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THE EFFECTS OF INDEPENDENTLY VARYING THE TEMPORAL POSITION OF ONSET AND OFFSET OF AN INTRUDED STIMULUS IN A FIXED-INTERVAL SCHEDULE

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The effects of independently varying the temporal position of onset and offset of an intruded stimulus in a fixed-interval schedule.

by

Victor Schildkraut

A dissertation submitted to the Graduate Faculty
in partial fulfillment for the requirements
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ABSTRACT

The effects of independently varying the temporal
position of onset and offset of an intruded
stimulus in a fixed-interval schedule.

by

Victor Schildkraut

Adviser: Professor Thom Verhave

Three groups of pigeons were exposed to a fixed interval schedule of reinforcement. For each group a new exteroceptive stimulus (S1), with a duration of 10% of the interreinforcement interval (I.R.I.), was introduced into each interval. For each group the initial point of intrusion was different. The transition points at which S1 and S2 were conterminous were called junctures. Each juncture was moved independently so that the duration of the newly intruded stimulus was successively increased until it filled the entire interval. In Phase 1 the onset (J1) of the intruded stimulus was moved toward prior reinforcement. In Phase 2 the offset (J2) of the intruded stimulus was moved away from prior reinforcement. The moving juncture was the independent variable. The temporal relations of this moving juncture, to both the stationary juncture and to reinforcement, was systematically explored.

Functions were presented showing the effects of the relative positions of the junctures at all points in the fixed interval.

A second procedure placed the animals on a higher value FI schedule. Half the birds received no baseline training, while, half received 30 sessions of baseline training. For both groups the intruded stimulus was then simultaneously placed in the first and last tenth of the I.R.I. for 30 sessions. Functions, obtained with the placement of S1 in bins 1 and 10 following zero, 30, and 60 sessions of baseline training conditions, were compared.

It was found that the strength of the stimulus that controlled responding was enhanced by virtue of its proximity to reinforcement. This was compatable with the majority of the findings in the stimulus control literature. Exceptions were also noted. Both the prevalent findings and the exceptions were shown to be limiting cases of related effects that occur within a single continuous dimension. The temporal positions of the junctures, in relation to both reinforcement and to each other, were shown to be responsible for the shape of the functions. Finally, it was demonstrated that the underlying factor which determines the influence of "stimulus" control is the "uncued" schedule itself.

To My Wife Debra

To My Sons Julian and Steven

To Drs. Sandra Shapiro and Brett K. Cole

Acknowledgements

The author wishes to express his deep gratitude to all those who have aided his efforts: Especially, Drs. W. N. Schoenfeld, Brett K. Cole, and Thom Verhave.

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INTRODUCTION

The term reinforcement refers to an empirical relation in which a particular stimulus that follows the occurrence of a particular response increases the frequency with which similar responses will recur. Stimuli which reliably produce such changes in behavior are called reinforcers (Skinner, 1938). Skinner (1948) has shown that any behavior that occurs closely antecedent to a reinforcer will increase the probability of the recurrence of similar behavior. Not all stimuli function as reinforcers however. Some stimuli can be considered to be "neutral". When presented by themselves such stimuli neither increase the probability of responding, nor do they maintain responding when substituted for a reinforcing stimulus. However, these neutral stimuli may come to influence behavior. In the words of Schoenfeld, et al.: "A stream of behavior controlled by a given reinforcement schedule provides a sensitive baseline for evaluating the effects of newly introduced stimuli that are not identical with reinforcement, and which have no demonstrable 'reinforcing' power when presented alone. The more precise the control, the more exactly the experimenter can specify the response sequences intercepted by the intruding stimuli." (Schoenfeld, et. al., 1972, pp. 70.) One such baseline schedule which permits excellent observation of the effects of "stimulus" control is the FI schedule. It is a schedule in which reinforcement is produced by the first response that follows a fixed period of time. The start of the FI may be initiated in several ways: one way is to time it from the offset of reinforcement (Skinner, 1938); another is by the clock (Cumming and Schoenfeld, 1958); a third way is to signal it by means of an exteroceptive cue which follows reinforcement offset. The cue initiates the interval and then extends through the entire interval (Dews, 1970). Empirically, FI schedules maintain a consistent temporal relation between the offset and the onset of reinforcement and therefore between an intruded neutral stimulus and the reinforcer. Skinner (1938) has argued that the offset of reinforcement in a fixed interval schedule of reinforcement, functions as a "discriminative" stimulus which signals a period of nonreinforcement (extinction).

It has been observed that in the case of brief FIs (15 seconds or less) responding occurs steadily throughout the interreinforcement interval (I.R.I.). For FI schedules longer than 15 secs. a post reinforcement pause ($PS^{R}P$) develops following reinforcement offset. Following this pause, which varies in length, responding resumes sometime prior to reinforcement availability. One important factor necessary for the development of the post reinforcement pause, then, is a minimum separation between the offset of one reinforcer and the onset of the next one. The offset and onset of reinforcement each control different behaviors. The offset produces "not responding" while the onset produces eating behavior (Keller and Schoenfeld, 1950; Skinner, 1938). Since the offset and onset of reinforcement affect different behaviors it seems appropriate to give each the status of a separately designated cue. Henceforth, the offset of reinforcement will be called C2 and the onset of reinforcement will be called C1. C2 begins the I.R.I, C1 ends it. It is important to note that when the I.R.I. is at least 15 secs. long, reinforcement offset (C2) functionally signals the start of a period of extinction. No exteroceptive cue, however, signals the end of the extinction period (C1).

If the I.R.I. is to be maintained at a minimum value the organism must begin responding sometime prior to reinforcememnt availability. Should the organism not respond at the time reinforcement becomes available, the I.R.I. will be increased, and will vary from reinforcement to reinforcement (cf., Dews, 1970; Schneider, 1969; Shull, 1970; Staddon, 1977).

Skinner (1938), Ferster and Skinner (1957), and Cumming and Schoenfeld (1958) have identified four stages in the development of the response patterning that emerges under FI schedules: When initially transferred from regular reinforcement to FI, the organism initially displays extinction behavior. As training continues this pattern changes to a low and constant rate of responding throughout the entire interval. Still later in training, "breaks" (periods of not responding) are seen in this previously steady rate. Finally, if FI training continues over an extended period, Cumming and Schoenfeld (1958) have shown that these "breaks" become longer and finally stabilize, commencing at reinforcement offset (C2) and terminating at about the 80th to 90th percentile of the I.R.I. (cf., Schneider, 1969; Shull, 1971). To sum up, it has been shown that there are three aspects of FI training which effect the establishment, the length, and the stability of the PS^RP. One is the constancy of the FI schedule itself, the second is the extent of the temporal separation between C2 and C1, the third is the length of training on a given FI value.

Skinner (1938) was the first investigator to examine the effects of introducing an exteroceptive cue (in addition to the inherent offset of reinforcement) in an "uncued" FI schedule. In his prototypic discrimination procedure, a click or light was intruded as a neutral stimulus (S1) into a 5 minute fixed interval schedule of reinforcement. The click, of course was instantaneous, the light remained on until reinforcement was procured. The new stimulus was presented at the moment reinforcement became available so that the first response that was made following the onset of either the the click or the light was reinforced. The FI cycle then began again, timed from reinforcement offset (C2). This new exteroceptive cue led to extremely precise stimulus control of the response distribution which previously had displayed a marked "temporal" gradient. This schedule is conventionally called "multiple EXT CRF" (Ferster and Skinner, 1957). After only 8 sessions of this procedure the rate in the I.R.I. dropped to virtual zero. In this case, there are two cues which delineate precisely where extinction begins and ends. Under these conditions the animal has no trouble clearly discriminating the extinction period. The "break-run" patterning of responding, which prior to the introduction of this added cue had maintained the regularity of the I.R.I., now resulted in "breaking" for the entire extinction period, up until reinforcement availability was cued. The organism could now "break" for the entire interval and yet not be penalized by disrupting the regularity of reinforcement deliveries. Cueing the end of extinction also signals the period of "reconditioning" (i.e., reinforcement availability). This was evidenced, behaviorally, by the reduction in latency of the reinforced response following the presentation of S1. Skinner called the portion of the I.R.I. prior to S1, S-Delta; it signified the discriminative stimulus which "sets the occasion" for a period of non reinforcement. S1 was called S-D, to signify the discriminative stimulus which "sets the occasion" for a period of reinforced responding (Keller and Schoenfeld, 1950; Skinner, 1938). As a matter of fact, when extinction is so explicitly demarcated it appears not to matter which schedule is being used. For example, in "multiple VI EXT" schedules, extinction behavior occurs during the stimulus that defines extinction (see Ferster and Skinner, 1957).

Byrd (1971) and Dews (1962) have shown that when S1 is placed contiguous to C2, it duplicates the effect of C2 and transfers the control of the post reinforcement pause to the offset of this additional exteroceptive stimulus. Given these two influences on responding: 1) the cueing of the start of the I.R.I. and 2) the signaling of its end, i.e., reinforcement availability, it seemed logically consistent to move an added exteroceptive cue (S1) between C2 (reinforcement offset) and C1 (reinforcement onset) in order to assess the behavioral effect of its proximity to either C2 or C1.

In 1966 Farmer and Schoenfeld investigated the effects of such a manipulation. Following 60 sessions of baseline training, sufficient to establish the typical effect of C2, they introduced an exteroceptive stimulus (S1) in the last tenth of the I.R.I.. (Hereafter, each tenth of the I.R.I. will be called a bin.) Once S1 is intruded into the I.R.I. it creates two stimuli: S1 and S2. S1 is the newly intruded stimulus which now alternately shares the key time with S2.

Following the introduction of S1 in the last bin, S1 was receded an additional bin on each subsequent eighth session. The final placement of S1 occurred in bin 1, immediately following reinforcement offset (C2). Farmer and Schoenfeld found that the effects of S1 were determined by its temporal placement within the I.R.I. Specifically, when S1 was placed in any of the first eight bins "breaking" occurred during S1. When positioned within the first 3 bins of the interval no responding occurred prior to, or during S1; a pause following S1, similar to, but smaller than the $PS^{R}P$ was seen. When S1 was placed in bins 4-8 responding occurred in both segments of S2, i.e., before and after S1. No responding occurred in S1. The positively accelerated response-rate function in each segment was similar to the baseline rate. When S1 was placed in bin 9, responding was quite low or virtually absent in the first segment of S2, i.e., prior to S1 onset. It commenced abruptly at the onset of S1 and continued throughout the second segment of S2 in bin 10 until reinforcement was delivered. When S1 was placed in bin 10 this latter effect was replicated, responding now began in bin 10 at S1 onset.

As S1 traversed the interval, it displayed the same kind of enhanced control over responding (and not responding) that was exhibited following extensive training on "uncued" FI (Cumming and Schoenfeld, 1958). But now, within the boundaries of S1, this hightened control was facilitated. Moreover, at particular placements, S1 appeared to make extensive training on "uncued" FI unnecessary. Specifically, following extensive training on "uncued" FI, a very low probability of responding obtains in the initial 8 bins of the I.R.I. whereas response probability is very high during the last 20%. In similar fashion, when S1 is placed within the initial 8 bins of the interval no responding occurs in S1; when placed in the last two bins of the interval responding always occurs in S1. Furthermore, when S1 is positioned in either bin 9 or 10 the entire response pattern, i.e., in both S1 and S2, resembles the pattern obtained following extensive training on "uncued" FI. There is virtually no responding prior to S1, responding commences at S1 and is maintained until reinforcement.

In either case, "cued" or "uncued", these findings are consistent with a premise that pervades the literature: the greater the proximity to reinforcement the greater the strength of responding (Bersh, 1951; Dews, 1970; Fantino, 1977; Gollub, 1958; Jenkins, 1950; Morse and Skinner, 1952; Pavlov, 1928; Skinner, 1938; Skinner, 1948; etc.). This premise applies equally to responding under "temporal" or exteroceptive "stimulus" control of responding. Hereafter, this premise will be referred to as the "potency by proximity" principle (cf., Zeiler, 1977, pp 221). One of the few exceptions to this rule was reported by Egger and Miller (1963). They found that a stimulus that is closer to reinforcement could be less potent than one that is further from reinforcement. Their procedure was as follows: hungry rats were presented with a stimulus (either a light or a tone) which began 2 seconds prior to food presentation. One half second after this stimulus began another stimulus was presented. The stimulus closer to reinforcement was called S1 and the one which preceded S1 was called S2. S1 was either a tone or a light for half of the animals, depending on the nature of S2. The stimulus conditions were reversed for the other half. Both S1 and S2 terminated with the presentation of food. The rats were then trained to press a bar for food reinforcement, after which followed a 10 minute period of extinction. Following this period of partial extinction each bar press was secondarily reinforced with a 1 second presentation of S1 for half the animals and a 1 second presentation of S2 for the other half. Responding to S2 was significantly higher than responding to S1. Egger and Miller concluded that S2, because of its prior placement, had signaled the food and rendered S1 "redundant", even though S1 was more contiguous to food. Other exceptions to the proximity rule are reported by Ferster (1953), Libby (1951), and others. Obviously, the exceptions differ from the general findings, but, as mentioned earlier, the general findings themselves have been treated by individual workers as orthogonal events. One of the primary reasons for the present design is to ascertain whether these previous studies, which have, by and large, been treated as orthogonal (in both procedure and effects) and which on occasion were disparate, will remain so; or will they be seen as limiting cases along a continuous dimension.

In the Farmer and Schoenfeld experiment, which intruded a single stimulus into an initially "uncued" FI, both the onset and offset of the stimulus (hereafter called J1 and J2, respectively) were relocated simultaneously. Therefore, it was not possible to determine the effect, if any, of either juncture, independently of the other. In a second experiment (Farmer and Schoenfeld, 1966, Experiment 2) the intruded stimulus was presented twice during each fixed interval; once at varied locations (as was the stimulus in their Experiment 1) and a second time when it was kept stationary in bin 10. The moving stimulus in Experiment 2 functioned oppositely to the moving stimulus in Experiment 1. In Experiment 2 responding occurred in the moving S1, whereas, in experiment 1 "breaking" occurred at corresponding locations in S1 (specifically, in bins 3-8). Since there are two intruded stimuli there are now 4 junctures in the I.R.I. These 4 junctures will be named in order of their consecutive appearance from C2 (reinforcement offset): J1 and J2 are the junctures of the moving S1, and J3 and J4 are the junctures of the stationary S1. Since J1 and J2 are relocated simultaneously, as they were in Experiment 1, it is again not possible to determine the influence of either juncture, independently of the other. Because J3 and J4 are stationary in bin 10 and are bound together in the same dependent manner, it is also not possible to determine the effect either of these two junctures might have, independently of the other. It is therefore not possible to know whether the altered effect of the moving S1 in Experiment 2 is determined by the physical sameness of the moving S1 to the stationary S1 or to the independent temporal positions of two unconfounded junctures.

