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A TEST FOR THE SUFFICIENCY OF HENDRY'S HYPOTHESIS CONCERNING THE REINFORCING EFFECTS OF TIMING STIMULI

by

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ABSTRACT

The relative reinforcing effectiveness of timing stimuli that terminated in food presentation was assessed. Pigeons were presented with a choice between timing stimuli with differing quantitative and qualitative informational value. The choice response initiated an interval containing different stimulus changes (e.g., six two-second stimuli versus one twelve-second stimulus). Either stimulus sequence always terminated in food presentation, or food availability in the response contingent groups.

The data were interpreted to indicate that timing information does not have an appreciable differential reinforcing effect. Thus Hendry's information hypothesis was not supported as a predictive model. It was noted, that information does have a dominant effect on behavior in its presence.

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CHAPTER I

INTRODUCTION

Conditioned Reinforcement and Observing Behavior

A reinforcer is defined as a stimulus which when presented following a response, increases the rate of occurrence of that response class. Conditioned reinforcers are defined as stimuli which function as reinforcers only by virtue of a specifiable training history. Extensive reviews of conditioned reinforcement have been provided by Kelleher and Gollub (1962), Wike (1966) and Hendry (1969a).

The variables which affect the acquisition, maintenance and loss of conditioned reinforcing effectiveness are commonly investigated using various chronic procedures which retain primary reinforcement, such as chain, second order, and observing response schedules. The more traditional method involved the development of behavior maintained by signaled primary reinforcement. The reinforcing value of the signal which preceded primary reinforcement was subsequently tested by comparing extinction with the signal retained as compared to a condition in which the signal was absent. A better but similar technique was to make the signal contingent on a "new" response. If the signal was effective in slowing extinction in the first case and increasing the rate of the new response in the second case, it was by definition a conditioned reinforcer. Unfortunately, these extinction methods did not usually generate large effects and they did not enable a chronic investigation of the factors involved in conditioned reinforcement. Wyckoff (1959) discussed the difficulties with the extinction methods and the importance of conditioned reinforcement. He pointed out the necessity of investigating conditioned reinforcement by chronic methods such as a choice or concurrent schedule in which an alternative response produced different stimuli correlated with the schedules of reinforcement.

Wyckoff (1951) had earlier introduced a procedure which allowed this type of chronic evaluation of conditioned reinforcement. He found that when discriminative stimuli were contingent upon an overt operant, they were sufficient to develop and maintain that operant. Because these responses produced stimuli which were correlated with the different schedule contingencies, he labeled them observing responses. Observing responses only produce correlated stimuli (i.e., observing stimuli) and do not differentially effect the scheduling of primary reinforcement. Wyckoff labeled responses instrumental in producing primary reinforcement effective responses. Observing behavior provides a direct measure of conditioned reinforcement. A stimulus differentially correlated with the schedule in effect is the only result of, and therefore the sole support for, the observing response.

The generality of observing behavior has been demonstrated in numerous situations. Observing behavior can be generated and maintained: A) by stimuli correlated with various schedules of primary reinforcement (Levis and Perkins, 1965; Dinsmoor, Brown and Lawrence, 1972; Kendall, 1973a); B) under several observing response schedules (Schaub, 1969; Branch, 1970; Kendall, 1973b); C) using various durations of the observing stimulus (Hendry and Dillow, 1966; Kendall, 1968; Dinsmoor, Brown, Lawrence and Wasserman, 1971); and D) with several species (Kelleher, 1958; McMichael, Lanzetta, and Driscoll, 1967; Steiner, 1967).

The Theoretical Accounts

It has been repeatedly demonstrated that stimuli which are differentially correlated with subsequent schedules of primary reinforcement are capable of reliably reinforcing contingent responses, i.e., observing behavior. These stimuli which are differentially correlated with schedules of reinforcement are frequently termed discriminative stimuli. For example, Hendry (1969a) defined discriminative stimuli as "any of the members of a set of stimuli correlated one-to-one with different schedules of reinforcement (p. 430)." This would therefore imply that discriminative stimuli are conditioned reinforcers. Unfortunately the term "discriminative stimulus" has been variously defined to denote other properties and procedures. Four factors may receive emphasis in its definition: pairing with the reinforcer, setting the occasion for a specific required response, being correlated with different schedule requirements and controlling behavior differentially. Which factor is emphasized is typically determined by the theory utilized to account for the reinforcing effectiveness of schedule correlated stimuli. The traditional definition (i.e., a stimulus which sets the occasion for a specific reinforced operant) will be used in the present paper without implying any theoretical orientation.

Hypotheses of two general types have been advanced to account for the reinforcing effectiveness of conditioned reinforcers in general and discriminative stimuli in particular. The first type of hypotheses are those that implement simple stimulus-reinforcer pairings, or those which implement stimulus-required response-reinforcer relationships and thereby emphasize the association of the stimulus with the primary reinforcer. The second general types are those hypotheses which invoke mechanisms other than simple association with the primary reinforcer. These approaches emphasize the predictive relationship of the stimuli to scheduled events.

Contiguity Hypotheses

The approaches which emphasize the association of the stimulus with primary reinforcement or with the primary reinforcement schedule will be labeled the <u>contiguity hypotheses</u>. An early proposal (Hull, 1943) suggested that "a stimulus gradually acquires its powers of secondary reinforcement as it acquires the power of evoking the reaction conditioned to it." Schoenfeld, Antonitis and Bersh (1950) suggested that a stimulus must control different behaviors preceding the primary reinforcer in order to function as a conditioned reinforcer. They demonstrated that a stimulus which occurred during eating would not subsequently reinforce an operant, while a stimulus which was presented prior to eating could serve as a reinforcer. Dinsmoor (1950) provided additional support for this interpretation. He found that extinction of the discriminative properties of a stimulus equally detracted from its conditioned reinforcing properties. Furthermore he found that extinction of its reinforcing properties equally detracted from its discriminative effectiveness.

Wyckoff (1952) therefore suggested that there was sufficient evidence to indicate that stimuli which set the occasion for reinforced operants were in fact conditioned reinforcers and that the acquisition and maintenance of observing behavior could be accounted for with that mechanism. Wyckoff also proposed that discriminative stimuli would reinforce observing behavior only to the extent that they controlled differential responding. Kelleher and Gollub (1962), also within a contiguity framework, however have suggested that a stimulus need not set the occasion for a reinforced operant to function as a conditioned reinforcer. They proposed that the reinforcing effectiveness of a conditioned reinforcer varied with the frequency with which it was associated with primary reinforcement.

Basically the contiguity approach invokes simple conditioning based on differential association of the stimuli with primary reinforcers to account for the reinforcing effects of conditioned reinforcers. This formulation is not entirely sufficient however. Observing response studies have found that an animal will usually work to change from a combination of schedules under a common or uncorrelated stimulus (eg. mixed schedule) to a condition in which each schedule is associated with a particular stimulus (eg. multiple schedule). This requires some additional factor, in that overall association with primary reinforcement is equal in both of these schedules.

The contiguity approach must therefore postulate non-linearity in the reinforcing effectiveness of schedules of reinforcement. Wyckoff (1952) suggested that a single stimulus which was associated with reinforcement half the time was not as reinforcing as a combination, containing one stimulus which was never associated with reinforcement alternated with another which was always associated with reinforcement, i.e.,

$$S_{50\%R+50\%\bar{R}} < S_{100\%\bar{R}} + S_{100\%R}$$

Bower, McLean and Meacham (1966) have also proposed that the contiguity hypothesis implied a weighted averaging process in the determination of the total reinforcing effectiveness of schedules under correlated stimuli. They suggested that the high density component schedules contributed disproportionately large amounts to the overall reinforcing effectiveness of the combination of separate schedules, and that this disproportionality was imposed on the stimuli associated with those schedules. The implied relationship, therefore, between the conditioned reinforcing effectiveness of stimuli associated with a single fixed (eg. FI 2), a variable (eg. VI 2 or *mix* FI 1 FI 3), and a combination of more than one fixed schedule under separate stimuli (eg. *mult* FI 1 FI 3) are not necessarily equivalent.

Information Hypotheses

The alternative approaches used to account for the reinforcing effectiveness of conditioned reinforcers utilize a fundamentally different approach. They implement mechanisms other than simple conditioning or postulate other mechanisms. Typically, these approaches stress the predictive relationship between the stimuli and different schedules of reinforcement. These interpretations will therefore be labeled the *information hypotheses*.

Perkins (1955, 1965, 1968) suggested that a schedule correlated stimulus allowed the animal to make appropriate preparatory responses, thereby increasing the total magnitude of reward associated with the situation. Unlike the contiguity interpretation, Perkins' interpretation implies that opportunity to prepare for the occurrence of any primary event, is reinforcing. Thus the schedule correlated stimuli would be reinforcing even when they signal extinction or aversive contingencies.

Berlyne (1960) advanced a similar mechanism to account for the conditioned reinforcing effects of observing stimuli. He proposed that the negative drive state "uncertainty" was generated in an ambiguous situation; that is, when one of several mutually exclusive behaviors were appropriate but no consistent stimuli were associated with the appropriate behavior.

The removal of uncertainty was postulated to be reinforcing through drive reduction. Berlyne suggested that the typical observing response paradigm in which two or more schedules of reinforcement alternate unpredictably without correlated stimulus changes generated uncertainty. He also stated that responses which resulted in the occurrence of schedule correlated stimuli (i.e., observing responses) were reinforced by uncertainty reduction.

Both Perkins and Berlyne emphasized that schedule correlated stimuli became reinforcers whether they signaled primary reinforcement or extinction contingencies. In their interpretations the predictive relationship of the stimuli with their respective schedules was the source of the conditioned reinforcing effectiveness of the observing stimuli, not the association of a stimulus with primary reinforcement. These information approaches invoke new mechanisms to account for the reinforcing effects of observing stimuli, "preparation" in the case of Perkins and "uncertainty" in the case of Berlyne. The major factor differentiating the predictions of this approach from those of the contiguity approach is that both (or all) relevant stimuli in an observing response paradigm are thought to be reinforcing, including stimuli associated with extinction.

The interpretations offered by Perkins and Berlyne appear to be contraindicated by several studies in which variability or uncertainty was preferred. Leventhal, Morrell, Morgan and Perkins (1959) found a preference for two pellets every other trial [illegible]
Logan (1960) found a preference for [illegible]

nine seconds of delay of reward over a constant five second delay; Pubols (1962) presented data indicating a preference for an alternation between zero and ten seconds delay of reward over constant five seconds delay; and Herrnstein (1964) found a preference for a variable schedule over a fixed interval schedule set at the arithmetic mean of the variable schedule.

In these situations animals preferred the schedule with variability under a single stimulus condition over a fixed contingency schedule with the corresponding mean value. These preferences would minimize the opportunity for precise preparatory responses and maximize uncertainty. Perkins and Berlyne could rejoin, albeit weakly, by indicating that their formulations are in terms of additional reinforcing effectiveness provided by correlated stimuli and adequate preparation. Therefore, in situations where variable schedules under a single stimulus are preferred to fixed schedules, the additional reinforcing value that they postulate may not be operative at all or could be outweighed by some other mechanism.

