of

responding in S_1^1 decreases systematically (while yet remaining greater than the amount of responding either before or after its occurrence) as its separation from S_1^0 (and S^R) lengthens, suggesting a generalization effect along a temporal continuum. It should be feasible, of course, to determine other generalization gradients for the physical properties of S_1^1 at each of its temporal separations from S_1^0 (and S^R).

REFERENCES

Dews, P. B. The effect of multiple S^Δ periods on responding on a fixed-interval schedule. *J. exp. Anal. Behav.*, 1962, 5, 369-374.

Ferster, C. B. and Skinner, B. F. *Schedules of Reinforcement.* New York: Appleton-Century-Crofts, 1957.

Kelleher, R. T. and Fry, W. T. Stimulus functions in chained fixed-interval schedules. *J. exp. Anal. Behav.*, 1962, 5, 167-173.

Kelleher, R. T. and Gollub, L. R. A review of positive conditioned reinforcement. *J. exp. Anal. Behav.*, 1962, 5, 543-597.

Segal, E. F. Exteroceptive control of fixed-interval responding. *J. exp. Anal. Behav.*, 1962, 5, 49-57.

Schoenfeld, W. N., Antonitis, J. J., and Bersh, P. J. A preliminary study of training conditions necessary for secondary reinforcement. *J. exp. Psychol.*, 40, 40-45.

Skinner, B. F. *Behavior of Organisms.* New York: Appleton-Century-Crofts, 1938.