In order to evaluate the effects of either one of two junctures (i.e., stimulus onset or offset), independently of one another and without the confounds of additional junctures or simultaneous repositionings, it is necessary to move a single boundary of a single stimulus, while holding the other boundary of the stimulus constant. The starting points of the expansion of S1 should be varied in order to cover the three major differential effects of S1 placement found by Farmer and Schoenfeld (1966) at the beginning, the middle, and the end of the interval. The purpose of the present study, then, is to independently move each juncture of a single intruded stimulus in order to assess their separate influence on performance in relation to reinforcement offset (C2), reinforcement onset (C1), as well as to each other.

METHOD

Subjects. Nine female White Carneaux pigeons, between six and eight years old and experimentally naive, were maintained at approximately 80% of their free feeding body weights. Water, and supplemental grit were available in the home cages.

Apparatus. Only the center response key of a three key Lehigh Valley Electronics operant chamber (Model # 1519C) was operative during experimental sessions. Approximately 15 grams were required to close the switch. Reinforcement was delivered through a lighted grain hopper located directly below the center key, for a period of three seconds. All timing functions were discontinued during reinforcement. The house light was lit continuously and deflected toward the ceiling of the chamber. A blower provided ventilation and a masking sound. Relay logic was used, and data were recorded on totalizing counters and a cumulative recorder.

Procedure. The nine birds were shaped to peck the center key of the intelligence panel, which was transilluminated with a 1.8 log foot lamberts white diffused light. The animals then received 100 regular reinforcements, which were followed by 60 sessions of exposure to a fixed interval schedule of reinforcement (FI). Two different FI values were used: 30 and 60 secs. (see Table 1). The intervals were timed from the end of the preceding reinforcement and each session terminated after 61 reinforcements. Through session 60, the key was white (S2) for the entire I.R.I. The manipulation of the independent variable took place in two phases. During the first phase, beginning with session 61, the baseline condition was altered so that, the key was changed (independently of responding) from a white light (S2) to a red light (S1) at .01 log foot lamberts. The red stimulus was presented for 10% of each FI. cycle, during the other 90% the key remained white. The temporal placement of the initial presentation of S1 varied for different animals. (See Table 1.) Every subsequent eighth session, the duration of S1 was increased an additional 10% by moving either one or the other transition points between S1 and S2, until, after 10 such increments, the interval was completely filled by S1. This was accomplished, first, by fixing the offset of S1 and receding its onset toward prior reinforcement. This phase will subsequently be referred to as Phase 1 (or the backward phase). After the completion of Phase 1 the initial placement of S1 intrusion was recovered. During the second phase of the study, the onset of S1 was fixed and its offset was extended forward by 10% increments every eighth session. This phase wil be susequently referred to as Phase 2 (or the forward phase).

Once the entire cycle was again filled with S1 a second recovery of the initial temporal placement of S1 was made.

The procedure simultaneously manipulates the duration and the temporal position of both the onset and offset of both stimuli. That is, the recession of the onset of S1 synchronously recedes the offset of S2 as a moving juncture. The other juncture (or transiton point) remains stationary. The two transition points will be referred to as J1 for the first juncture during the interval following reinforcement and as J2 for the second one. Each stimulus in the present study will be designated by its temporal location, with respect to reinforcement. Specifically, S1 is always the continuous stimulus between successive reinforcers. Its complement, S2, is always the stimulus that is interrupted by reinforcement. To enable the reader to keep track of the colors, each stimulus designation will be given an additional subscript: r for the red and w for the white key light. The complete designation is as follows: S1r will refer to the continuous stimulus within the I.R.I. as a red key light; S1w will refer to the continuous stimulus within the bounds of the I.R.I. as a white key light; S2r will refer to the segmented stimulus as a red key light; and S2w to the segmented stimulus as white key light. In the graphs which follow, the upward arrow always designates the onset of the red stimulus, and therefore also the offset of the white stimulus. This is the case whether the upward arrow appears first or second in the interval. The downward arrow always designates the offset of the red stimulus, and therefore also the onset of the white stimulus. When the first arrow in the I.P.I. (J1) points upward, the stimulus between J1 and J2 is the red key light (S1r). When the first arrow in the I.R.I. (J1) points downward, the stimulus between J1 and J2 is the white key light (S1w). It is important to note that the stimulus between the arrows is always referred to as S1 and that its complement is always referred to as S2, whether it is white or red.

TABLE 1

Enumeration of FI. value and Phase of each Figure in Figures 1-12.

GROUP	I.P.*	FIGURE	FI VALUE	PHASE **
1	BIN 1	1	30	1
		2	60	1
		3	30	2
		4	60	2
2	BIN 7	5	30	1
		6	60	1
		7	30	2
		8	60	2
3	BIN 10	9	30	1
		10	60	1
		11	30	2
		12	60	2

KEY:

* Initial Position

** PHASE 1 = WHEN J1 IS RECEDED AND J2 REMAINS STATIONARY.

PHASE 2 = WHEN J2 IS ADVANCED AND J1 REMAINS STATIONARY.

RESULTS AND DISCUSSION

After the initial stimulus placement was introduced, the 6 birds which displayed response patterns similar to those reported in the literature were retained as subjects for "the experiment proper", reported here. (Bruner, 1981; Dews, 1962; Evra, 1974; Farmer and Schoenfeld, 1966; Martin, 1971; Snapper, et al., 1975; and others.)

GENERAL FINDINGS

In panels A and K of Figures 1-12 performance under "uncued" FI is shown. Panel A shows baseline performance, when the key light is always white. Panel K displays the function when the key light is always red, following the complete extension of the duration of the intruded stimulus. In all of these panels the functions of Figures 1-12 resemble normal FI responding. Panel B of Phase 1 (the odd numbered figures) shows the initial placement of S1. The three different initial placements in the present study duplicate the results found by Farmer and Schoenfeld (1966) when S1 was similarly positioned within the I.R.I., in their study. Such data have been replicated by many workers; with rats as well as pigeons, with mild shock as well as with a light as the intruded stimulus. (Kadden, et.

al., 1975; Snapper, et. al., 1971.) Panel L, of Phase 1 of Figures 1-12 (the odd numbered figures), shows the data obtained during the first recovery of the initial placement of S1. Panel B of Phase 2 also displays the first recovery, while, panel L of this forward phase shows the second recovery.

SPECIFIC FINDINGS

In the discussion which follows, it is helpful to bear in mind the dichotomy between the probablity of responding and the probability of not responding, which obtains following 60 sessions of baseline training. It is also important to recall that this dichotomy is enhanced by either extensive training or the introduction of an additional exteroceptive cue.

RESPONDING BETWEEN THE JUNCTURES

When both junctures are positioned within the first seven bins no responding occurs between them. (See Figures 1 and 2, panels E-J; Figures 3 and 4, panels B-G; Figures 5 and 6, panels B-H).) The first time that responding occurs between the junctures (i.e., in S1) is when J2 extends to bin 8. This is consonant with the "potency by proximity" principle. Responding, in this latter condition, occurs in an accelerated fashion, which is also consistent with that principle. No responding occurs when both junctures are located anywhere between bins 2 and 8. The only time that responding does occur within the first eight bins is when J1 and J2 are placed in bins 1 and 8. Within these confines, the separation between the junctures is at a maximum, with J1 at its greatest distance from reinforcement. This result is inconsistent with the "potency by proximity" principle. When J2 is held constant in bin 8, only the furthest placement of J1 from reinforcement (i.e., when J1 is in bin 1) yields responding between the junctures. This makes S1 more potent by virtue of its greater distance from reinforcement. Stated in conventional terms: When S1 is located exclusively in bin 8 (Farmer and Schoenfeld, 1966) or extends from bin 2 through bin 8, as in the present study, no responding occurs in S1. When S1 extends from bin 1 through bin 8 it is further from reinforcement than when it was positioned at any of the 2-8 values, yet, responding occurs in S1. This finding is unpredictable from the proximity to reinforcement rule.

When J2 is placed in bin 9, S1 displays greater strength. Responding always occurs between the junctures, regardless of the placement of J1 (Figures 1 and 2, panel C; Figures 3 and 4, panel J; Figures 7 and 8, panel, D). The greater proximity of J2 to reinforcement renders S1 potent, no matter where J1 is located. This latter result, as well as the accelerated function seen between the junctures, is again consistent with the "potency by proximity principle.

This same rule further dictates that an additional extension of J2 torward reinforcement (into bin 10) should also yield increased graded responding between the junctures. This follows from the fact, that when J2 is advanced from bin 8 to bin 9 responding always results between the junctures (i.e., in S1), regardless of where J1 is located. When J2 is in bin 10, and the temporal separation between J1 and J2 is "relatively short" (i.e., J1 occurs in bins 5-9) this is exactly what happens. Responding occurs between J1 and J2, generally at an intermediate rate (Figures 9 and 10, panels B-F). When J2 is in bin 10, however, and the separation between the junctures is "relativaly large" (e.g., when J1 in bin 2), rather than produce the expected increase in responding, moving J2 closer to reinforcement, produces a complete diminution in responding over the entire interval. In other words, when S1 extends to bin 10 it is (at one end) as close to reinforcement as it can be, yet responding is nil. The argument cannot be made that it is the greater distance of J1 (S1 onset) from reinforcement which is the dynamic component, since that same factor was seen to initiate the opposite effect when J2 was held constant in bin 8. (See above.) As long as neither J is at either end of the interval, S1 displays a strength commensurate with its distance from reinforcement. When either J is placed at either extremity of the interval, however, the effects may be contrary to what is predicted by the "potency by proximity" rule. Whether the effects are contrary to what is predicted, or not, depends upon the relative positions of both junctures. These inconsistencies, seen when each J is at either extremity of the interval (and when the other J is appropriately placed) suggest that previous theoretical accounts regarding potency and proximity may have to be revised or amended to include all of the presently obtained results.

By and large, when responding occurs between J1 and J2 (i.e., in S1) it occurs at a rate that is intermediate between zero and baseline responding. There are two exceptions to this: One is when J2 is in bin 10, contiguous to reinforcement, and the separation between J1 and J2 is "relatively large". At these parameter values, virtually no responding occurs throughout the entire interval. The second exception is seen, although only occasionally, in the performance of bird #11 (see Figure 10, panels B and C; and Figure 12, panel L). This latter exception appears to be a result of the temporal control established during the baseline training of this animal, in which the function displays an exceptionally strong acceleration of the rate in bin 10 (Figure 10, panel A).

The rationale for the occurrence of the predominantly found intermediate rate is as follows: The duration between J1 and J2 demarcates extinction; the animal never gets reinforced between J1 and J2. When the junctures appear at a portion of the interval where the response tendency is less than maximum, "breaking" (a period of not reponding) occurs within these junctures. On the other hand, when J2 is placed at the portion of the interval at which the organism has demonstrated maximum probability to respond, the high probability to respond and the cue that defines extinction behavior compete and a compromise rate obtains. When J2 moves through reinforcement this intermediate effect is not seen. Under this condition, J1 and J2 occur at the beginning of the interval and no longer define extinction at the later portion of the interval (where response probability is at a maximum). Therefore, there exists no competitively defined extinction demarcations to retard the prevailing temporal control, and the baseline rate function obtains.

At most of the parameter values of the temporal placements of the junctures, the obtained results replicate the findings of Farmer and Schoenfeld. Both the latter and present studies replicate the effects found when "uncued" FI is employed specifically, the dichotomizing of the FI into: 1) minimum probability of responding during the initial 80% of the interval and 2) maximum probability of responding in the last 20% of the interval. This dichotomy is seen to some degree in the baseline ogive, and to a markedly greater degree following extended training (Cumming and Schoenfeld, 1958). In spite of the exceptions, then, at most parameter values of the present study, the more proximal either "time" (cf., Catania, 1970;

Pavlov, 1927, pp 41; Stubbs, 1968) or an exteroceptive stimulus is to reinforcement, the greater the probability of responding. This being the case, it is easy to see why many theorists would advance the "potency by proximity" principle (Jenkins, H. M., 1970), or a retroactive enhancing effect of reinforcement (Dews, 1970). In the light of the the present data, however, it appears that both of these formulations may be incomplete.

RESPONDING PRIOR TO J1

When both junctures are positioned within the first eight bins, responding prior to J1 resembles the baseline distribution. There is virtually no responding before J1 (Figures 5 and 6, panels F-H) when J1 is placed in any of the first 3 bins. When both junctures are positioned between bins 4 and 8, irrespective of their temporal separation from one another, the same scalloped response distribution is obtained that appears prior to J1 during baseline conditions: the post reinforcement pause is followed by probability of responding, which gradually increases until J1. Since no responding occurs between the junctures, there are now two scallops (Figures 5 and 6, panels B-E). This effect, previously reported by Farmer and Schoenfeld (1966) Martin (1971), and others, does not obtain for Bird 10 (Figure 7, panels H & I). It appears that for this animal the particular experimental history of segment 2 of S2 is responsible for the attenuation of the first scallop. Specifically, for 21 sessions, prior to its extension to bins 4 and 5, Segment 1 of S2 had been an S-Delta. A similar diminution of the first scallop is seen to a lesser degree for Bird 6 (Figure 8, panels H & I). This reduced responding in segment 1 of S2 may well be the result of these 21 sessions. In all of the previous studies which have replicated Farmer and Schoenfeld and in the present one as well, when J1 and J2 have been initially placed in bins 4-8, and no such experimental history has taken place, a rate comparable to baseline has invariably been obtained (Evra, 1974; Farmer and Schoenfeld, 1966; Kadden, et. al., 1975; Snapper, et. al., 1971, etc).

When J2 extends to bin 9 and J1 is positioned in bin 7, there is a large reduction in responding prior to J1 (Figures 7 and 8, panel D). This same reduction was also reported by Farmer and Schoenfeld (1966) when J2 was similarly located. In the latter experiment, J1 was also located in bin 9. It has been shown that the addition of cues to a previously "uncued" FI schedule generally facilitate and sharpen the dichotomy between the high and low probability of responding that is originally obtained in the "uncued" condition. In both the present study and in the Farmer and Schoenfeld experiment, when J2 is located in bin 9 and the separation between J1 and J2 is "relatively short" the sharpening of the dichotomy begins to emerge. Responding, prior to J1, is greatly decreased.

When J2 is moved to bin 10 and J1 occurs centrally, in bin 7, no responding occurs prior to J1 (Figures 7 and 8, panel E). At these latter parameter values, the dichotomy between probability of responding and probability of not responding is more precise. When both junctures are initially placed in bin 9 (Farmer and Schoenfeld) or bin 10 (Farmer and Schoenfeld and the present study), the dichotomy is facilitated (see Figures 9 and 10, panel B), but does not reach the degree of precision seen when J2 is in bin 10 and J1 is more centrally placed. In either case, with a cue propitiously placed in the interval, this transition develops quickly following baseline training. With an "uncued" FI schedule, however, this precision occurs only after extensive training. When J1 and J2 are in bins 7 and 10, respectively, the stimulus arrangement may be conventionally labeled "multiple EXT FI" (Ferster and Skinner, 1957). Technically, this is not so, because J2 occurs (or S1 ends) just as reinforcement becomes available. Whereas, in a truly conventional "multiple EXT FI", J2 (or the second boundary of S1) would continue until reinforcement is procured. It shall be subsequently demonstrated that when J1 is located past the center of the interval (as it is here) extending J2 (S1 offset) to bin 10, through reinforcement, or even placing it in bin 9, does not effect the function. (See the section on contiguity.)