The information hypothesis implies that a multiple schedule (eg. mult FI 1 FI 3) is more reinforcing than its respective mixed schedule (eg. mix FI 1 FI 3) because the stimuli provide information. This approach is indeterminant concerning the effects of the primary reinforcement schedules in fixed (eg. FI 2), variable (eg. VI 2 or mix FI 1 FI 3), or more than one fixed schedule under correlated stimuli (eg. mult FI 1 FI 3).

Kendall and Gibson (1965) provided data which were also critical of the mechanism proposed by the information hypotheses. They found that a mixed FR 50 FI 2 minute schedule would maintain observing behavior if both of the stimuli correlated with their respective schedules were available or if only the stimulus associated with the FR schedule were available. However, if the FI stimulus were available and the FR stimulus were removed, observing behavior deteriorated and schedule control was lost. This finding indicated that the schedule stimuli had different reinforcing effectiveness. Neither the preparatory response nor the reduction of uncertainty hypotheses would seem to have been able to predict these results. As Kendall and Gibson noted, there was no reason to suspect beforehand that the FR stimulus reduced more uncertainty or provided for better preparatory responses than the FI stimulus. Kendall and Gibson's findings were essentially corroborated by data obtained by Kendall (1972).

Hendry's Information Hypothesis

Hendry (1969b, 1969c) has recently formalized a predictive account of the mechanism involved in the development of conditioned reinforcement. His approach is based on observing response investigations, and is similar to Berlyne's approach. Hendry (1965) initially postulated that stimuli correlated with a schedule of reinforcement were reinforcing by providing "information", and that both positive and negative discriminative stimuli were reinforcing. He further suggested that a stimulus could be both positively and negatively reinforcing. He presented data which indicated that both of the correlated stimuli [illegible] with the [illegible] components of a mixed VR extinction schedule would reinforce observing behavior and, furthermore, that the stimulus associated with the extinction component could reinforce response contingent removal. This latter finding supported his contention that a negative stimulus was both positively and negatively reinforcing. He also found that the observing response rate was highest when the probability of obtaining the stimulus associated with the VR components was at an intermediate value (i.e., near 50%).

Hendry interpreted this final result as strong support for the contention that information was the reinforcing factor in observing response maintenance, rather than association with the primary reinforcer. He pointed out that the association with food was highest when every stimulus was associated with primary reinforcement, however, uncertainty was lowest at this percentage. On the other hand, uncertainty was maximal when either schedule was equally probable, however, association with food was only at a moderate value.

Hendry (1969b) pointed out that the traditional discriminative stimulus approach (Skinner, 1938; Keller and Schoenfeld, 1950) concerning the source of conditioned reinforcement value could not account for all of the data. Ferster (1953) and Autor (1960) provided evidence indicating that the establishment of a stimulus associated with the final link in a chain as a conditioned reinforcer most likely did not require it to control a specific reinforced operant. Also, that its reinforcing effectiveness typically varied with the frequency of reinforcement in that link not the specific rate controlled.

Kelleher and Gollub's (1962) review has also argued that discriminative stimulus properties are neither necessary nor sufficient for conditioned reinforcement.

In addition, Hendry (1969b) noted that there were data available which were contrary to the predictions of a simple stimulus-reinforcer pairing explanation of conditioned reinforcement. He cited the findings of Egger and Miller (1962, 1963) which indicated that the temporally first stimulus to hold a necessary and sufficient relationship with the subsequent presentation of food, became a more effective reinforcer than a stimulus which had occurred closer to food presentation in the traditional sense of "pairing".

Rescorla (1968) provided additional data bearing upon theories of conditioned reinforcement which utilize a framework based on simple pairing of the stimulus with the primary reinforcer. He varied the probability of shock in the conditioned stimulus (CS) interval and the intertrial interval (ITI). When the probabilities were equal he obtained little conditioning; however, when shock probability was lower in the ITI, he did obtain conditioning. This demonstrated a case where contiguity of the CS with shock remained the same but conditioning varied with ITI shock probability. His finding did not support the notion that simple pairing is sufficient to establish conditioning or conditioned reinforcement.

Bloomfield (1972), Wilton (1972) and Baum (1973) have also proposed accounts which favor an information approach to conditioned reinforcement and have added credence to Hendry's attack on "contiguity" and "control of responding" as the basis for conditioned reinforcement. Bloomfield and Baum have noted, however, that ultimately it is unlikely that contiguity theories could be denied by removing contiguity while maintaining a predictive relationship. In all cases, hypothesized events could be postulated which would allow a contiguity interpretation to be used. This, however, could be viewed as extending the meaning of contiguity to the point that it becomes equivalent to information.

Information and Timing Stimuli

Traditionally the observing response method of assessing conditioned reinforcement has been applied to stimuli correlated with the presence or absence of primary reinforcement (Wyckoff, 1952; Prokasy, 1956). This type of schedule correlated stimuli do not exhaust the meaning of schedule correlated stimuli, however. Stimuli correlated with two different schedules both terminating in primary reinforcement can also maintain observing behavior (Kendall, 1965a; 1965c). There is a third procedure in which stimuli can be related to primary reinforcement as informative stimuli. Stimuli can be temporally correlated with primary reinforcement, such as in Egger and Miller's (1962, 1963) designs. Stimuli which are correlated with the passage of time in a temporal schedule of reinforcement are labeled as "timing" or "clock" stimuli. Various investigators have provided data concerning the discriminative or controlling effects of these temporally correlated stimuli.

Ferster and Skinner (1957) demonstrated that the addition of timing stimuli to fixed interval schedules had the effect of delaying the onset of responding and increasing the abruptness of the transition from the initial low rate to the final high rate. Segal (1962) investigated the effects of response independent and response dependent timing stimuli in fixed interval schedules. Her data could not easily be used to assess the reinforcing effects of the timing stimuli, however, because the response which satisfied the contingency to produce the clock stimuli also satisfied the fixed interval requirement. In addition to finding the suppressive effects of early response independent timing stimuli, she found that response dependent timing stimuli slightly increased the proportion of responses occurring in the middle components of the interval when compared to the condition with response independent clock stimuli. She also found very low rates during the first fourth of the interval regardless of whether the timing stimuli were response dependent or response independent. She interpreted this latter finding as suggesting that the initial stimulus functioned as an S^- or punisher.

Hendry and Dillow (1966) proposed that stimuli which were correlated with the passage of time in interval schedules provided information and would therefore reinforce observing behavior. They presented data which indicated that clock stimuli did function as conditioned reinforcers. In one of Hendry and Dillow's (1966) experiments, observing responses intermittently produced timing stimuli which partially converted a <u>tandem</u> FI FI FI to its respective chain schedule. In their two remaining experiments, timing stimuli associated with blocks within a simple FI schedule could be obtained by an observing response. Their data indicated that observing behavior was maintained throughout the interval. They also found that the stimulus which controlled the highest observing response rate was typically the stimulus associated with the middle temporal block of the interval, not the initial stimulus which the Egger and Miller (1962, 1963) formulation would have predicted. Egger and Miller had postulated that the first stimulus to hold a necessary and sufficient relationship with the subsequent presentation of food was the occasion for the maximum amount of drive reduction and therefore should become the most powerful conditioned reinforcer.

The most apparent interpretation of the contiguity hypothesis was not confirmed by Hendry and Dillow either. The final temporal stimulus, which was most closely associated with food presentation did not control the highest observing response rate. However, Kelleher, Riddle and Cook (1962) and Kendall (1965b, 1965c) indicated that observing responses may compete unfavorably with effective responses when food controlled behavior is occurring at a high rate as in the final segment of a fixed interval schedule.

In addition to postulating that timing stimuli were reinforcing, Hendry and Dillow (1966) concluded that: 1) "timing cannot be accomplished by mere activity without systematic sensory consequences", in that explicit timing stimuli were reinforcing relative to the no timing stimulus condition; and, 2) "all clock stimuli not just the stimulus closest to reinforcement became reinforcing", in that all stimuli controlled observing behavior, including the stimulus associated with the temporal block furthest removed from the occurrence of the reinforcer even when it controlled a near zero rate on the food key.

Hendry and Dillow interpreted their data as indicating that stimuli other than the initial stimulus would reinforce observing behavior, thus extending the position of Egger and Miller (1962, 1963). Other investigators have demonstrated that stimuli other than a final predictive stimulus would reinforce observing responses (Mitchell, Perkins and Perkins, 1965; Bower, McLean and Meacham, 1966; and Kendall, 1969) thus extending a strict contiguity hypothesis. It would appear, therefore, that neither the first nor the final predictive stimulus is entirely responsible for the conditioned reinforcing effects of timing stimuli. It may be that the relative frequency or the temporal point of change of timing stimuli, within a particular interval, and between alternative timed intervals may in some way differentially contribute to the conditioned reinforcing effectiveness of stimuli within any particular interval.

Present Proposal

It would be useful to assess some of the implications of timing information. Hendry and Dillow (1966) had proposed that timing stimuli were informative and therefore reinforcing. Unfortunately they had compared the total reinforcing effectiveness of explicit timing stimuli with a response requirement, relative to the total reinforcing effectiveness of "internal timing stimuli" without a response requirement. It is important therefore to assess the reinforcing effectiveness of timing stimuli in a situation where both alternatives had identical response requirements and one in which food-controlled behavior did not compete with observing behavior.

An additional factor conspicuously absent from Hendry's information hypothesis was that he made no substantial statement concerning the concomitant effects a stimulus can have on the rate of occurrence of behavior. A stimulus can exert control over responses which follow its onset as well as those which precede it. Traditionally, these relationships have been termed stimulus control and schedule control, respectively.

It has been proposed recently (Bloomfield, 1972; Bolles, 1972) that a stimulus correlated with the occurrence of primary reinforcement can lead to behavioral effects following its onset due to its predictive property alone. Bloomfield and Bolles cite classical conditioning and autoshaping (Brown and Jenkins, 1968) as examples. Data concerning the factors involved in autoshaping are very sparse, unfortunately. The autoshaping literature (eg. Brown and Jenkins, 1968; Williams and Williams, 1969; Gamzu and Williams, 1971) has indicated, however, that a stimulus with a differential predictive relationship with the occurrence of primary reinforcement, will reliably evoke a complex skeletal behavior, such as key pecking. The effect occurs without prior key peck training, and even when the peck delays or prevents primary reinforcement (Williams and Williams, 1969). This latter finding suggests that a simple explanation of autoshaping in terms of superstitious behavior is inappropriate.

It would be useful to extend the assessment of the relative reinforcing and controlling effectiveness of timing stimuli to a variety of complex types of sequences. The relative reinforcing effectiveness could be determined when both sequences provided some timing information but differed with respect to the quantity or quality of information. Hendry's (1969b, 1969c) proposals suggest that various types of information would have various reinforcing or controlling values, but he does not provide any specific predictions. Information theory is in need of data on which to build systematic predictions.

A simultaneous assessment of both effects (i.e., reinforcing and controlling) of the informative stimuli could be implemented in a choice design by providing a choice between two response initiated, but otherwise response independent, stimulus sequences terminating in response independent food presentations. Differential choice measures would indicate differential reinforcing effectiveness of compared timing sequences. Hendry (1969b) and Honig (1969) have both pointed out that choice designs are especially sensitive for an analysis of this type. Different distributions of stimulus evoked responding during the interval would simultaneously indicate the differential controlling effects of informative stimuli.