When J2 extends to bin 10 and the J1-J2 separation is very short (e.g., J1 occurs in bin 9 or 10), responding prior to J1 sometimes occurs and sometimes does not. This stimulus arrangement, too, is virtually a conventional "multiple EXT FI", although the FI is relatively brief. Why does responding sometimes occur prior to S1 when J2 is in bin 10 and J1 occurs late in the interval? By contrast, when J1 is more centrally located and J2 is in bin 10 no responding occurs prior to J1. The answer appears to be that the temporally controlled behavior (created during baseline) is always present and is merely modulated by the exteroceptive cues. When J1 occurs in bin 10 and J1 occurs in bin 9 or 10, no exteroceptive cue occurs prior to the point of maximum response probability, to modulate this maximum probability. Reponding may occur prior to J1, and often does. But, when J1 occurs, e.g., in bin 7, it provokes the first responding in the interval. Yet, it occurs early enough in the interval, i.e., prior to maximum reponse probability, to control not responding prior to its occurrence.

RESPONDING POSTERIOR TO J2

The response rate function which follows J2 (i.e., segment 2 of S2) almost always occurs at a rate approximating baseline rate. This results irrespective of the temporal placements of both junctures. When the transition from no responding to responding is abrupt, as it often is at long temporal separations between J1 and J2, the rate is usually commensurate with baseline (Figure 1, panel C; Figure 3, panel J; Figure 6, panel H; Figure 11, panels C-D; Figure 12, panels C-D). Less often, the rate under these parameter values exceeds the baseline rate (Figure 2, panel C; Figure 4, panel J; Figure 5, panel H). These effects are not systematic within this condition. They occur idiosyncratisally and merely allow speculation as to their determinants.

The one consistent addition to the baseline function resulting from the intrusion of J2, respecting the response distribution following J2, is a post J2 pause. This pause is seen during the relocation of J2, but only within the first five bins of the I.R.I.

POST J2 PAUSE

In Figures 1-4 it may be seen that as J2 approaches the mid-point of the interval, the function is altered from one that yields a brief pause following J2 to one that produces an immediate resumption of responding following J2. This alteration is seen in Figure 1, panels G-H, and in Figures 3 and 4, panels E-F. The two different effects may be distinguished in these panels by the fact that the data point either rises above zero directly at J2 (no pause), or rises above zero at the next bin following J2 (post S1 pause). A similar effect, i.e., going from no pausing to pausing following a stimulus offset, is seen in "uncued" FI when the distance between C2 and C1 is increased from very brief FIs to longer ones; in the Farmer and Schoenfeld study (1966) when the distance between J2 and C1 increases; and again in Byrd's (1971) data in which a relatively brief blackout "stimulus" was inserted between C2 and the start of the next component of a second order FI schedule. These data, as well as the studies previously reviewed, indicate that any cue, be it reinforcement offset, "neutral" stimulus offset, or the offset of a blackout period, equivalently yields a similar function when placed within the I.R.I. These effects depend upon the proximity of the stimuli to reinforcement, not on their physical properties (cf., Dews, 1970; Morse and Kelleher, 1970; Stubbs, 1971).

REDUNDANCY

One question suggested by the findings of the previous studies, which have employed the intruded stimulus paradigm, is whether segment 2 of S2 in bin 10 is redundant when S1 is positioned exclusively in bin 9 (cf., Egger and Miller, 1963). Had Farmer and Schoenfeld extended the offset of S1 into bin 10 instead of moving the entire stimulus (i.e., both junctures synchronously) this specific inquiry would have been experimentally addressed. But, their design did not include this manipulation. The following series of operations addresses this question.

When J1 is positioned anywhere in the second half of the interval (e.g., in bin 7) whether J2 is in bin 9, bin 10, or for that matter is extended through reinforcement, the functions are similar (Figures 7 and 8, panels D, E, and F, respectively). In other words, the functions remain unchanged with or without a change of cue in bin 10. On the other hand, when J1 is positioned early in the interval (e.g., in bin 1 or 2), the relocation of J2, to either bin 9, or bin 10, or through reinforcement, results in a different function for each relocation. Specifically, when J1 is in bin 2 and J2 is in bin 9, the rate function between the junctures is intermediate, then abruptly shifts to a high rate at J2 (Figures 1 and 2, panel C). However, when J1 is in bin 2 and J2 is in bin 10 (coincedent with reinforcement) S1 extends through bin 10. In this case, the rate function between the junctures diminishes to virtual zero. The abrupt shift in responding is again evidenced at J2. Here, the shift occurs following zero responding. Since, at this experimental point, the response that follows zero responding is the reinforced response, no rate is forthcoming. However, the small response function seen in Figures 9 and 11, panel J results from some responding that occurs during the first few intervals of the session. In virtually every single remaining interval, at this experimental point, no responding occurs prior to J2. Lastly, when J2 is relocated past bin 10, and is coextensive with reinforcement, there is no cue change in bin 10 to signal the end of a demarcated period of extinction. In the present procedure, when the junctures demarcate extinction and J2 is located in bin 9 or 10, the function has been shown to yield, at best, an intermediate rate of responding, followed by an abrupt transition. Neither is in evidence here. In the present case, the function accelerates at a rate comparable to baseline until reinforcement is gained (Figures 3 and 4, panel B). Whether a stimulus change that occurs in bin 10 is differentially effective, or redundant, then, is a function of the temporal placement of J1 (cf., Kamin, 1965, pp 142).

CONTIGUITY

For the discussion which follows the nomenclature thus far employed will be dispensed with. The reason for this is that the contiguity of the offset of S1 to reinforcement is to be compared to coextension of the offset of S1 with reinforcement. The terminology that has been used before would be unnecessarily cumbersome. Until now the criterion for labeling a stimulus S2, was the interruption of that stimulus by reinforcement. For the present purpose, the stimulus that is to be specified will be designated either Sr (red) or Sw (white) and will be distinguished by its offset being either contiguous to or coextensive with reinforcement. The interruption by reinforcement does not change the designation of that stimulus.

It was shown above that whether or not J2 is redundant when located in bin 10 depends on the temporal position of J1. The same is true with respect to the effects of the contiguity of S1 to reinforcement vs the coexistence of S1 with reinforcement. Whether or not the effect of contiguity, or coexistence, produces either similar or differential results, depends on the placement of S1 onset (J1). It was seen in Figures 7 & 8, when comparing panel E to panel F, that the functions are similar whether S1 offset is contiguous to reinforcement (see panel E) or coextensive with reinforcement (see panel F). In both of these functions the onset of Sr occurs in bin 7. This is consonant with what Skinner (1938) found. In his prototypic discrimination experiment both the click (contiguous) and the light (coextensive) produced identical functions.

Alternatively, when the onset of Sr (or Sw, as the case may be) is located in bin 2 the functions are dramatically disparate, depending on whether S1 offset is contiguous to or coextensive with reinforcement. When Sr onset is in bin 2, for example, and its offset is contiguous with reinforcement responding is at virtual zero in Sr (Figures 9 & 10, panel J). However, when the onset of Sr is in bin 2 and the offset of Sr is coextensive with reinforcement responding is equal to baseline rate (Figures 1 & 2, panel, B; see also Figures 1 and 2, panel J). The former parameter values are reminiscent of Skinner's (1938) discrimination paradigm and the present results are consistent with those previously found by Skinner. Specifically, there is virtually no responding in the precisely demarcated extinction period, i.e., S1. As was seen in the case of redundancy, when S1 onset is positioned late in the interval, the function is unaffected whether S1 offset is contiguous or coextensive with reinforcement. Alternatively, when S1 onset is positioned early in the interval, the function is dramatically different, depending whether the offset of S1 is either contiguous or coextensive with reinforcement. Although Skinner (1938) noted that the click (contiguous) or light (coextensive) produced equivalent functions, the altering effect of separating the junctures was not demonstrated until the present study.

THE INFLUENCE OF BASELINE FI TRAINING ON AN INTRUDED STIMULUS

It appears from all of the studies so far reviewed, which have employed FI schedules with an added stimulus, that the added stimulus accentuates the temporally controlled behavior originally "created" by the baseline FI schedule. If it is the case that such control of responding, by the schedule, determines what the stimulus does, one might expect that an organism which had not developed typical FI baseline characteristics in its behavior would not display differential behavior to S1 control when the stimulus is positioned at the two extremities of the interval. That is to say, the amount of baseline training received on an "uncued" schedule of reinforcement should directly influence the amount of differential responding to S1 when it is simultaneously located in bins 10 and 1. Figures 13-15 show three birds (#s 1, 6, and 8) taken from the present procedure, placed on FI 300", and given no baseline training. Following ten sessions of exposure with S1 positioned in bin 10 the animals were then exposed for 30 sessions to S1 positioned in bins 10 and 1 (remaining on through reinforcement). The results of this condition show that the animals display no differential responding between bin 10 and bin 1. Figures 16-18 show the other three birds from the present experiment (Birds #s 9, 10, and 11). These animals received thirty sessions of baseline training, followed by ten sessions of S1 placed in bin 10, which was then followed by 30 sessions in which S1 was placed in bins 1 and 10. This latter condition results in a function which displays differential responding between bins 1 and 10 that falls half way between the complete differential responding that obtains between those bins following 60 sessions of baseline training and the zero differential responding that obtains between those bins following zero sessions of baseline training. Compare Figures 13-15 (zero sessions of baseline training) and Figures 16-18 (30 sessions of baseline training) with Figure 19 (60 sessions of baseline training). The amount af baseline training, which produces the temporally controlled graded FI function, is thus seen to directly influence the amount of stimulus control that obtains at the extremities of the I.R.I. This latter finding seems to substantiate the hypothesis that the control exerted by the exteroceptive stimulus is determined by the control exerted by the schedule.

SUMMARY AND CONCLUSIONS

The data of the present study show that the duration of S1 or of S2, per se, i.e., without reference to the temporal placement of J1 and J2, has no systematic effect. The direction in which the junctures were moved was also seen to be inconsequential. Except for two occasions, the influence of experimental history was completely reversible. Essentially, control of the response distribution can be relegated to the relative temporal positions of the junctures of the intruded stimulus.

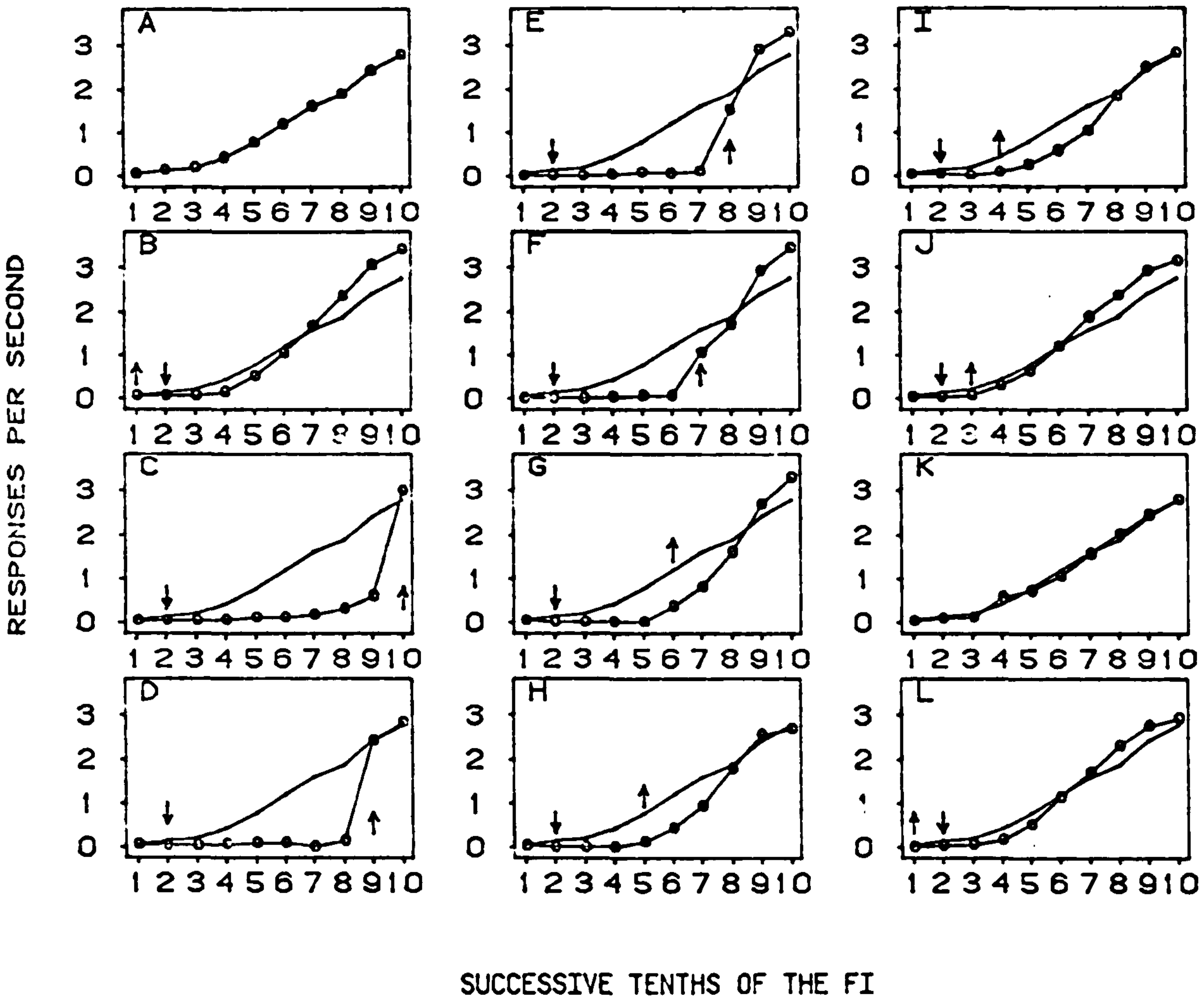
At most temporal placements the junctures obey the potency by proximity rule. Stimulus control of responding generally increases in strength as reinforcement is neared. Additionally, it was shown that this increase in the probability of responding is a reasonable duplication of the control exerted by the "uncued" FI schedule on the response distribution. This fact implies that stimulus control may ultimately be ascribed to the reinforcement schedule. On "uncued" FI, control of the response distribution eventually results in a $PS^{R}P$ which extends for approximately 80% of the I.R.I., while, the probability of response commencement occurs with greater consistency at about the 80th to 90th percentile of the interval. With the addition of S1 to the FI schedule the sharpening of this dichotomy was achieved with marked facility. However, at some of the parameter values of the junctures the results do not show the potency by proximity effects commonly found in the stimulus control literature. These contrary effects obtain when the junctures are positioned at large temporal separations from one another, and with either one or both junctures being contiguous to C2 or C1. When this does happen, dramatic changes in the response distribution occur which are contrary to expected influences of stimuli. These antipodal effects, can emerge as a result of a very small movement of a juncture. These contradictions, which are here viewed as part of a single continuous dimension, demonstrate that concepts which are formed from incomplete data, may be revealed by apparently minor changes along a continuous independent variable.

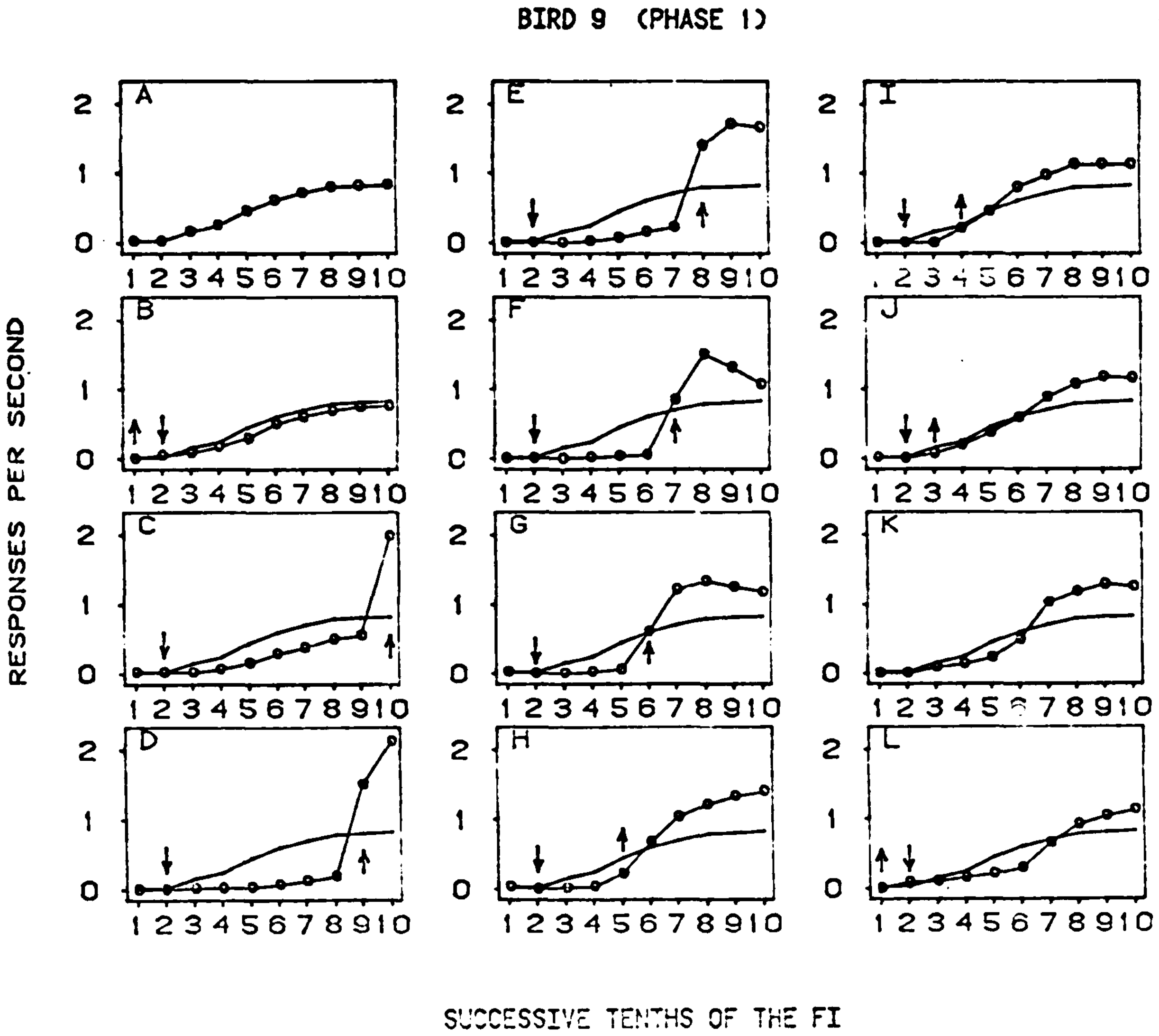
Many of the present results defy interpretion of the stimuli as S-Ds or S-Deltas. Prior to the present findings the Farmer and Schoenfeld study (1966) had already demonstrated that the conventional way of describing a stimulus as either an S-D or S-Delta is inadequate. In their experiment when S1 is located in bin 9 both S1 and segment 2 of S2 in bin 10 produce responding. Which one is S-D? And where is S-Delta? Equivalently, when S1 is in bin 2 both it and segment 1 of S2 (in bin 1) yield no responding. Similar discrepancies are found in the present study. Other hypothetical concepts (e.g., Redundancy and Contiguity) were also shown to be equivocal; the results obtained depend upon the temporal placement of the junctures.

To conclude: a procedure has been implemented and reported which located the variety of effects to be accounted for by the most rudimentary principles of stimulus control on a single temporal dimension. The spectrum of effects reported here is exhaustive by virtue of the procedure which independently repositioned the two boundaries of an intruded stimulus. In traversing the entire dimension exceptions to major interpretations of the source of exteroceptive stimulus control were noted. Future theoretical principles of stimulus control must encompass the entire range of effects revealed in the present study. Until such time, the temporal dimension itself must suffice to direct further research.

Figures 1-4. Performances of Birds #1 and #9. Each panel displays the temporal position of both boundaries of S1, indicated by two arrows. The first arrow in a panel is J1 and the second one is J2. Panel A (without arrows) represents baseline performance on a 30-sec and 60-sec FI schedule for Birds 1 and 9, respectively, before the introduction of S1. In panel B the initial intrusion of S1 is shown. For these birds, the initial placement of S1 is in bin 1. In Figures 1 and 2 the movement of J1 is toward prior reinforcement, while, J2 remains stationary. In Figures 3 and 4 the movement of J2 is away from prior reinforcement, while, J1 remains stationary. Panel L (without arrows) represents the performance when S1 fills the entire interval. Each datum point represents the average rate for the last 5 sessions of 60 approximately 1-hr daily sessions of baseline training. Each point represents a tenth of the FI. The form of the baseline function is redrawn as a simple line in all succeeding panels to allow comparisons. The data points in all of the other panels are the averages of the last two sessions taken as criterion performances from seven approximately 1-hr daily sessions. The numbers on the abscissae denote each successive tenth of the interval. Redeterminations of the individual intrusions of S1 are shown in panel L of all these Figures (see text).

BIRD 1 (PHASE 1)




BIRD 9 (PHASE 1)
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI
A
B
C
D
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G
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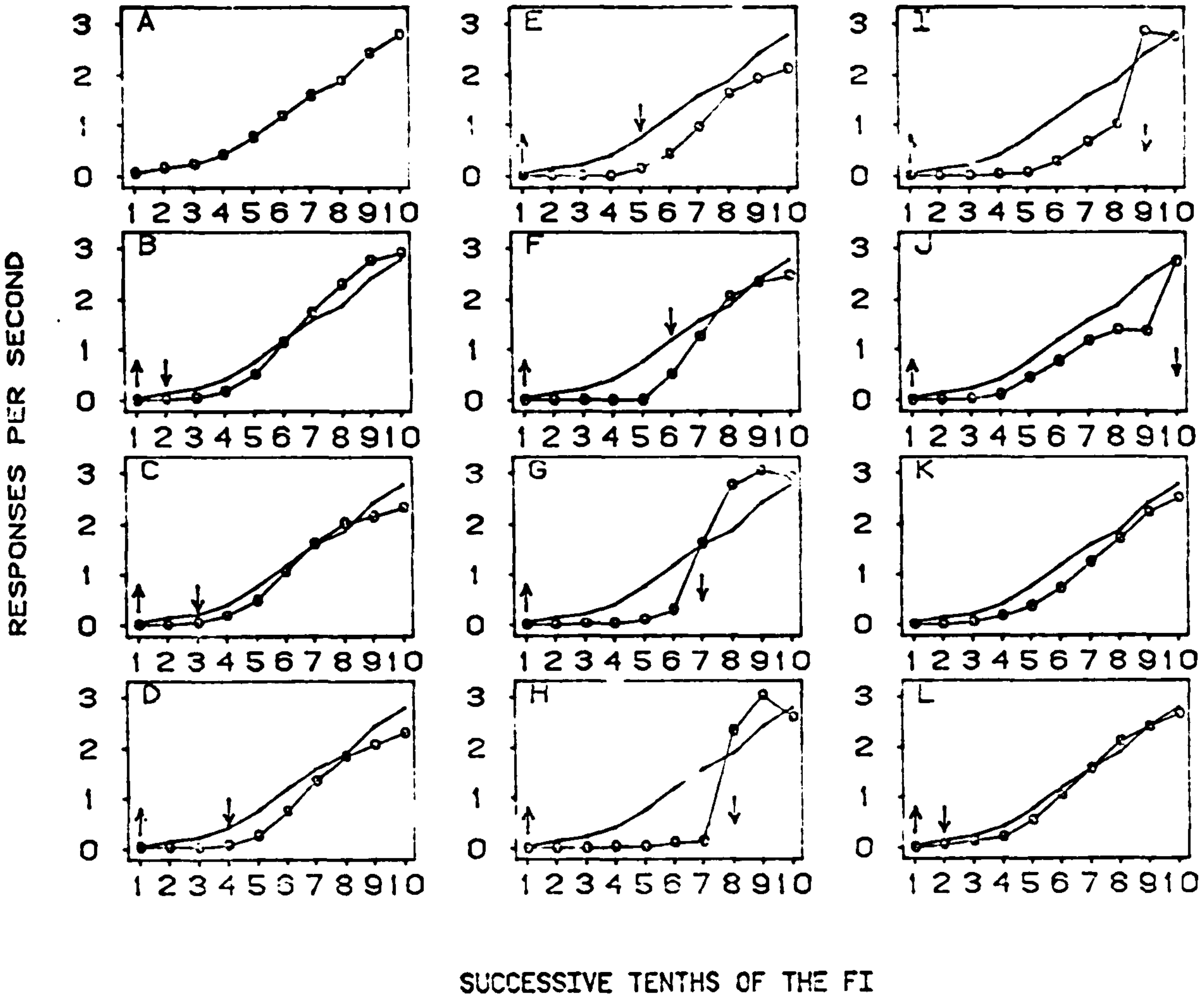
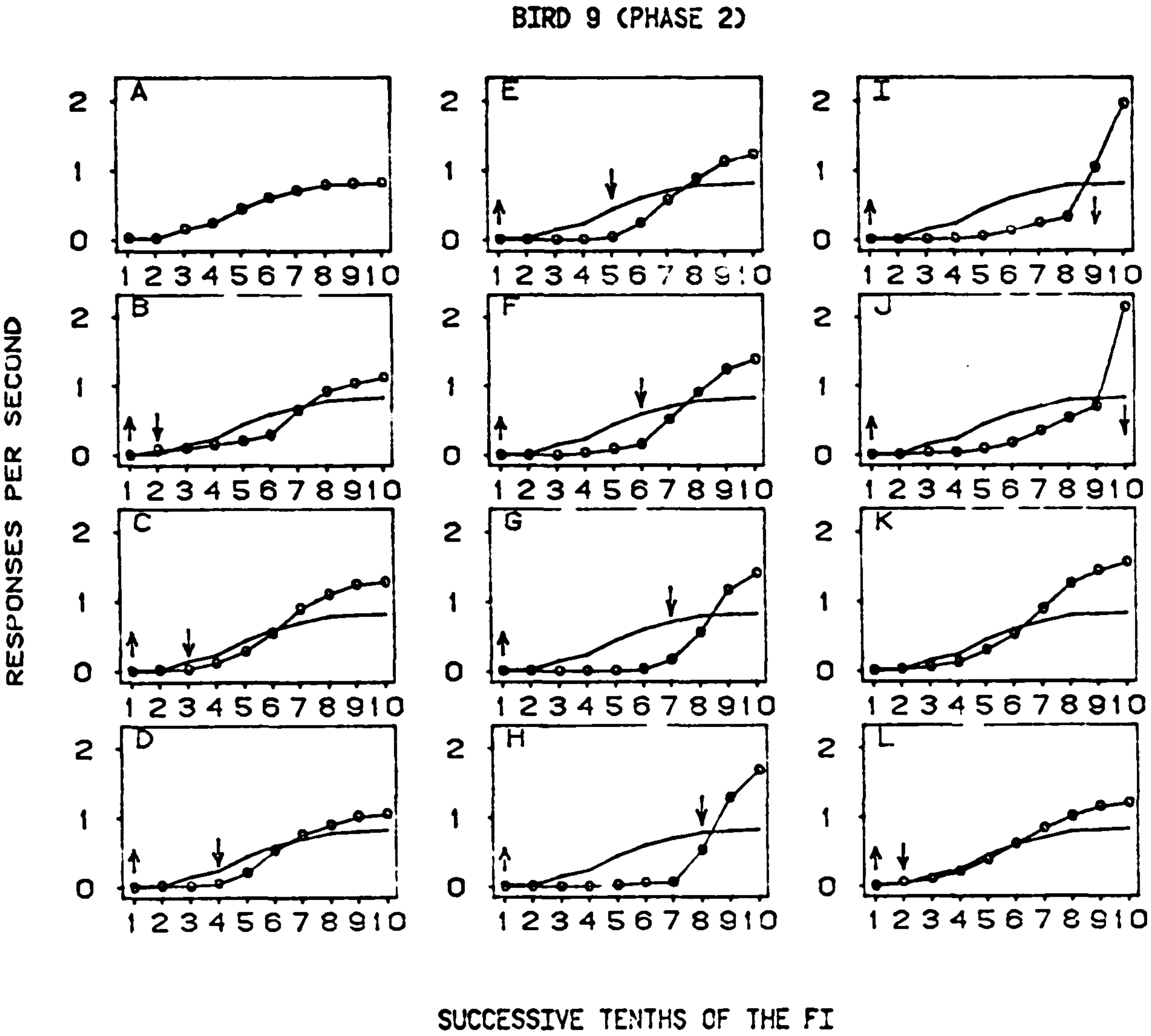
0
1
2
1 2 3 4 5 6 7 8 9 10

BIRD 1 (PHASE 2)