An added advantage of this design would be that the stimuli would not necessarily function as discriminative stimuli, in that they would not set the occasion for a specifically reinforced response. The source of their reinforcing effects would be limited to their information value. That is, there would be no necessity of interpreting the timing stimuli as reinforcing by virtue of their being discriminative stimuli. A subsequent determination of the effects of the sequences as discriminative stimuli could be made which would allow a comparison of both the reinforcing and controlling effects of timing stimuli both when they were and were not discriminative stimuli.

The initial response requirement of a response choice design would insure an orientation toward the key. Sutherland (1959), Hendry (1969b) and Bloomfield (1972) all suggest that stimuli which are informative will be "registered" and "attended to". It should be expected, therefore, that the stimuli would not only be "potential" stimuli but "effective" stimuli. It would also be expected that whatever differential control informative stimuli exert on behavior, that that control would be apparent as either a differential choice or differential distribution of evoked key pecking within the interval, or both.

The present investigation was therefore undertaken to assess the control exerted by timing stimuli. The effects that the timing stimuli had on behavior which preceded and followed their occurrences was observed in both response independent and response dependent intervals in order to bring data with a broader base to bear on Hendry's information hypothesis of conditioned reinforcement. Rather than limiting the design to a simple contrasting of information versus no information, various types of information, i.e., timing stimuli, were contrasted. Thus the effectiveness of some qualitative and quantitative types of information was assessed. The quantitative type utilized different numbers of component stimuli. The qualitative type utilized different temporal locations for the onset of a second stimulus within the interval. Egger and Miller's(1962, 1963) formulation suggests that temporal priority is the major determinant of conditioned reinforcement. Kendall(1969) demonstrated that schedule correlated stimuli would maintain observing behavior early in an interval, even when the stimuli were availiable later in the interval without a response requirement, and before any food controlled behavior was necessary. Wilton(1972) has proposed that the alternative which provides a stimulus change following a shorter delay would be more reinforcing than one following a longer delay. A formal property common to quantitative and qualitative variations of information of this type has not been advanced however.

CHAPTER II

METHOD

Hendry and Dillow (1966) postulated that interval schedules with explicit timing stimuli were more reinforcing than interval schedules without explicit timing stimuli. The effectiveness of several patterns of timing stimuli in both reinforcing the behavior which produced them and controlling the behavior patterns which occurred during their presence, were assessed in the present investigation.

Subjects

Twenty-six naive, white carneaux pigeons from three to five years old were maintained between 75% and 85% of their free feeding body weight as determined at the beginning of the experiment.

Apparatus

Five experimental chambers were used. Four (A, C, D, and E) were 305 by 305 by 381 mm (12 by 12 by 15 inches) high, similar to one described by Ferster and Skinner (1957) and Hendry (1969b). The top, bottom, and three sides were painted high gloss white. The remaining side, the response panel, was an aluminum plate. A grid floor was provided.

Medially located on the aluminum plate, 89 mm (3.5 inches) above the grid floor, a 64 mm (2.5 inch) diameter aperture permitted access to the grain reinforcer. Six watt houselights covered with white translucent domes were 114 mm (4.5 inches) to either side of the food aperture. Two 19 mm (0.75 inch) circular translucent operanda or "keys" were mounted on the plate 241 mm (9.5 inches) above the grid floor and 75 mm (3 inches) to either side of center. The keys were adjusted to require approximately 15 grams (0.15 N) force and equal excursion for their operation. A response "feedback" relay which could provide audible clicks was centrally mounted behind the aluminum plate. Seven-watt Christmas tree lights, also mounted behind the aluminum plate, could transilluminate the keys with various colors. A vacuum hose provided ventilation for these chambers. Chamber E had two sheet metal operanda mounted on the grid. These "treadles" extended 51 mm (2 inches) to either side of each key and projected 102 mm (4 inches) from the plate. The treadles were adjusted to require approximately 50 grams (0.49 N) force and equal excursion for their operation.

The remaining chamber, B, was smaller; it was 280 by 280 by 280 mm (11 by 11 by 11 inches) high. The interior surfaces were painted high gloss white. An expanded metal floor was provided. Medially located on one wall 114 mm (4.5 inches) above the floor, a 51 mm (2 inch) diameter aperture permitted access to the reinforcer. A translucent panel mounted in the ceiling above the food aperture could be transilluminated to provide general illumination. Two 19 mm (0.75 inch) circular translucent keys were mounted above the food aperture 229 mm (9 inches) above the floor and 89 mm (3.5 inches) to either side of center. The keys were adjusted to require approximately 15 grams (0.15 N) force and equal excursion for their operation. Seven-watt Christmas tree lights mounted behind the response panel could transilluminate the keys with various colors.

All chambers were located in a room in which masking noise was present at all times. Conditions were programmed and recorded from an adjacent room on standard-electro mechanical devices (Ferster and Skinner, 1957; Dinsmoor, 1966). An Esterline Angus 20 pen event recorder was also used.

Procedure

Sessions were conducted daily. Sessions contained approximately 50 reinforcer presentations. Variable periods of blackout preceded and followed every session. Before the pigeons entered the first phase of their respective conditions they were adapted to the experimental chamber, magazine trained and shaped to peck both keys which were dark. The birds of Condition E were not shaped to keypeck. When one of the larger four chambers was used, these pecks were accompanied with feedback clicks. The smaller chamber was not equipped to provide feedback clicks.

The experiment was composed of five conditions, each condition was divided into phases and the phases were divided into subphases. Each condition used different pigeons and compared a different pair of timing sequences. A change in phases was a major modification of procedures within a condition whereas a subphase change was typically a minor procedure change such as a reversal of the sequences associated with a particular side of the experimental chamber. Changes in procedures required extensive modification of the interlocking apparatus, therefore a phase or subphase was continued for all the birds until there did not appear to be any consistent or systematic changes in the behavior of concurrently running conditions.

All conditions were programmed using the same basic design, which is depicted in Figure 1 using Mechner (1959) contingency notation. A peck to either key immediately illuminated that key, started a recycling timer, and made the other key inoperative. The recycling timer stepped a stepper switch through six positions or "blocks". Each of these blocks could provide the same stimulus, each block could be associated with a different stimulus, or some combination of these could occur, depending upon the particular condition. Table 1 indicates the stimulus sequences used in each condition, and the label which is used to refer to that pattern.

Conditions A and D investigated timed intervals which opposed different numbers of timing stimuli or which were quantitatively different. In Condition A, a single stimulus interval was compared to a six stimulus interval. In Condition D, a three stimulus interval was compared to a two

Figure 1. A Mechner diagram of the general procedure in all conditions.

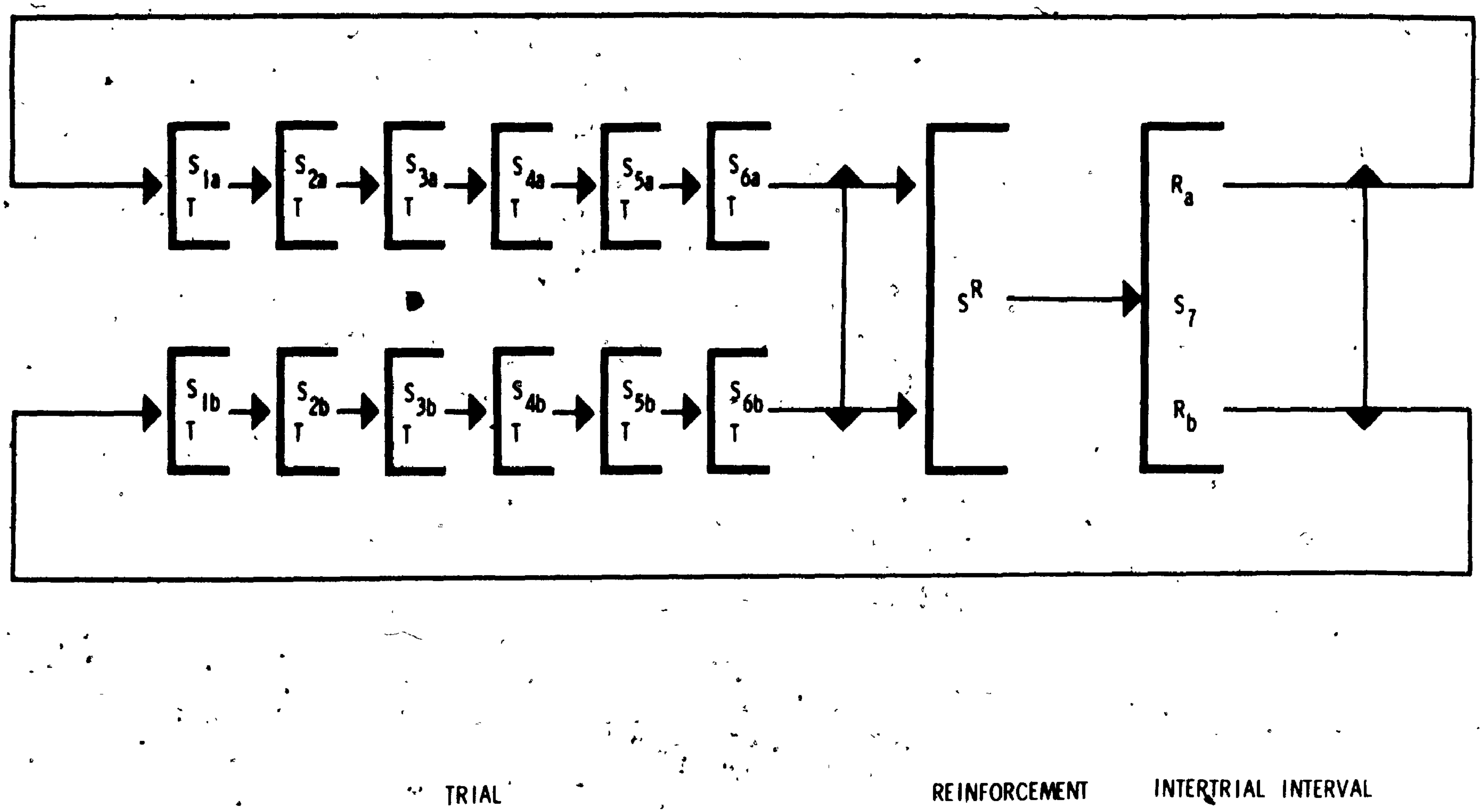

S_{1a} T
S_{2a} T
S_{3a} T
S_{4a} T
S_{5a} T
S_{6a} T
S_{1b} T
S_{2b} T
S_{3b} T
S_{4b} T
S_{5b} T
S_{6b} T
S^R
R_a
S_7
R_b
TRIAL
REINFORCEMENT
INTERTRIAL INTERVAL

Table 1. Alternative sequences of timing stimuli available in each condition.

Legend:

Y = Yellow
O = Orange
V = Violet
R = Red
B = Blue
D = Dark
W = White
G = Green

Condition	Designation	S1	S2	S3	S4	S5	S6	S7
A	6	Y	O	R	V	B	G	D
	1	W	W	W	W	W	W	D
B	5+1	W	W	W	W	W	O	D
	1+5	R	G	G	G	G	G	D
C	5+1	R	R	R	R	R	G	D
	3+3	W	W	W	O	O	O	D
D	2+2+2	R	R	G	G	B	B	D
	3+3	W	W	W	O	O	O	D
E	6	Y	O	R	V	B	G	D
	1	W	W	W	W	W	W	D

stimulus interval. The six stimulus interval in Condition A and the three stimulus interval in Condition D would provide more information, less uncertainty, more opportunity for preparation, more precise control over behavior during the interval, and the stimulus which had the highest density of reinforcement. The alternatives were very different in Condition A, while the alternatives were more similar in Condition D.