BIRD 9 (PHASE 2)
A
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I
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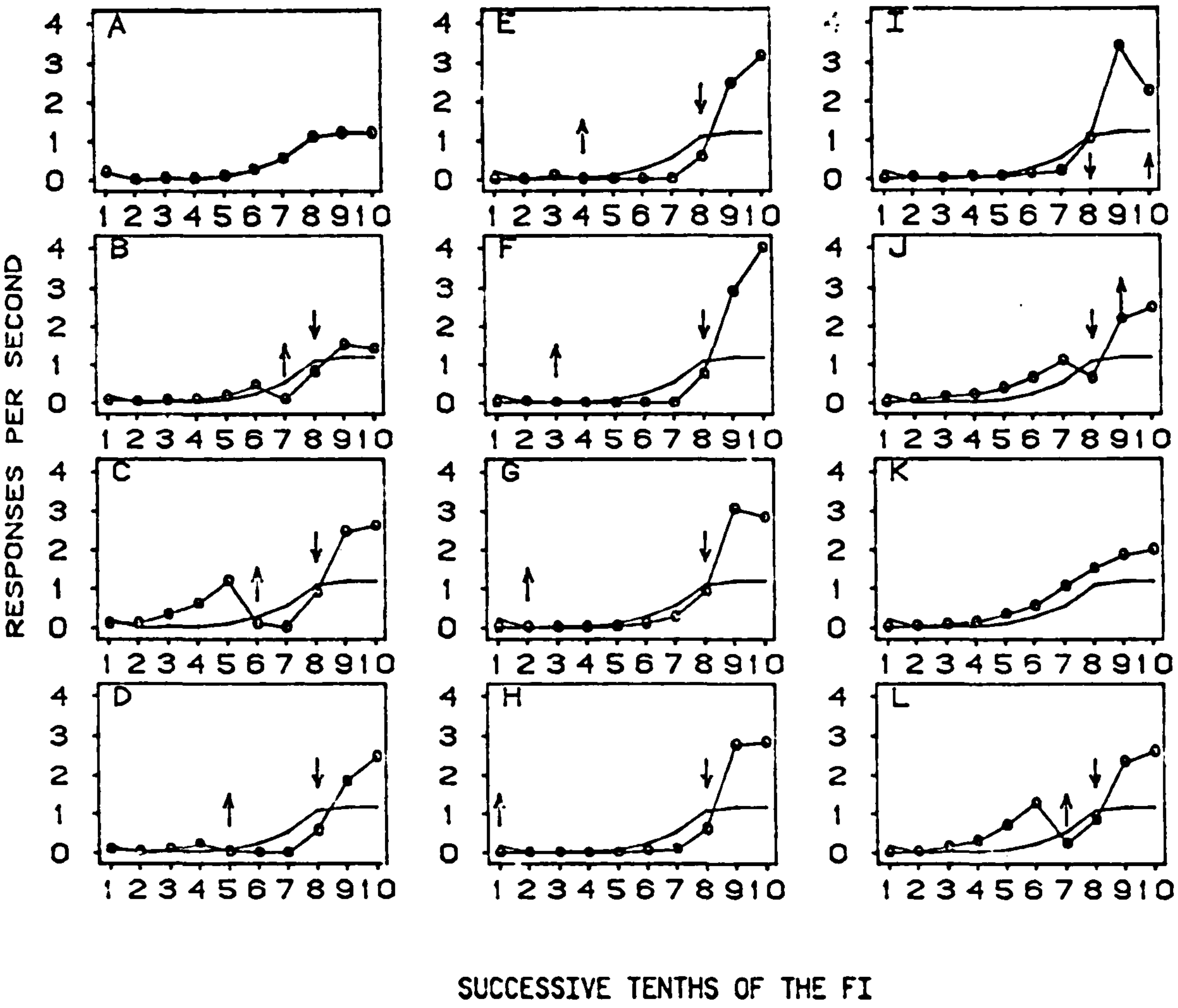
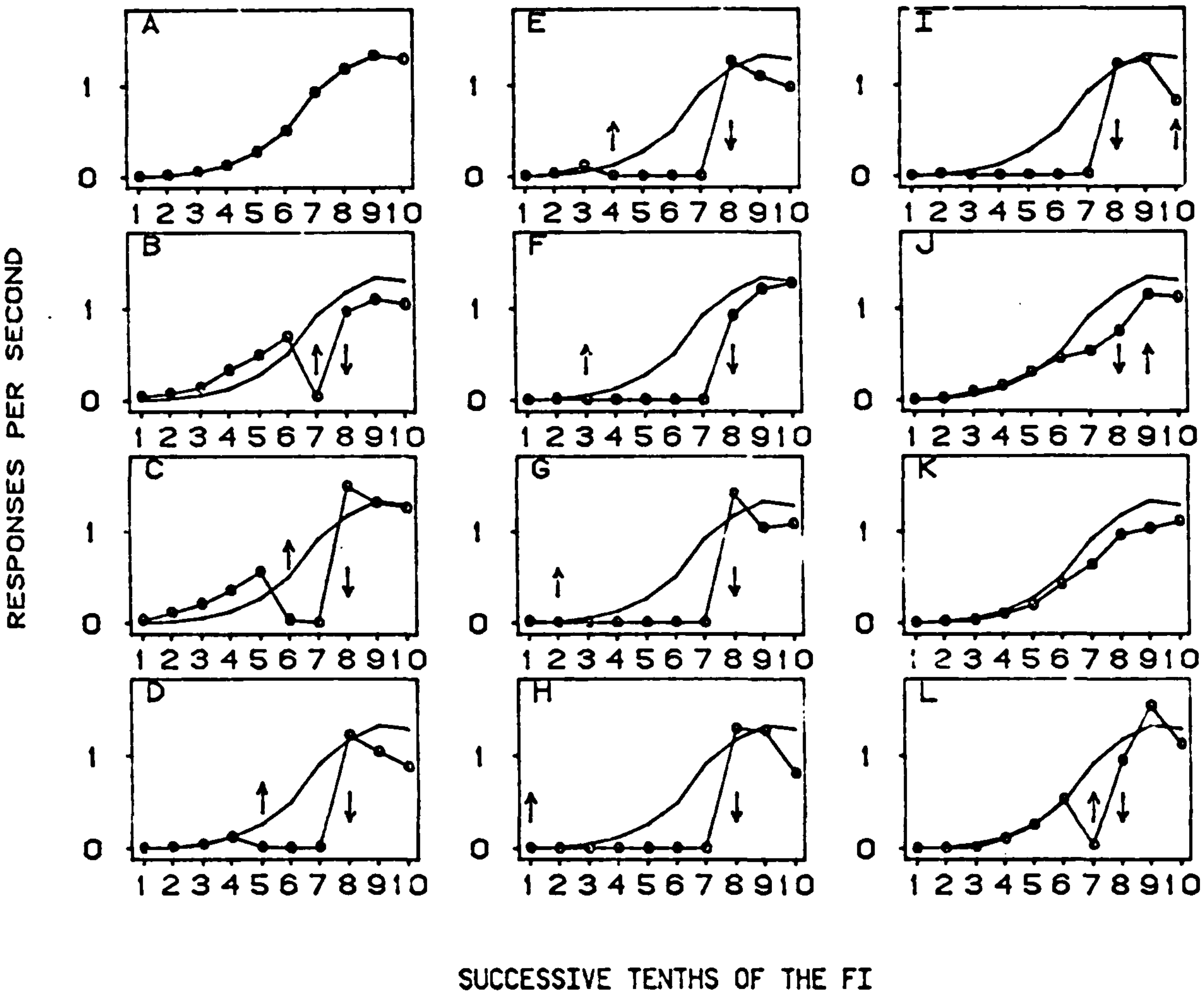
0
1
2
1 2 3 4 5 6 7 8 9 10
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI

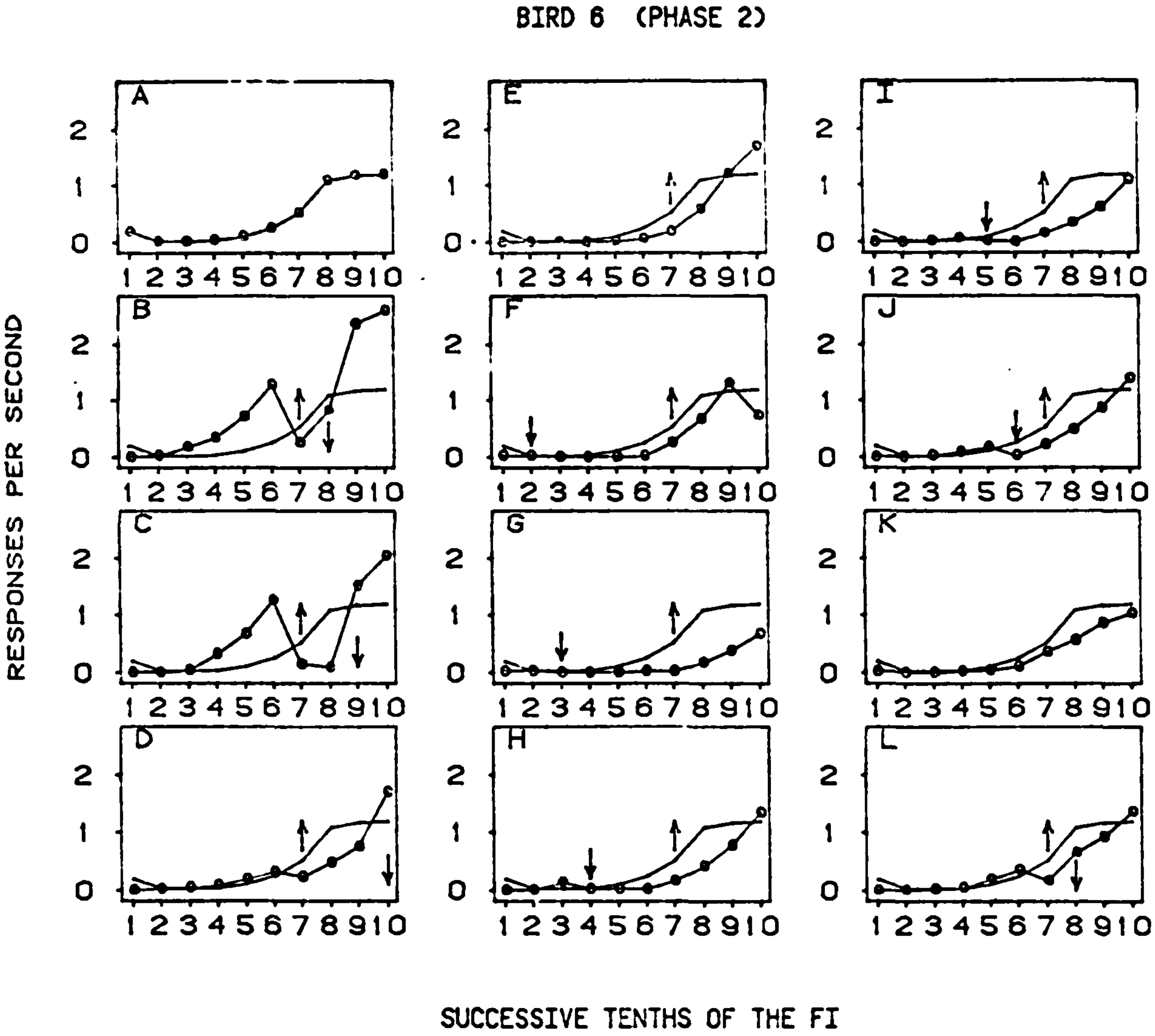
Figures 5-8. Performances of Birds #6 and #10. The legend for Figure 1 is applicable here. The single exception is the point of intrusion of S1. For these Birds the intruded stimulus is initially placed in bin 7.

BIRD 6 (PHASE 1)



BIRD 10 (PHASE 1)




BIRD 6 (PHASE 2)
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C
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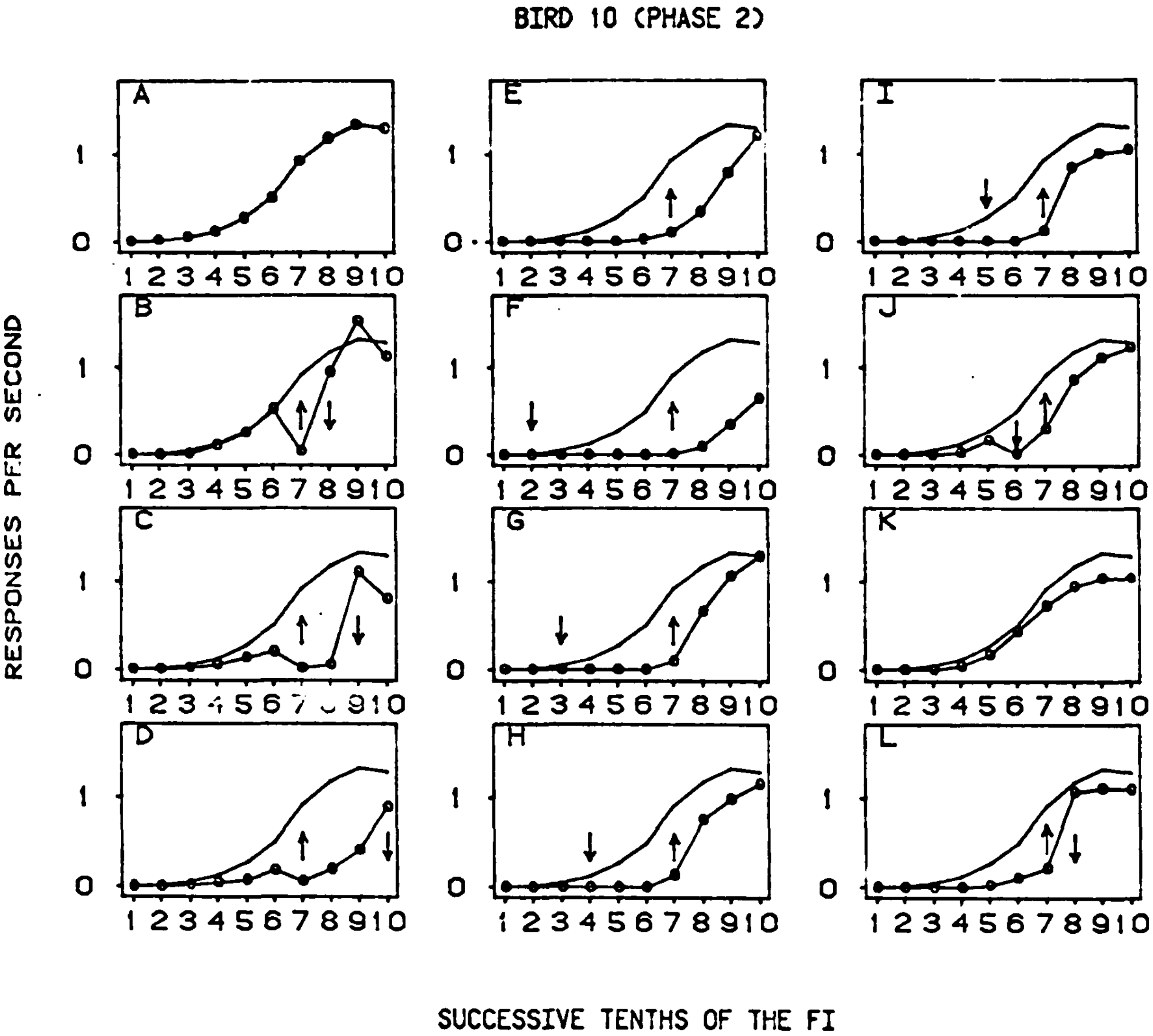
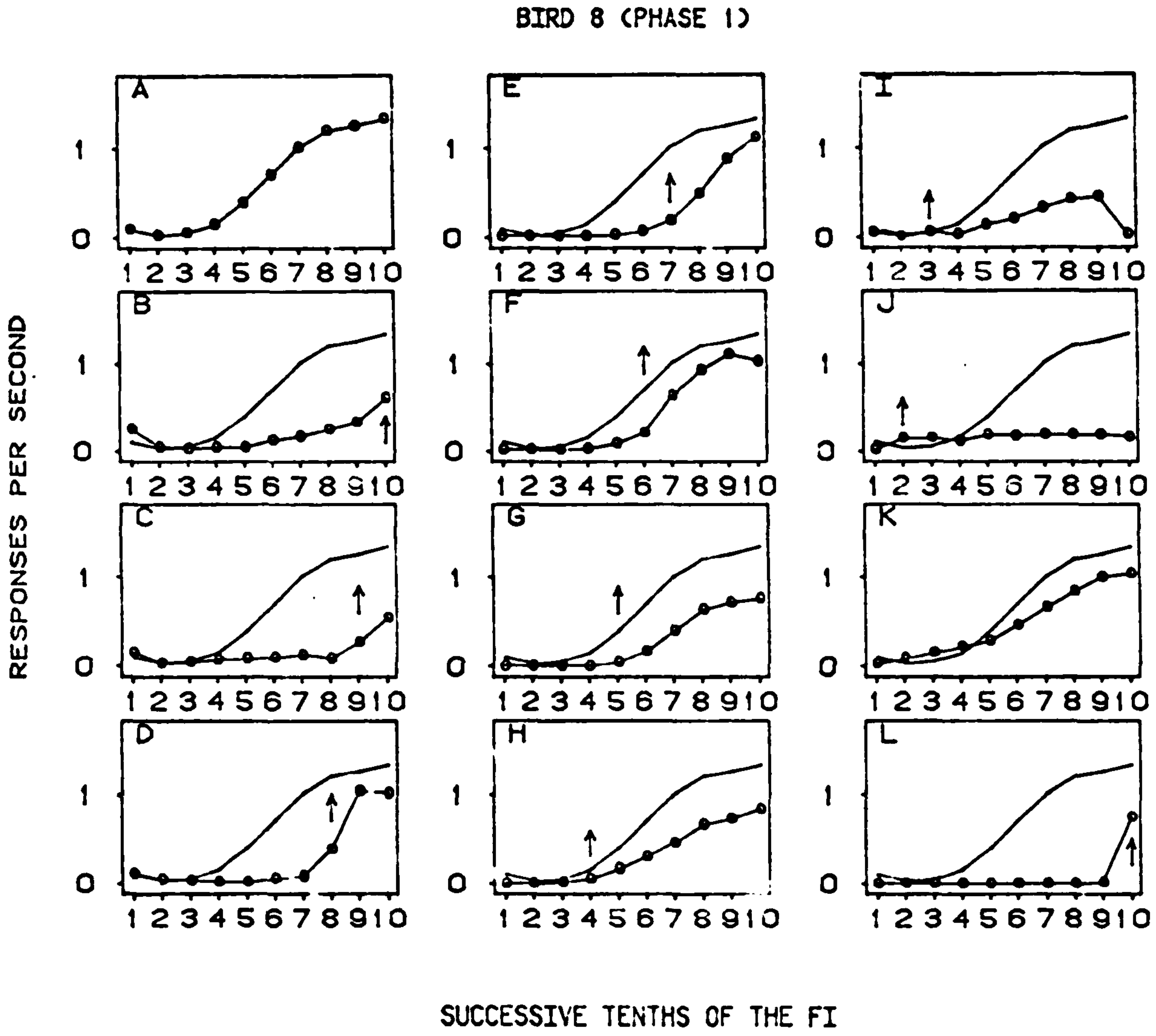
1 2 3 4 5 6 7 8 9 10
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI


BIRD 10 (PHASE 2)
A
B
C
D
E
F
G
H
I
J
K
L
0
1
1 2 3 4 5 6 7 8 9 10
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI

Figures 9-12. Performances of Birds #8 and #11. The legend for Figure 1 is applicable here. The single exception is the point of intrusion of S1. For these Birds the intruded stimulus is initially placed in bin 10.


BIRD 8 (PHASE 1)
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI
A
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C
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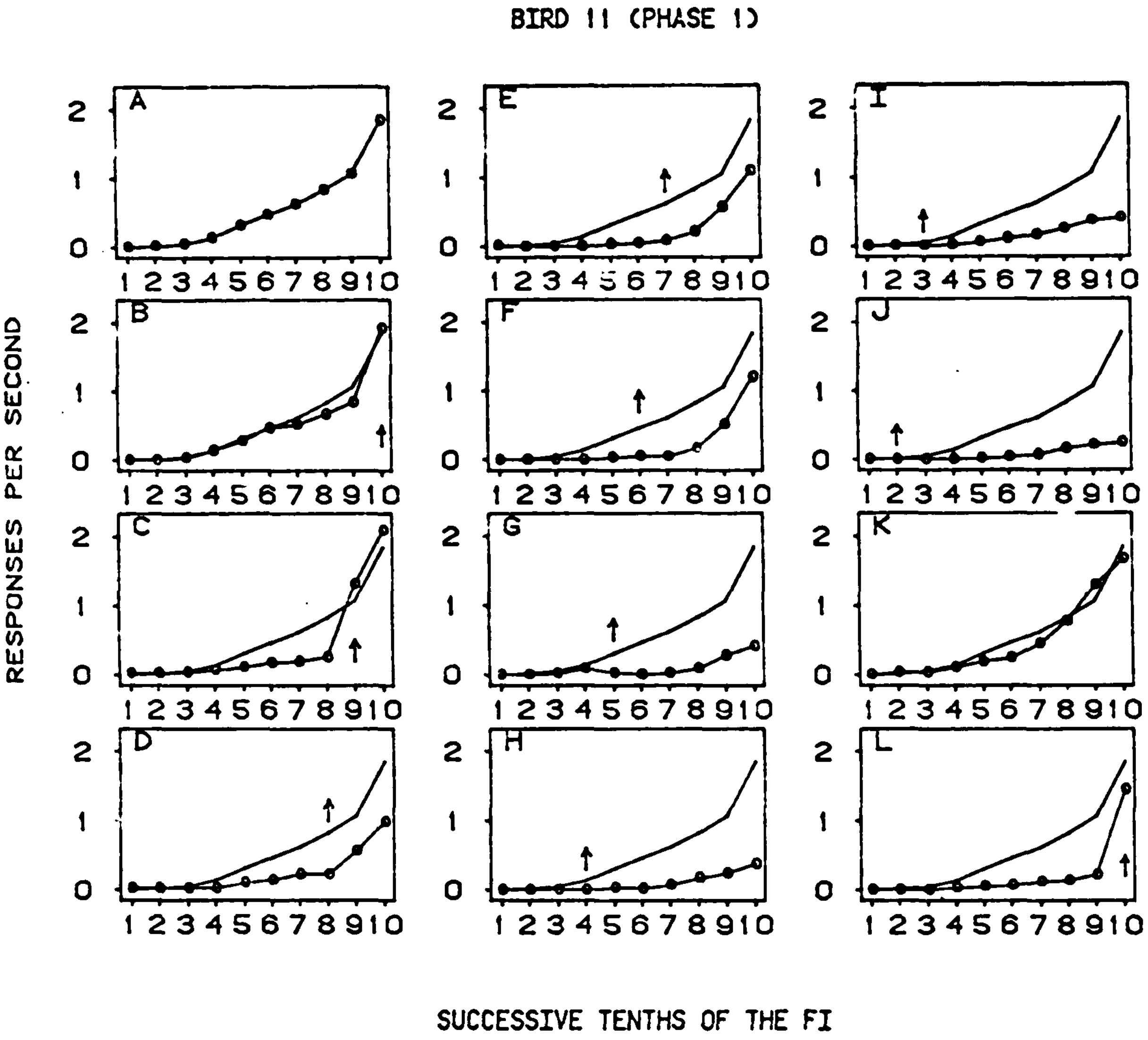
0
1
1 2 3 4 5 6 7 8 9 10


BIRD 11 (PHASE 1)
RESPONSES PER SECOND
SUCCESSIVE TENTHS OF THE FI
A
B
C
D
E
F
G
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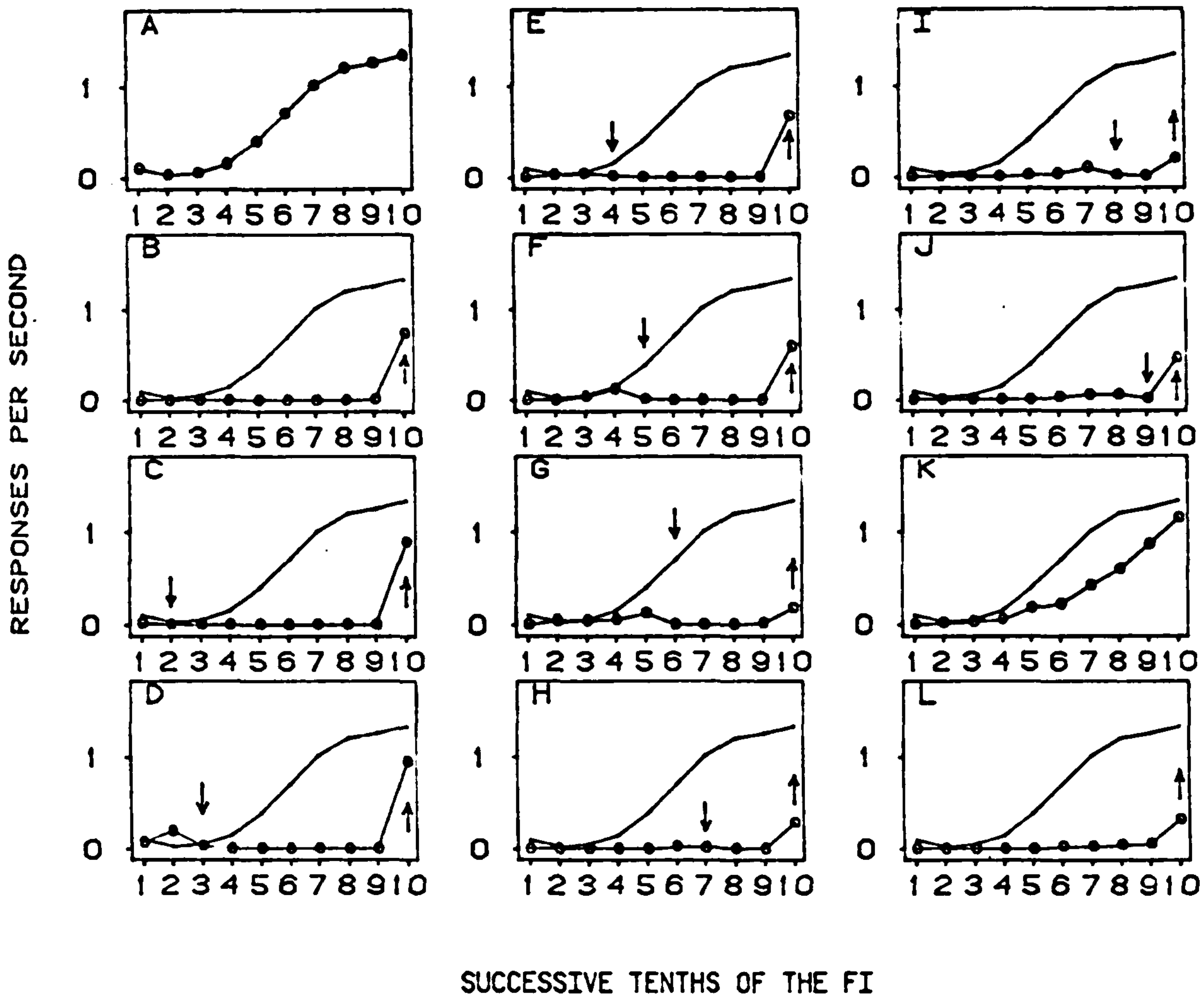
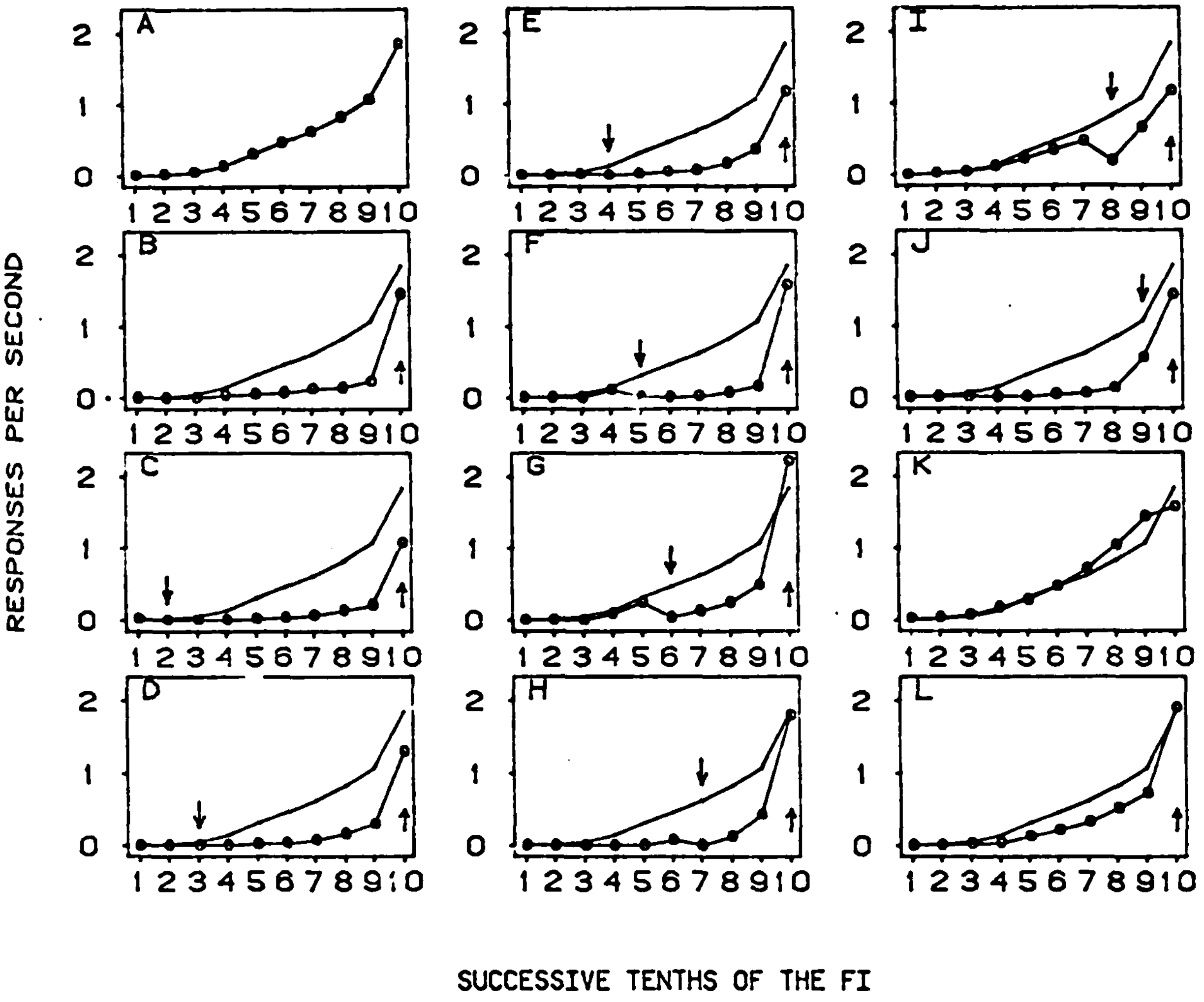
0
1
2
1 2 3 4 5 6 7 8 9 10