Conditions B and C investigated timed intervals which all contained two stimuli but which were qualitatively different. In Condition B, a stimulus change which occurred after one-sixth of the interval elapsed was compared to a stimulus change which occurred following five-sixths of the interval. Condition C opposed an interval with a stimulus change in the middle, with an interval with a stimulus change following five-sixths of the interval. The alternatives were very different in Condition B, while the alternatives were more similar in Condition C.

It should be noted that comparisons are between sequences which contain a terminal stimulus of different durations, thus possibly having different effects when considering only the pairing of the final stimulus of the sequences with food presentation. Hendry's interpretation of conditioned reinforcement however, suggests that reinforcing effectiveness stems from the information provided by a stimulus, not as a result of pairing with primary reinforcement. Hendry's information hypothesis subsumes stimulus contiguity as a relationship which provides information. In this regard, attempts to balance the sequences for contiguity factors would be unwarranted and could in fact also balance the sequences for the critical informative factors.

Reinforcement was typically programmed to occur unconditionally following the sixth block of a timing sequence. Reinforcement consisted of making available and illuminating a grain hopper (filled with grain) for four seconds. During reinforcement the houselights were out, and the keys were dark and inoperative. Reinforcement was followed by a period during which both keys were dark and a sequence was again available.

The general procedure was composed of a session in which only one of the two programmed sequences was available (Type 1); followed by a session in which only the other sequence was available (Type 2); and then a test session during which either sequence could be initiated (i.e., concurrent, or choice). This was followed by one session each of Type 2, Type 1, and then a concurrent session. This counterbalanced procedure was continued until no consistent or systematic changes in the behavior were evident (eg. Subphase 1). This procedure was then followed with a replication in which the side on which the particular stimulus sequences had occurred was reversed (eg. Subphase 2). An additional procedure was used in Phase I and is presented below. Following a determination of the effect and a reversal, a change in phases (a major contingency modification) was made. Stimulus sequences were not reversed at the same time that a phase was changed.

In Phases I and II a peck was required to start the sequence, however, no other pecks were necessary following the choice response. That is, a response initiated the sequence and the food hopper was activated by a timer irrespective of any behavior occurring within the interval. This procedure is referred to as a fixed time (FT) (Herrnstein and Morse, 1957) schedule in that the elapse of time is the only schedule requirement. Phase I utilized a fixed time 12 second schedule while Phase II utilized a fixed time 120 second schedule.

In Phase III a key peck was required to start the sequence. In addition, a peck was required after the elapse of the interval for food presentation to occur. This schedule is a fixed interval (FI) schedule which is initiated following the choice response. Phase III utilized a fixed interval 120 second schedule. Condition B was changed from a FT 12 second schedule in Phase I to a 12 second FI schedule in Phase II.

Data

Four dependent measures, "choice", "pause", "ratio", and "distribution", were presented. The data were gathered over the last five sessions of each procedure for each bird. Two measures, choice and pause, reflect the relative reinforcing effectiveness of the alternative timing sequences. Two measures, ratio and distribution, reflect the control exerted by the timing stimuli on responding in their presence. These measures are presented in Figures 2 through 12.

Choice

The mean and range of the choice responses, in percent, was presented. By definition of reinforcement the sequence which maintained the greater percentage of choice responses was more reinforcing than its alternative for that bird. The choice measure answered directly Hendry's proposals concerning the relative reinforcing effectiveness of various pairs.

Pause

The mean and range of the pauses (or latency between the offset of the grain hopper and the first peck) was presented. This measure could be used to provide an additional indication of the relative reinforcing effectiveness of the timing sequences for each bird (Schlosberg and Solomon, 1943). The pause data typically consisted of three different measures. Pause time collected during sessions in which only one of the sequences was availiable (type 1 or type 2 sessions) and pause time during the concurrent or choice sessions. For example, the pause measure would present separately the mean and range of times during sessions when only the six stimulus sequence was availiable; the mean and range of pause times during sessions when only the single stimulus sequence was availiable; and the mean and range of pause times during concurrent or choice sessions when either sequence could be initiated. It should be noted that the choice measure and the pause measure associated with a particular stimulus sequence were not collected during the same session. The pause measure is presented in the second vertical column of each figure.

Ratio

The mean and range of the ratio (i.e., the mean of responses occurring during one sequence to the mean in both) (Appel and Hiss, 1962) of responding during the two sequences was also presented. A value of .5 indicates that an equal amount of responding occurred during both stimulus sequences. The ratio measure is greater or less than .5 as the amount of responding in the indicated sequence was greater or less respectively. The ratio provided a comparison of the differential control exerted by the informative sequences on the amount of responding for each bird. The ratio measure also provided an indication of the extent to which the choice measure was determined by the relative amount of responding in the sequence (Steiner, 1967; Baum, 1973). The ratio measure is presented in the third vertical column of each figure.

Distribution

The distribution measure was the mean percentage of responding in each consecutive sixth of the sequence taken over the last five sessions. This measure provided a measure of the sequential control the timing sequences exerted on responding in their presence. It should be noted that responding in the presence of a stimulus can not be attributed to the reinforcing effectiveness of that stimulus. A reinforcer is a stimulus change following the occurrence of a response, whereas stimulus control refers to the effects of an antecedent stimulus on a subsequent response. The distribution measure is presented in the fourth vertical column of each figure.

Condition A

One schedule contained six stimuli while the alternative schedule contained a single stimulus.

Subjects

A1, A2, A3, and A4.

Apparatus

Chamber A, one of the larger boxes.

Procedure

Phase I

The pigeons were manually shaped to peck the two dark keys at a relatively steady and equal rate. Experimental conditions were then changed, initiating Phase I. Three types of sessions alternated in a counterbalanced order.

In Type 1 sessions only the sequence with six stimuli was available. The houselight under the alternative key and that key were always dark and pecks to that key had no programmed consequences. A peck to the operative key was followed with a feedback click and immediately transilluminated that key with two seconds each of yellow, orange, red, violet, blue and green. This sequence was immediately followed unconditionally with four seconds of access to the grain hopper regardless of the behavior which had occurred within the stimulus interval. All pecks to the operative key which did occur within the interval were followed with feedback clicks. They were recorded according to the timed block in which they occurred. Following reinforcement the operative key was dark until a peck was made to it which initiated the sequence again.

In Type 2 sessions all trials were forced to the single stimulus sequence. The houselight under the alternative key and that key were always dark and pecks to that key had no programmed consequences. A peck to the operative key was followed with a feedback click and immediately transilluminated that key with twelve seconds of white light. This sequence was immediately followed unconditionally with four seconds of access to the grain hopper regardless of the behavior which had occurred within the interval. All pecks to the operative key which did occur within the interval were followed with feedback clicks and were isolated and recorded according to the timed block in which they occurred. Following reinforcement the operative key was dark until a peck initiated the sequence again.

In the final type or Concurrent sessions, both houselights were on and both of the sequences were available. Following the first response to either key the respective sequence was initiated, a feedback click occurred, and the alternative key became inoperative. Following each reinforcement both keys were dark and either sequence could be initiated.

The counterbalanced procedure (i.e., Type 1, Type 2, Concurrent; Type 2, Type 1, Concurrent; etc.) was continued for 45 sessions, followed by 35 Concurrent only sessions and finally 55 counterbalanced reversal sessions in which a response to a particular key during the intertrial condition was followed on that key by the sequence which had followed a peck to the alternative key.

Phase II

The duration of the timing blocks was increased by a factor of ten, from two seconds to twenty seconds giving a total delay of 120 seconds from the choice peck to reinforcement. Otherwise, the procedure was unchanged from the concurrent procedure. This procedure continued for 36 sessions, followed by 21 reversal sessions, in which responses to a particular key were followed on that key by the sequence which had followed a peck to the alternative key.

Phase III

The reinforcer was contingent on a response occurring at the end of the interval and the sequence duration was 120 seconds in this phase. The final stimulus remained in effect until the response requirement was met. Otherwise, the procedure was basically unchanged from Phase I. Three types of sessions alternated in a counterbalanced order as in Phase I. Sessions were alternated for 23 sessions. This was followed by 23 sessions in which response key functions were reversed.

Results

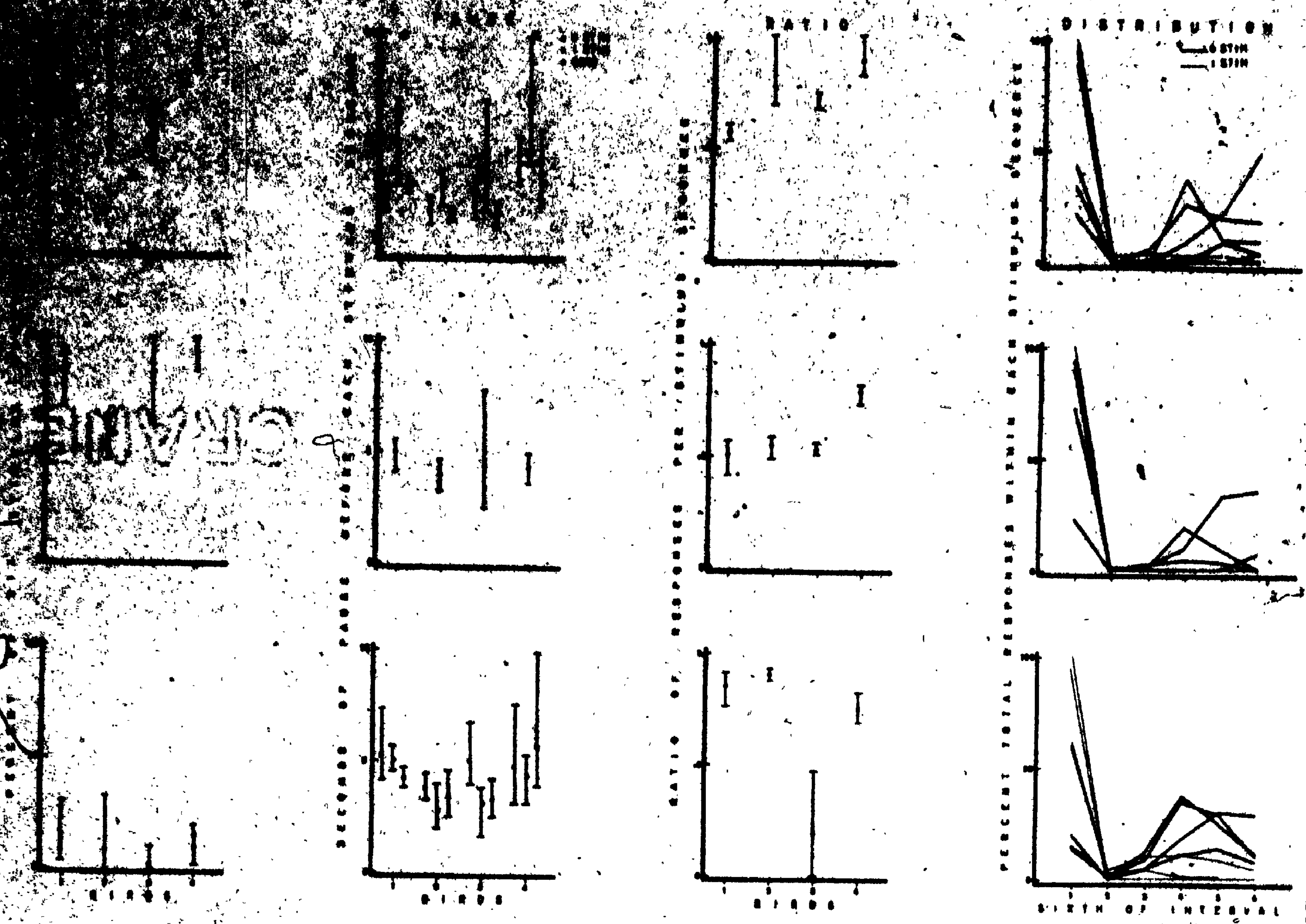
Phase I

Figure 2 presents the data for Phase I of Condition A. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data for Phase I indicated that the same timing sequence was not initiated most frequently before and after the response key functions were reversed in all birds. That is, there was key preference rather than a sequence preference. Typically pauses were shorter preceding the initial response on the preferred key. The ratio of responses during each sequence indicated that typically the six stimulus sequence controlled the greatest relative amount of responding before and after the key reversal.