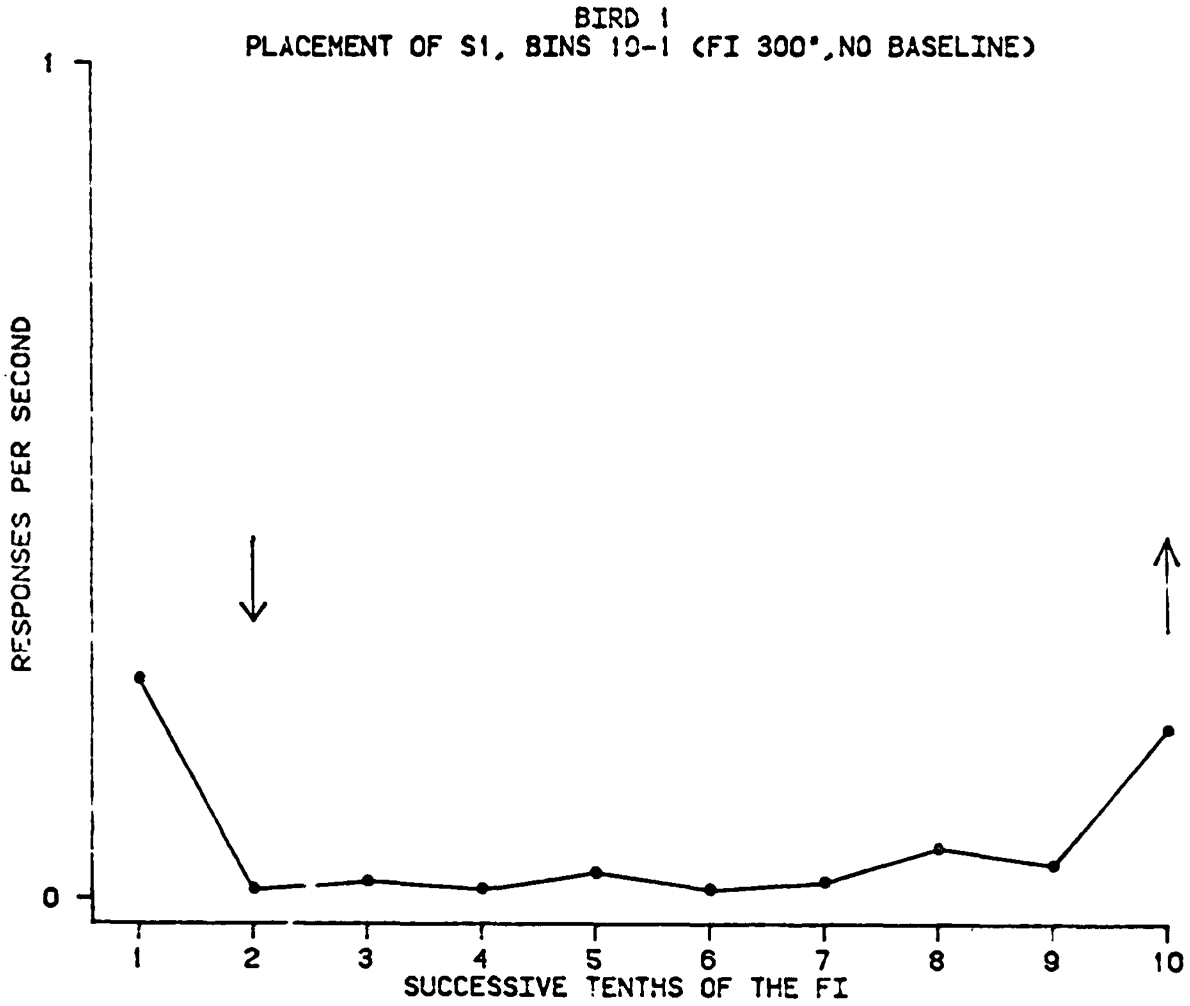
BIRD 8 (PHASE 2)

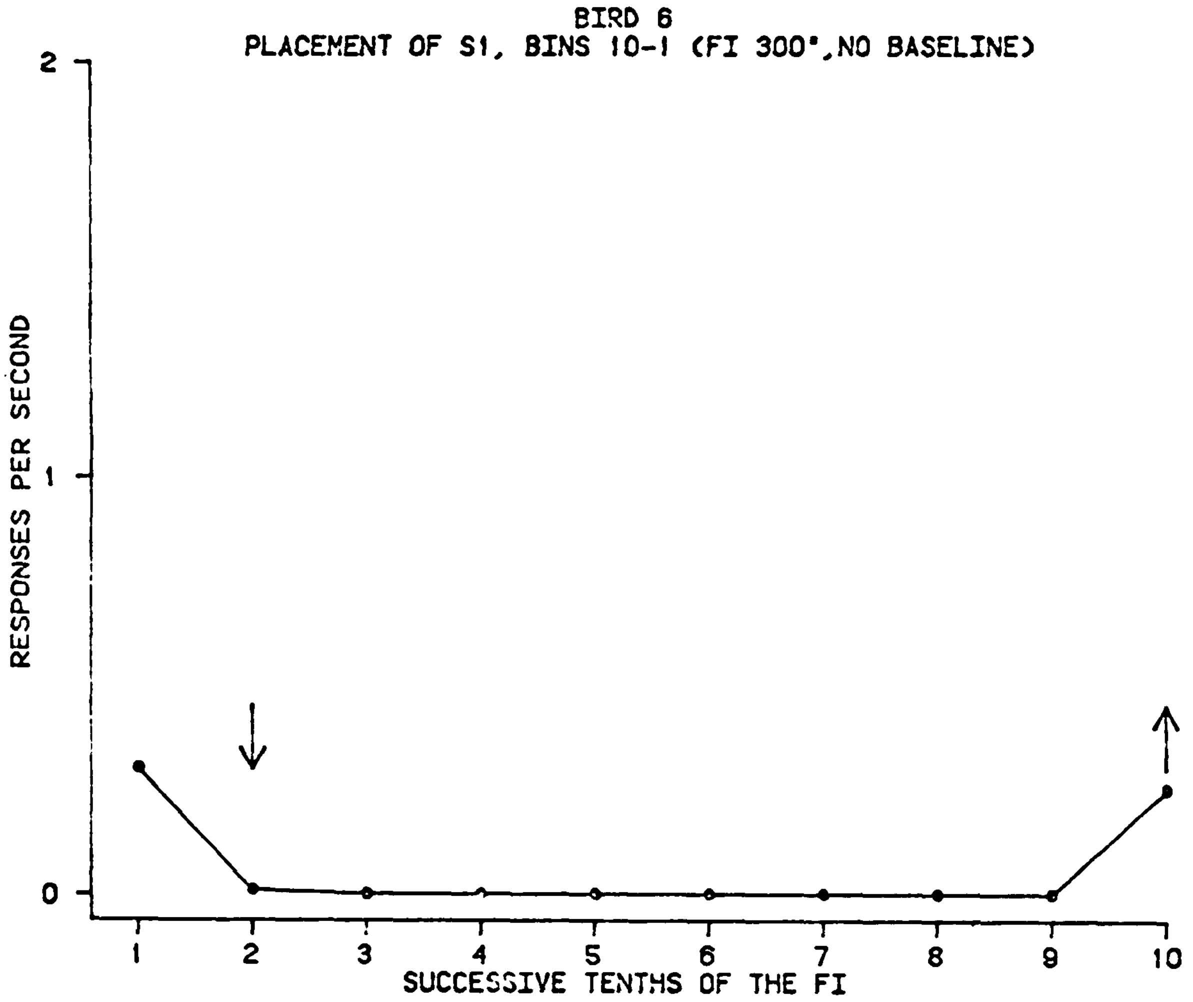


BIRD 11 (PHASE 2)



Figures 13-15. The function shows Birds 1, 6, and 8 with no baseline training on a FI 300" schedule. The stimulus placement is S2r in bins 1 and 10 and S1w in bins 2-9. (See text for explanation.)


BIRD 1
PLACEMENT OF S1, BINS 10-1 (FI 300",NO BASELINE)
RESPONSES PER SECOND
1
0
1
2
3
4
5
6
7
8
9
10
SUCCESSIVE TENTHS OF THE FI


BIRD 6
PLACEMENT OF S1, BINS 10-1 (FI 300",NO BASELINE)
RESPONSES PER SECOND
2
1
0
1
2
3
4
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6
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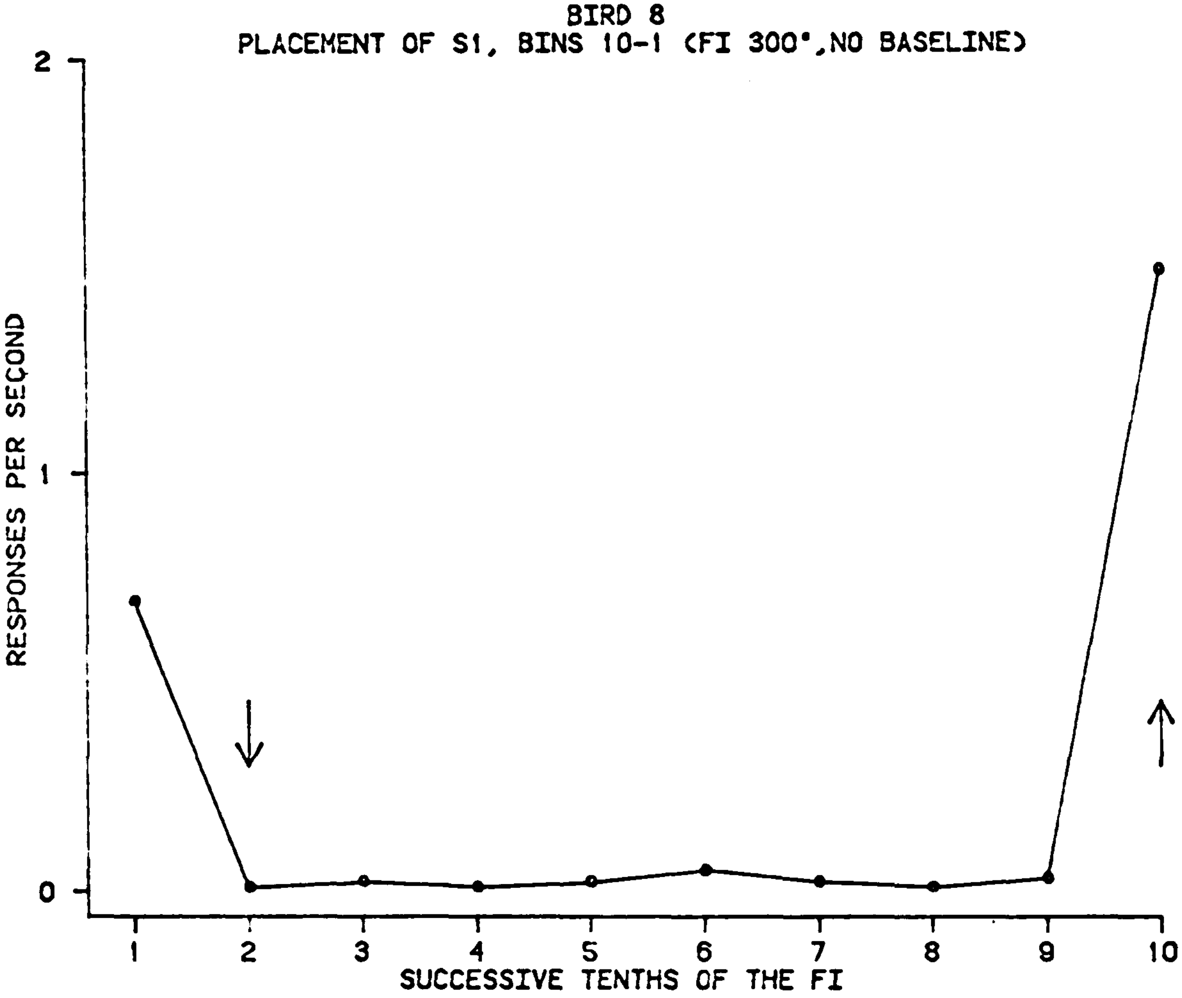
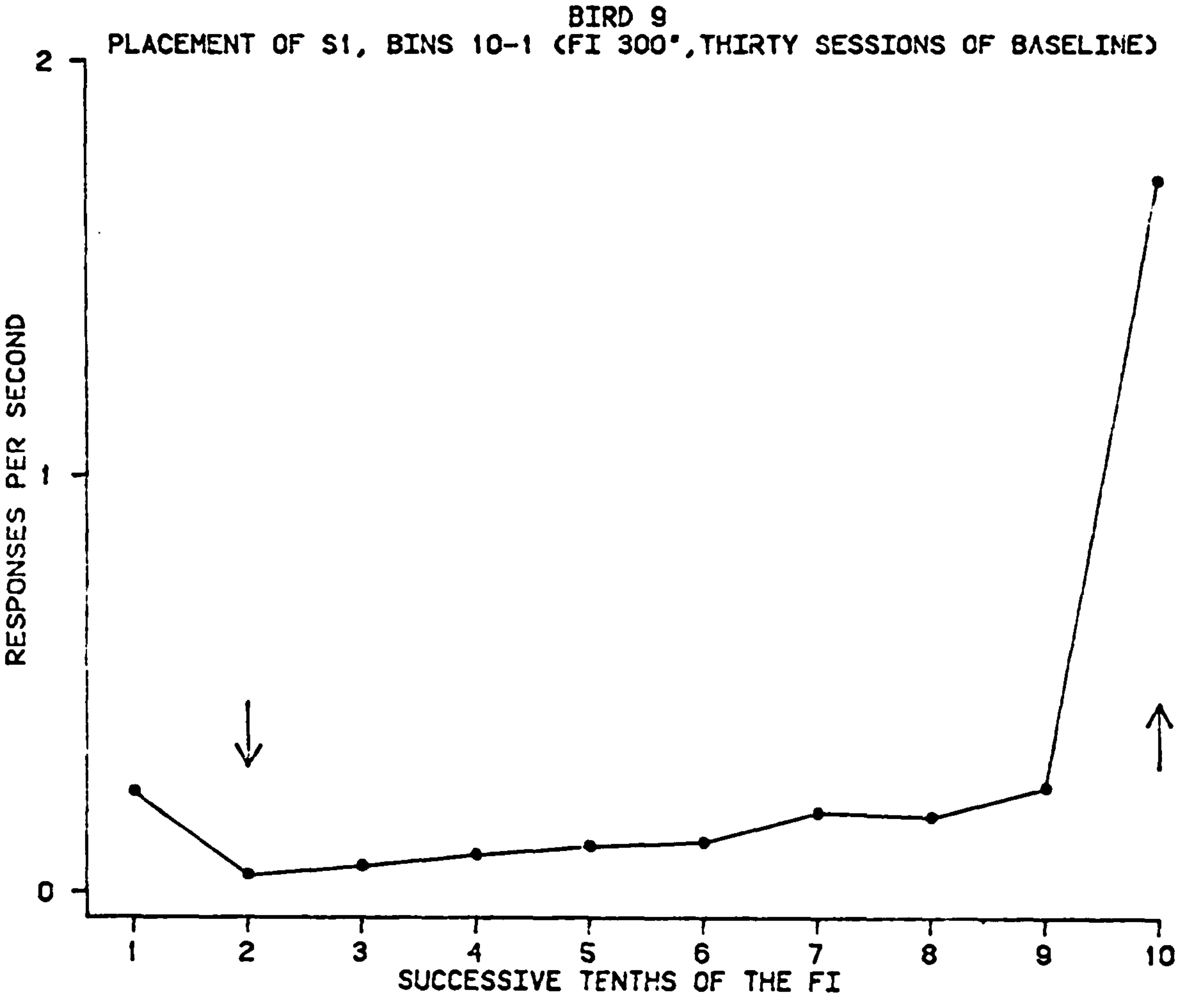
8
9
10
SUCCESSIVE TENTHS OF THE FI