The distribution of the responding which occurred during the intervals under this procedure indicates that substantially different behaviors occurred during alternative intervals. Almost all responding was concentrated in the first two seconds of the single stimulus sequences. The responses which initiated the interval were counted within the first block of this distribution and the obtained distribution was indicative of responding once or emitting a cluster of responses which initiated the interval and responding at a low rate throughout the rest of the interval. The distribution of responding in the sequence which contained six stimuli was different

Figure 2. Data for Phase I of Condition A. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the six stimulus sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the six stimulus sequence; the triangles represent the mean pause before the single stimulus sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the six stimulus sequence. The ratio is formed by dividing the mean number of responses per six stimulus sequence by the mean number occurring per six stimulus sequence plus the mean number per single stimulus sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the six stimulus sequence was greater or lesser than the single stimulus sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the six stimulus sequence. The dotted lines present the distribution of responding during the single stimulus sequence.



DISTRIBUTION
6 STIM
1 STIM
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
SIXTH OF INTERVAL
RATIO
RATIO OF RESPONSES PER STIMULUS SEQUENCE
BIRDS
PAUSE
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
BIRDS
BIRDS

8

however. A burst of responses occurred at the beginning of the interval followed by a subsequent decrease. However responding tended to increase again in the middle blocks of the interval and subsequently decrease toward the end of the interval.

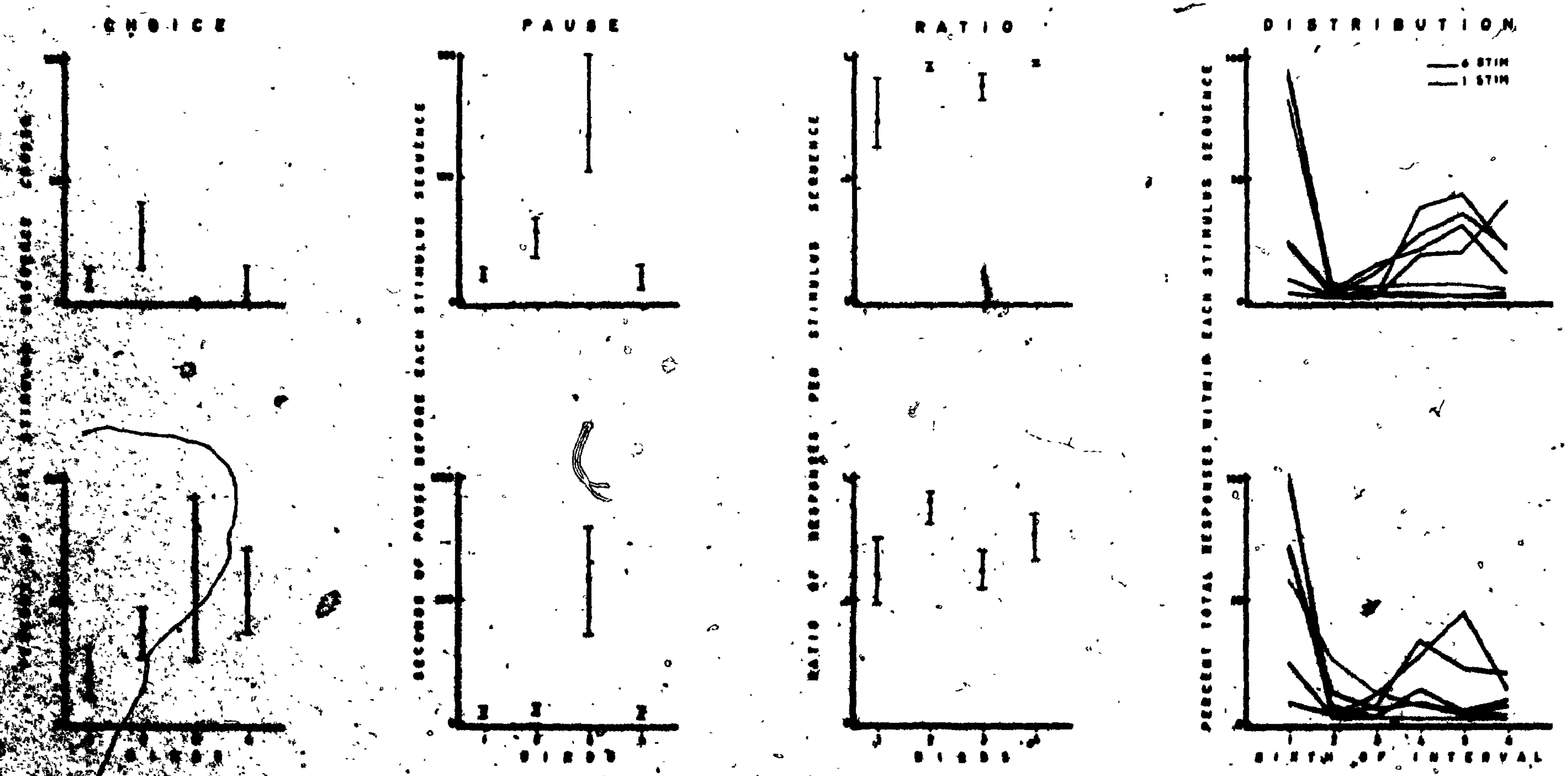
Phase II

Figure 3 presents the data for Phase II of Condition A. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice measure indicated that two birds maintained a preference for the single stimulus sequence when the interval duration was 120 seconds. The ratio measure indicated that the tendency for the six stimulus sequence to control more responding than the single stimulus sequence was comparable to Phase I.

The distribution measure remained relatively similar to the distributions obtained in Phase I even though the interval duration had been increased by a factor of ten. The distribution of responding in the single stimulus sequence was concentrated in the first twenty seconds of the interval. This type of distribution was indicative of responding once or in a burst which initiated the interval and responding at a low rate throughout the rest of the interval. Responding under the six stimulus sequence was different. Following the initiation burst and subsequent

Figure 3. Data for Phase II of Condition A. The vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the six stimulus sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of a sequence. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the six stimulus sequence. The ratio is formed by dividing the mean number of responses per six stimulus sequence by the mean number occurring per six stimulus sequence plus the mean number per single stimulus sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the six stimulus sequence was greater or lesser than the single stimulus sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the six stimulus sequence. The dotted lines present the distribution of responding during the single stimulus sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
6 STIM
1 STIM
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
BIRDS
1
2
3
4
SIXTH OF INTERVAL
1
2
3
4
5
6

decrease, responding increased in the middle blocks of the interval and tended to decrease during the remainder of the interval.

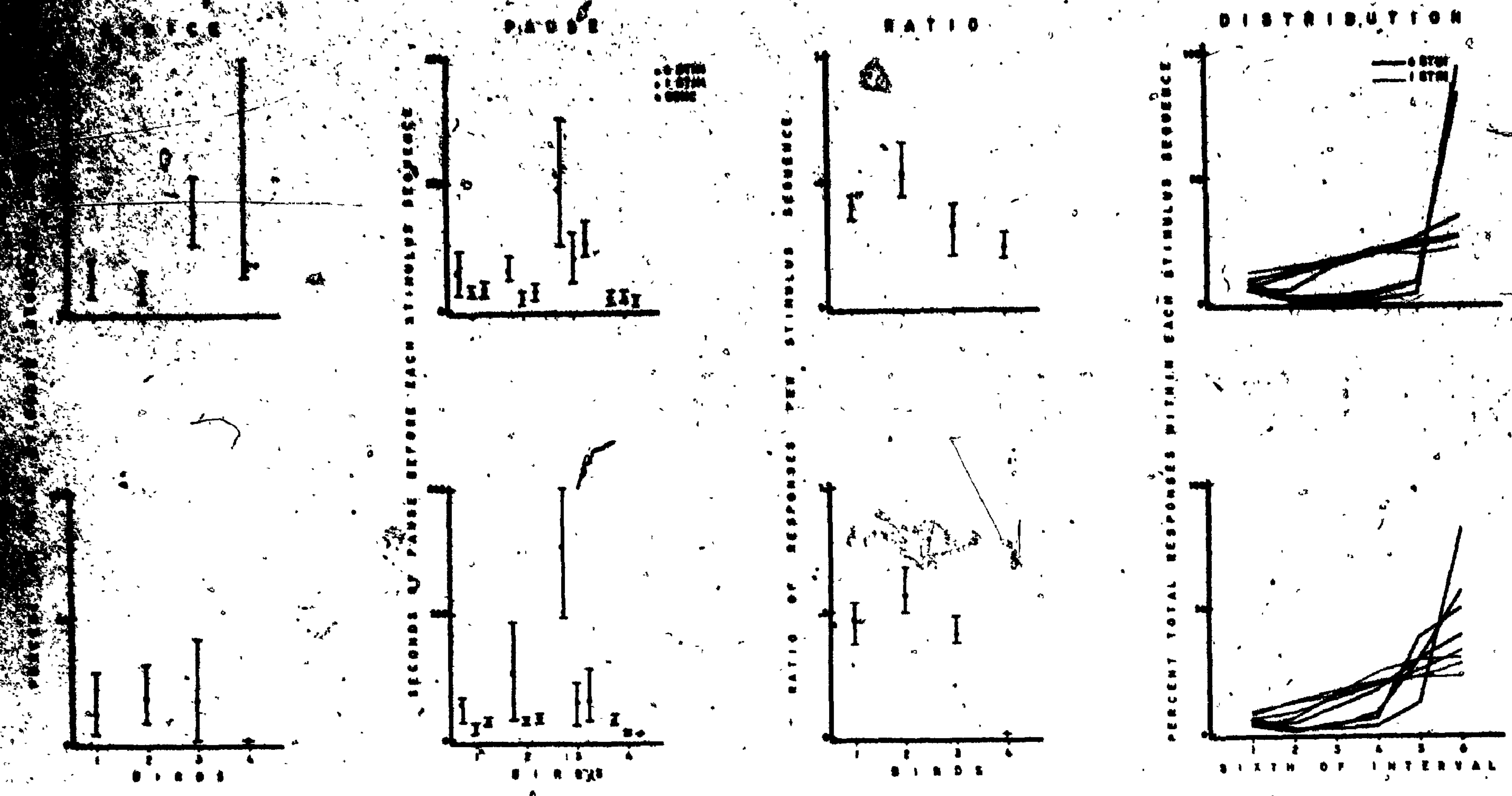
Phase III

Figure 4 presents the data for Phase III of Condition A. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice measure indicated that all birds initiated the single stimulus sequence more frequently than the sequence which contained six stimuli when the reinforcer was contingent on a response at the end of the interval. The range of preference in one subphase for one bird was large however. Longer pauses occurred before the initiation of the six stimulus sequence in all cases. The ratio measure indicated a tendency for more responding to occur in the single stimulus sequence.