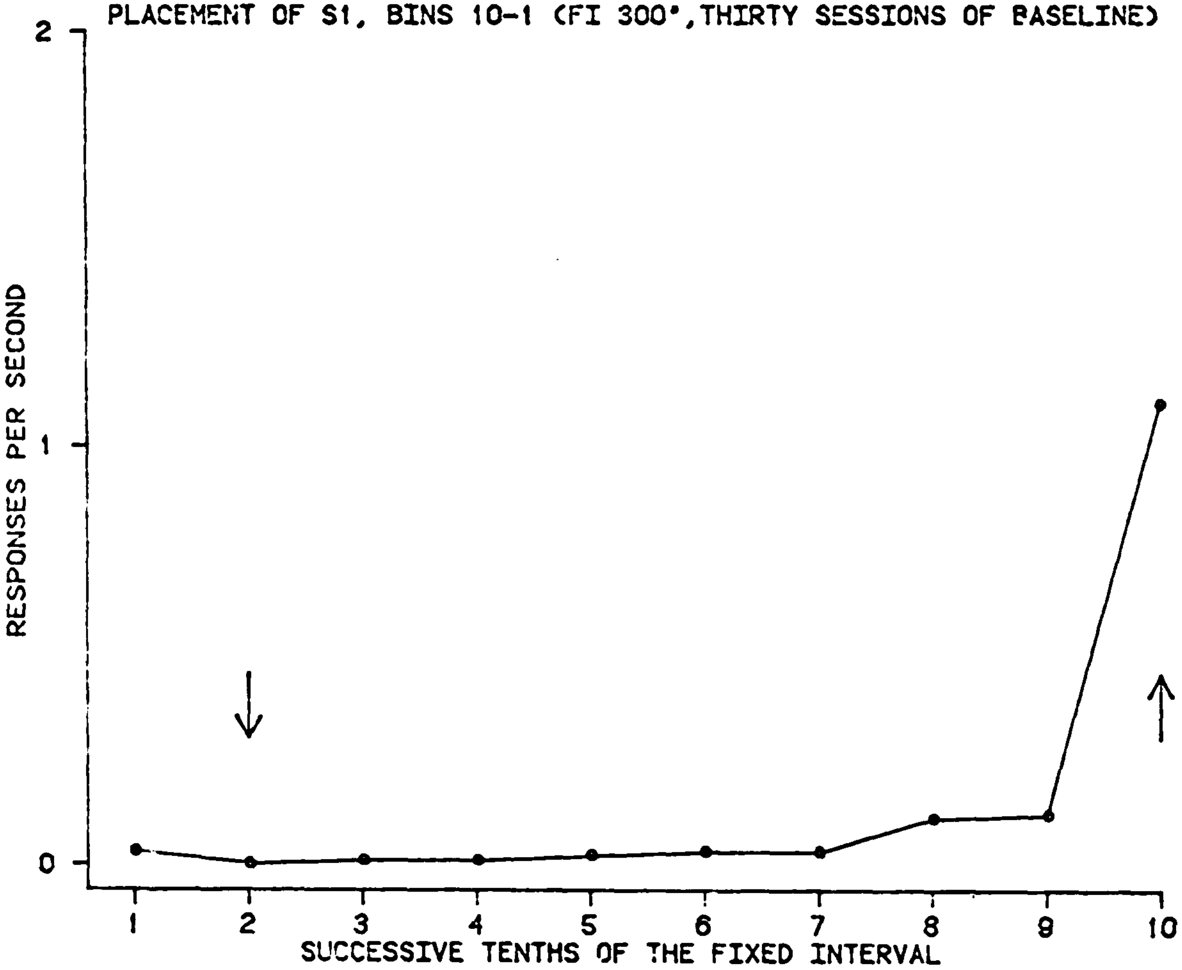

BIRD 8
PLACEMENT OF S1, BINS 10-1 (FI 300",NO BASELINE)
RESPONSES PER SECOND
2
1
0
1
2
3
4
5
6
7
8
9
10
SUCCESSIVE TENTHS OF THE FI

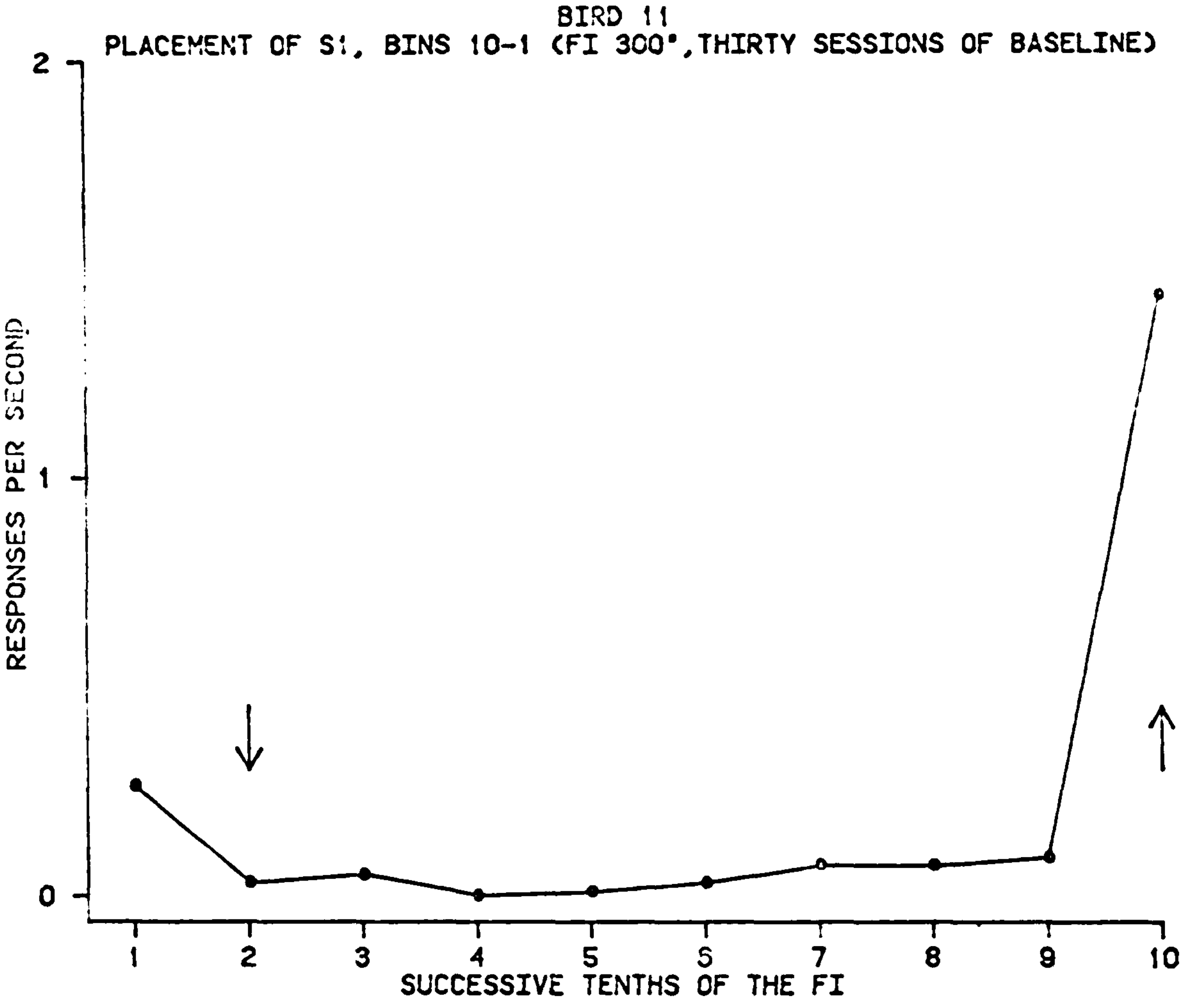
Figures 16-18. The function shows Birds 9, 10, and 11 with thirty sessions baseline training on a FI 300" schedule. The stimulus placement is S2r in bins 1 and 10 and S1w in bins 2-9. (See text for explanation.)



BIRD 9
PLACEMENT OF S1, BINS 10-1 (FI 300", THIRTY SESSIONS OF BASELINE)

BIRD 10
PLACEMENT OF S1, BINS 10-1 (FI 300", THIRTY SESSIONS OF BASELINE)




BIRD 11
PLACEMENT OF S1, BINS 10-1 (FI 300", THIRTY SESSIONS OF BASELINE)
RESPONSES PER SECOND
2
1
0
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4
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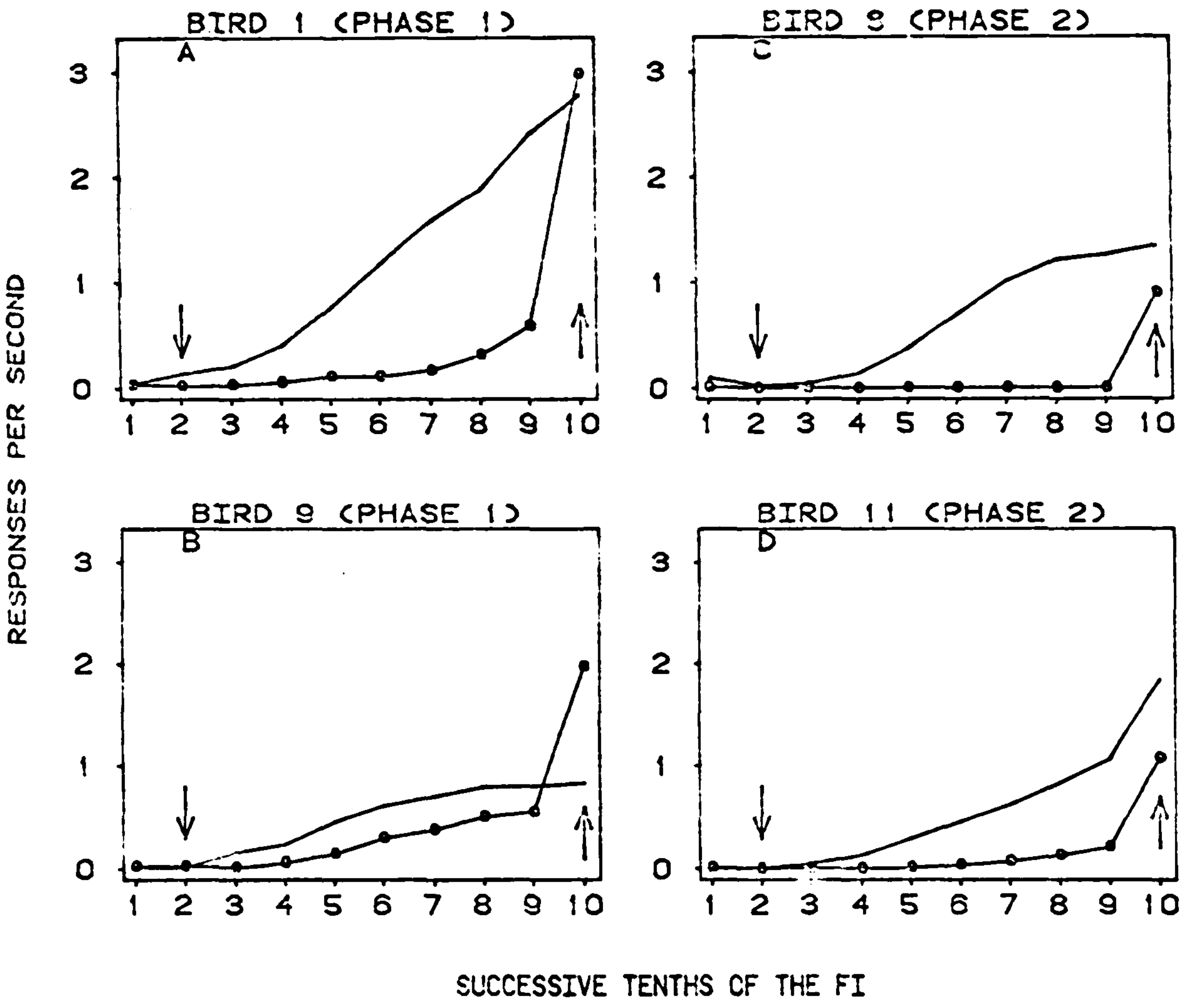
10
SUCCESSIVE TENTHS OF THE FI

Figure 19. The functions show Birds 1, 8, 9, and 11 under conditions in which S1 is located simultaneously in bins 10 and 1, following 60 sessions of baseline training. The stimulus placement is S2r in bins 1 and 10 and S1w in bins 2-9. (See text for explanation.)


BIRD 1 (PHASE 1)
A
BIRD 8 (PHASE 2)
C
BIRD 9 (PHASE 1)
B
BIRD 11 (PHASE 2)
D
RESPONSES PER SECOND
0
1
2
3
1
2
3
4
5
6
7
8
9
10
SUCCESSIVE TENTHS OF THE FI

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