The distribution measure indicated a continued difference in the pattern of responding in the two sequences. In the sequence which contained six stimuli, almost all responding occurred in the final sixth of the interval. The sequence which contained a single stimulus throughout the interval, generated a steady increase in the percentage of responses in succeeding twenty second blocks.

Figure 4. Data for Phase III of Condition A. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the six stimulus sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the six stimulus sequence; the triangles represent the mean pause before the single stimulus sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the six stimulus sequence. The ratio is formed by dividing the mean number of responses per six stimulus sequence by the mean number occurring per six stimulus sequence plus the mean number per single stimulus sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the six stimulus sequence was greater or lesser than the single stimulus sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the six stimulus sequence. The dotted lines present the distribution of responding during the single stimulus sequence.


PAUSE
RATIO
DISTRIBUTION
0 STIM
1 STIM
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
1
2
3
4
BIRDS
1
2
3
4
5
6
SIXTH OF INTERVAL

Condition B

This procedure opposed two sequences, both of which had two stimuli and both of which were composed of a stimulus which was one-sixth of the interval in duration and a stimulus which was five-sixths of the interval in duration. The 5+1 sequence provided a stimulus change when one-sixth of the interval remained before the occurrence of food. The 1+5 sequence provided a stimulus change when five-sixths of the interval remained before the occurrence of food.

Subjects

B1, B2, B3 and B4.

Apparatus

Chamber B, the smaller box.

Procedure

Phase I

The pigeons were manually shaped to peck the two dark keys. The schedule requirement was increased to a concurrent variable interval one minute schedule under dark keys. When a relatively steady and equal rate occurred to both keys Phase I was initiated.

When the intertrial condition was in effect a peck to Key A deactivated

Key B and immediately illuminated Key A with ten seconds of white light followed by two seconds of orange light. This sequence was followed unconditionally with four seconds access to the food hopper regardless of the behavior which had occurred within the interval. During the intertrial condition a peck to Key B deactivated Key A, and immediately illuminated Key B with two seconds of red light followed by ten seconds of green light. This sequence was followed unconditionally with four seconds access to the food hopper regardless of the behavior which had occurred within the interval. This procedure was continued for 14 sessions and was followed by 20 sessions in which a peck to a particular key was followed by the stimulus sequence which had followed a peck to the alternative key. A peck to Key A was followed by two seconds of white light followed by ten seconds of orange light. A peck to Key B was followed by ten seconds of red light followed by two seconds of green light.

Phase II

The pigeons were previously under the experimental procedures of Phase I. Experimental conditions were modified initiating Phase II. The procedures used were identical to Phase I with the exception of the addition of a response contingency at the end of the timed interval. The final timing stimulus remained in effect until the contingency was met. This procedure was continued for 23 sessions and was followed by 23 sessions in which the response key functions were reversed.

Results

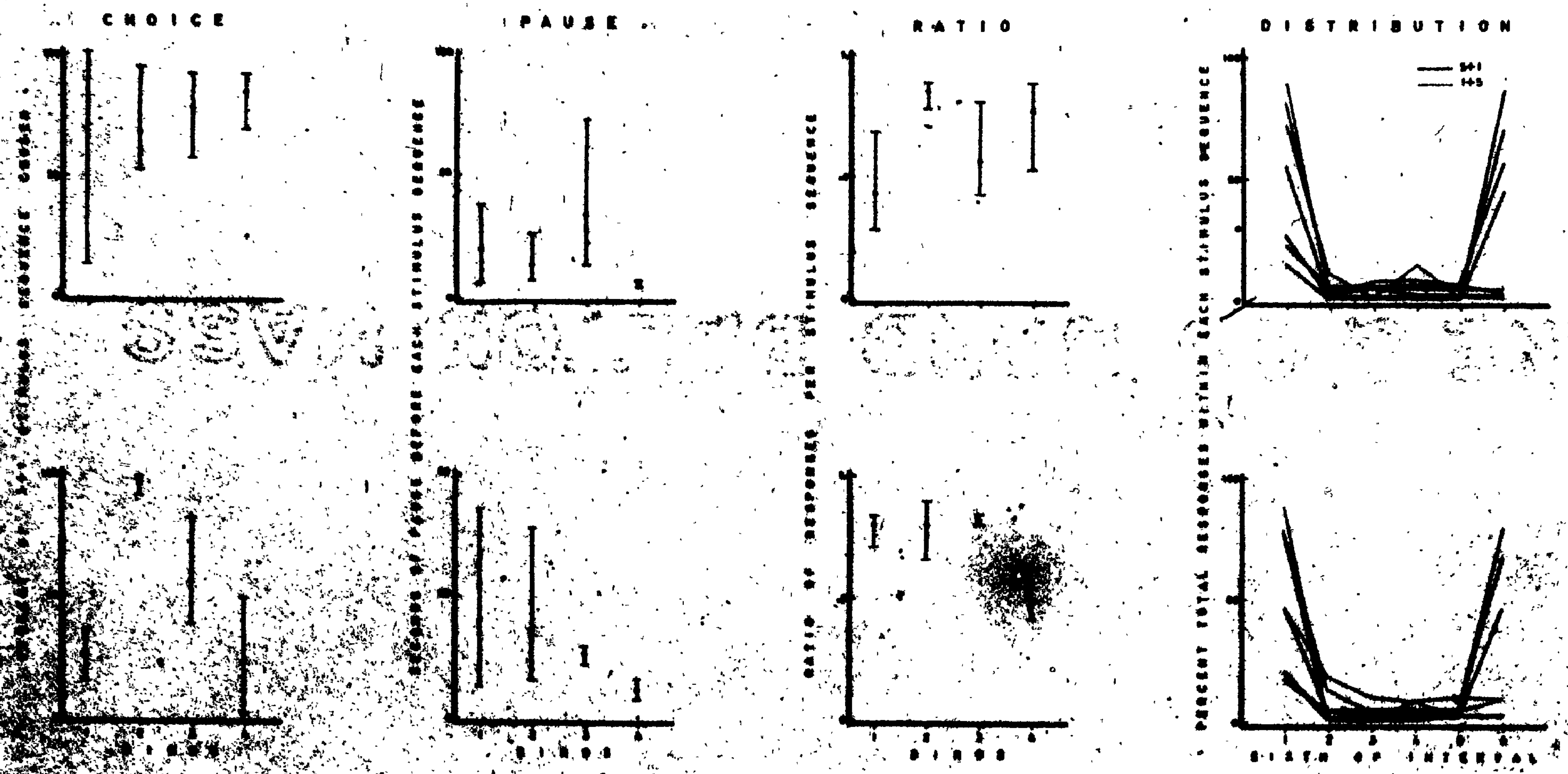
Phase I

The alternatives in this condition were a 5+1 sequence which was characterized by a ten second stimulus followed by a two second stimulus and a 1+5 sequence which was characterized by a two second stimulus, followed by a ten second stimulus. Figure 5 presents the data for Phase I of Condition B. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data indicated that two birds initiated the 5+1 sequence more frequently before and after the reversal, while two continued to most frequently initiate whichever sequence was available on Key A. Differential pause data were not available in this condition. The ratio calculation indicated that two birds which maintained a preference for the 5+1 sequence also maintained a higher proportion of responding during the preferred sequence.

The distribution of responding during the intervals in this condition indicated that substantially different behaviors occurred during the alternative intervals. Almost all responding was concentrated in the first two seconds during the 1+5 sequence. The 1+5 sequence was a two second stimulus followed by a ten second stimulus. The 5+1 sequence, however, generated a large amount of responding in the final two seconds

Figure 5. Data for Phase I of Condition B. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 5+1 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of a sequence. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 5+1 stimulus sequence. The ratio is formed by dividing the mean number of responses per 5+1 sequence by the mean number occurring per 5+1 sequence plus the mean number per 1+5 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 5+1 sequence was greater or lesser than the 1+5 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 5+1 sequence. The dotted lines present the distribution of responding during the 1+5 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
S+1
1+5
100
50
0
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
1
2
3
4
BIRDS
5
6
SIXTH OF INTERVAL

of the interval. The 5+1 sequence in this condition was a ten second stimulus followed by a two second stimulus.

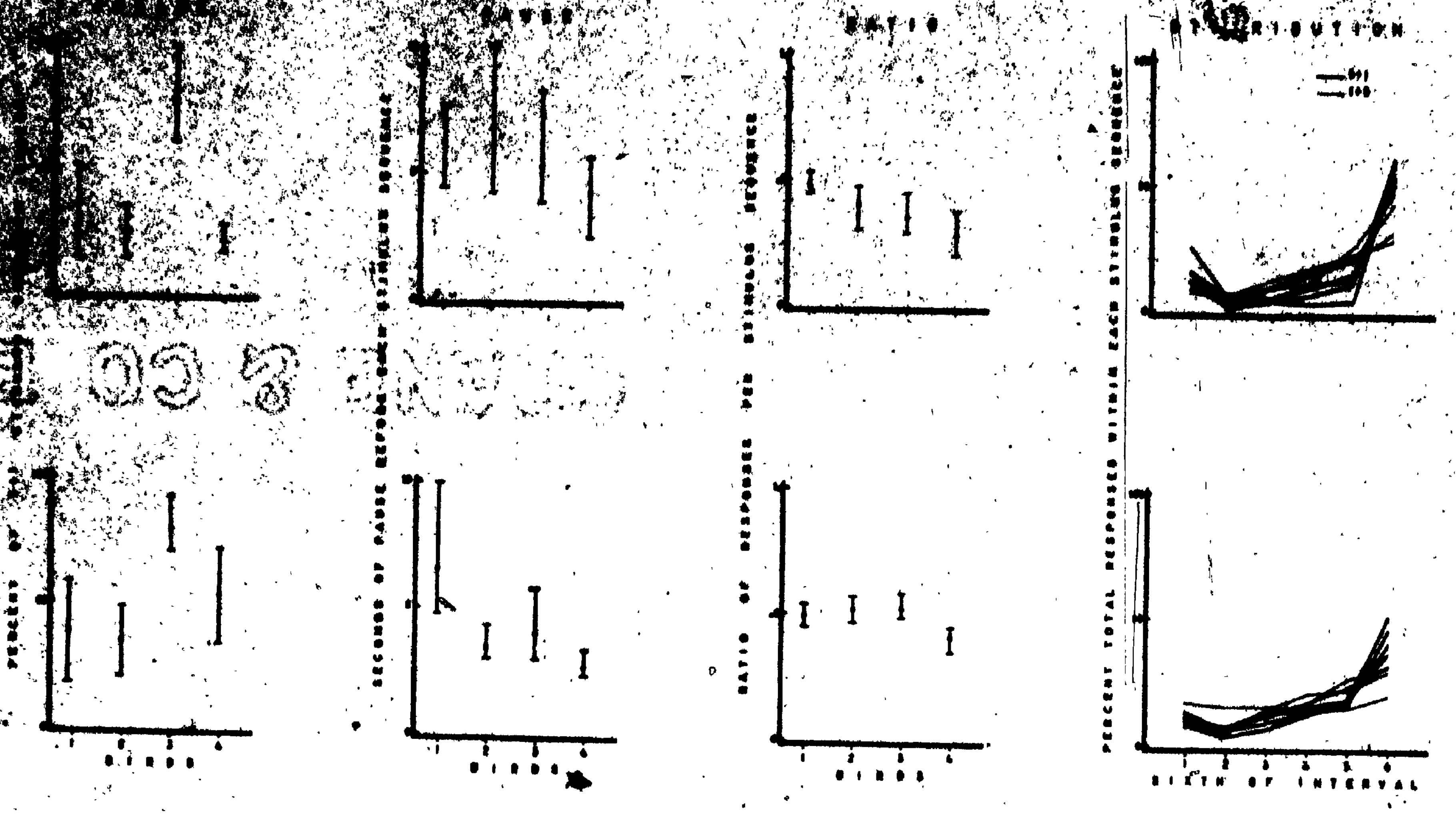
Phase II

Figure 6 presents the data for Phase II of Condition B. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice measure indicated that two birds maintained a preference for the 1+5 sequence, and one maintained a preference for the 5+1 sequence. The ratio of responding measure indicated that two birds tended to respond more in the 5+1 sequence while two responded more in the 1+5 sequence.

The distribution measure indicated that both sequences generated most responding in the final two seconds when the response contingency was in effect. The 5+1 sequence which had a stimulus change immediately preceding the final block had a pronounced increase during the final block. The 1+5 sequence in which the final stimulus change occurred ten seconds before the response requirement exhibited a more gradual increase in the percentage of responses which occurred in succeeding blocks of the interval.

Figure 6. Data for Phase II of Condition B. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 5+1 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of a sequence. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 5+1 sequence. The ratio is formed by dividing the mean number of responses per 5+1 sequence by the mean number occurring per 5+1 sequence plus the mean number per 1+5 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 5+1 stimulus sequence was greater or lesser than the 1+5 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 5+1 sequence. The dotted lines present the distribution of responding during the 1+5 sequence.


DISTRIBUTION
RATIO
PAUSE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
SIXTH OF INTERVAL
1
2
3
4
5
6
RATIO OF RESPONSES PER STIMULUS SEQUENCE
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
PERCENT OF
BIRDS
1
2
3
4

Condition C

This procedure opposed two sequences, both of which had two stimuli. The 5+1 sequence provided a stimulus change when one-sixth of the interval remained before the occurrence of food. The 3+3 sequence provided a stimulus change when three-sixths of the interval remained before the occurrence of food.

Subjects

C1, C2, C3 and C4.

Apparatus

Chamber C, one of the larger boxes.

Procedure

Phase I

This condition used a procedure almost identical to that of Condition A. The pigeons were manually shaped to peck the two dark keys and the feedback contingency was in effect. Sessions were alternated between forced and free trials in a counterbalanced fashion. The 5+1 light sequence followed a response to Key A and was ten seconds of red light followed by two seconds of green light. Responses to Key B were followed by the occurrence of the 3+3 sequence which was six seconds of orange light followed by six seconds of white light.

This procedure was continued for 45 sessions followed by 35 Concurrent sessions and finally 55 reversal sessions in which a response to a particular key was followed on that key by the sequence which had followed a peck to the alternative key.

Phase II

The duration of the timing blocks was increased by a factor of ten in this phase. The pigeons had been under the experimental procedures of Phase I. The experimental conditions were modified initiating Phase II. The procedures used were similar to Phase I with the exceptions that the timing blocks were 20 seconds each making the interval 120 seconds in duration, and that all sessions were the Concurrent type. The 3+3 sequence followed a response to Key A and was 60 seconds of white light followed by 60 seconds of orange light. Responses to Key B were followed by the 5+1 sequence which was 100 seconds of red light followed by 20 seconds of green light. This procedure was continued for 36 sessions and was followed by 21 reversal sessions.

Phase III

The reinforcer was response contingent in this phase. The pigeons had been under the experimental procedures of Phase II. Experimental conditions were modified initiating Phase III. This phase used a procedure almost identical to that of Phase I. In Phase III sessions alternated between forced and free trials in a counterbalanced fashion. The light sequence for a response to Key A was 100 seconds of red light followed with 20 seconds of green light. Responses to Key B were followed with 60 seconds of white light and then 60 seconds of orange light. The reinforcer was response contingent following the elapse of the interval. The final timing stimulus remained in effect until the contingency was met. This procedure continued for 23 sessions, and was followed by 23 reversal sessions in which a peck to a particular key was followed on that key by the sequence which had followed a peck to the alternative key.

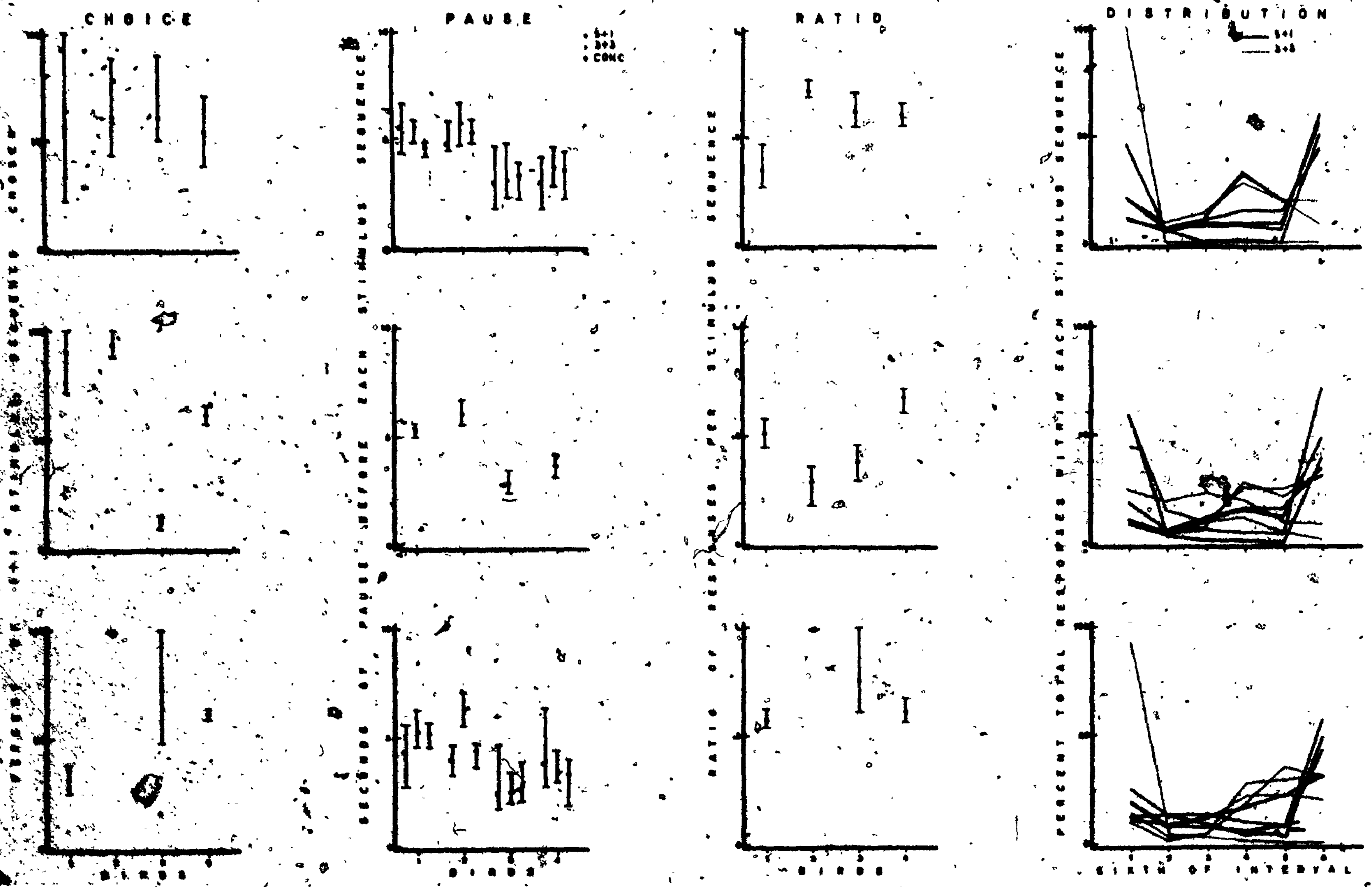
Results

Phase I

Figure 7 presents the data for Phase I of Condition C. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data for Phase I of Condition C indicated that in two of four birds the 5 + 1 sequence, which was characterized by a ten second stimulus followed by a two second stimulus, was initiated more frequently than the 3 + 3 sequence, which was characterized by a six second stimulus followed by six seconds of another stimulus. The pause data indicated a tendency for

Figure 7. Data for Phase I of Condition C. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 5+1 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the 5+1 sequence; the triangles represent the mean pause before the 3+3 sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 5+1 sequence. The ratio is formed by dividing the mean number of responses per 5+1 stimulus sequence by the mean number occurring per 5+1 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 5+1 stimulus sequence was greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The solid lines present the distribution of responding during the 5+1 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
5+1
3+3
CONC
PERCENT OF 5+1 STIMULUS SEQUENCES CHOSEN
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
BIRDS
SIXTH OF INTERVAL

longer pauses before the 3+3 sequence in three of four birds. The greatest difference occurred in the bird with the most pronounced preference for the 5+1 sequence. The ratio data indicated that the 5+1 sequence tended to control more responding than the 3+3 sequence.

The distribution measures for this condition indicated that in the 5+1 sequence most responding occurred during the final two seconds, or at the onset of the final stimulus. The response distribution for the 3+3 sequence also increased at the onset of the final stimulus, which was in the middle block during this sequence. During the 3+3 sequence the rate tended to decrease toward the end of the interval.

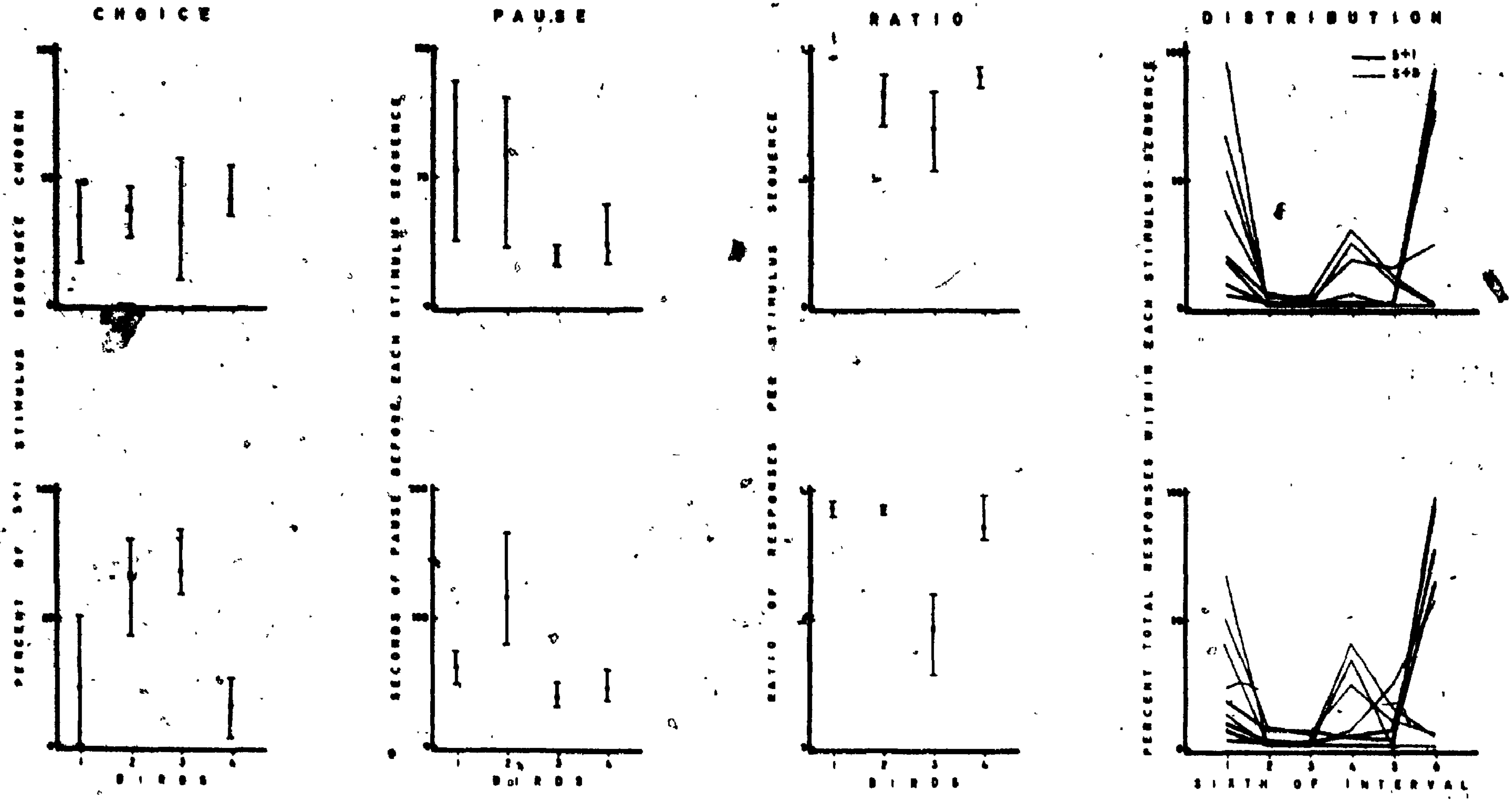
Phase II

Figure 8 presents the data for Phase II of Condition C. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data for Phase II of Condition C indicated that two birds maintained a preference for the 3+3 sequence. The ratio of the amount of responding controlled by the two sequences indicated that in three of four birds more responding occurred during the 5+1 sequence than in the 3+3 sequence.

The distribution data indicated that the 5+1 sequence which contained a 100 second stimulus followed by a 20 second stimulus generated most

Figure 8. Data for Phase II of Condition C. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 5+1 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of a sequence. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 5+1 sequence. The ratio is formed by dividing the mean number of responses per 5+1 sequence by the mean number occurring per 5+1 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 5+1 sequence was greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 5+1 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
S+1
S+B
PERCENT OF S+1 STIMULUS SEQUENCE CHOSEN
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS-SEQUENCE
BIRDS
1
2
3
4
SIXTH OF INTERVAL
1
2
3
4
5
6
100
50
0

responding in the final stimulus preceding the occurrence of food. The 3+3 sequence which contained two, 60 second stimuli, also generated most responding at the onset of the final stimulus with a tendency for the amount of responding to decrease toward the end of the interval.

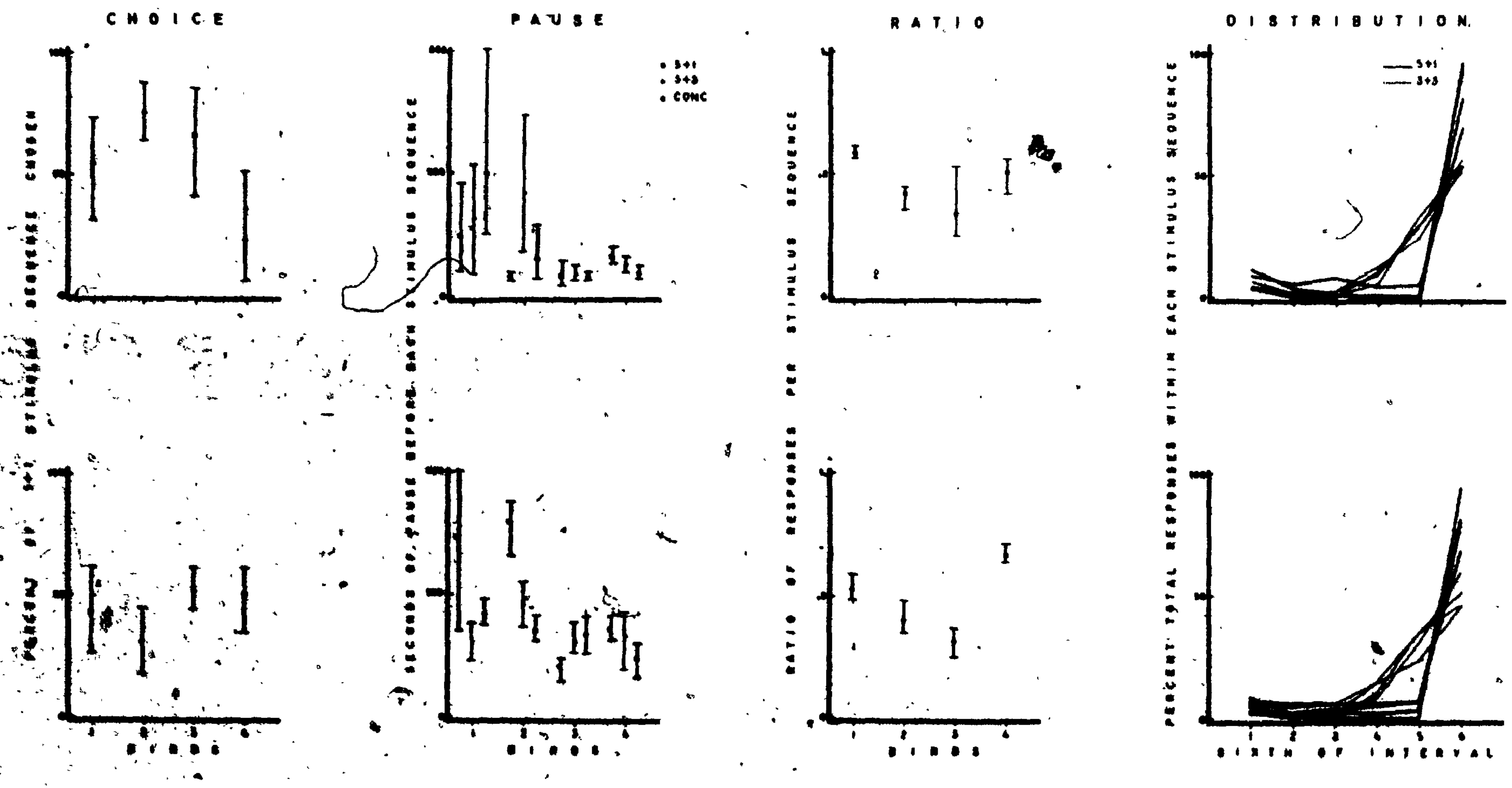
Phase III

The data for Phase III of Condition C is presented in Figure 9. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The 5+1 sequence in Phase III of Condition C contained a 100 second stimulus followed by a 20 second stimulus, while the 3+3 sequence contained two, 60 second stimuli. The choice data indicated that typically side preferences were maintained across the reversal. Pausing was shorter before initiating the preferred sequence. The ratio measure indicated that the sequence which controlled the most responding before the key reversal also controlled the most responding after the reversal.

The distribution data indicated that the 5+1 sequence which provided a stimulus change immediately before the final sixth of the interval generated almost all responding in the final sixth. The 3+3 sequence which provided a stimulus change half way through the interval generated a steady increase in the percentage of responding in the last half of the interval.

Figure 9. Data for Phase III of Condition C. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 5+1 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the 5-1 sequence; the triangles represent the mean pause before the 3-3 sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 5+1 sequence. The ratio is formed by dividing the mean number of responses per 5+1 sequence by the mean number occurring per 5+1 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 5+1 sequence was greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 5+1 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
PERCENT OF S+1 STIMULUS SEQUENCE CHOSEN
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
S+1
S+3
CONC
100
50
0
1
2
3
4
5
6
BIRDS
SIXTH OF INTERVAL

Condition D

This procedure opposed a sequence with three stimuli with a sequence with two stimuli. The 2+2+2 sequence provided a stimulus change when four-sixths and again when two-sixths of the interval remained before the occurrence of food. The 3+3 sequence provided a stimulus change when three-sixths of the interval remained before the occurrence of food.

Subjects

D1, D2, D3 and D4.

Apparatus

Chamber D, one of the larger boxes.

Procedure

Phase I

This condition used a procedure almost identical to that of Condition A. The pigeons were manually shaped to peck the dark keys and the feedback contingency was in effect. Sessions were alternated between forced and free trials in a counterbalanced fashion. The 2+2+2 sequence followed a response to Key A and was four seconds of red light, followed by four seconds of green light, followed by four seconds of blue light. Responses to Key B were followed by the 3+3 sequence which was six seconds of white light followed by six seconds of orange light. This procedure was continued for 45 sessions which was followed by 35 Concurrent sessions and finally 55 reversal sessions.

Phase II

The duration of the timing blocks was increased by a factor of ten in this phase. The pigeons had been under the experimental procedures of Phase I. The experimental conditions were modified, initiating Phase II. The procedures used were similar to Phase I with the exceptions that the timing blocks were 20 seconds each making the interval 120 seconds in duration, and that all sessions were the Concurrent type. The 3+3 sequence followed a response to Key A and was 60 seconds of white light followed by 60 seconds of orange light. Responses to Key B were followed by the 2+2+2 sequence which was 40 seconds of red light followed by 40 seconds of green light followed by 40 seconds of blue light. This procedure was continued for 36 sessions and was followed by 21 reversal sessions.

Phase III

The reinforcer was response contingent in this phase. The pigeons had been under the experimental procedures of Phase II. Experimental conditions were modified initiating Phase III. This phase used a procedure almost identical to that of Phase I. In Phase III, sessions alternated between forced and free trials in a counterbalanced fashion. The light sequence for a response to Key A was 40 seconds of red light followed by 40 seconds of green light followed by 40 seconds of blue light. Responses to Key B were followed with 60 seconds of white light and then 60 seconds of orange light. The response contingency was in effect, and the final timing stimulus remained in effect until the response contingency was met. This procedure was continued for 23 sessions and was followed by 23 reversal sessions.

Results

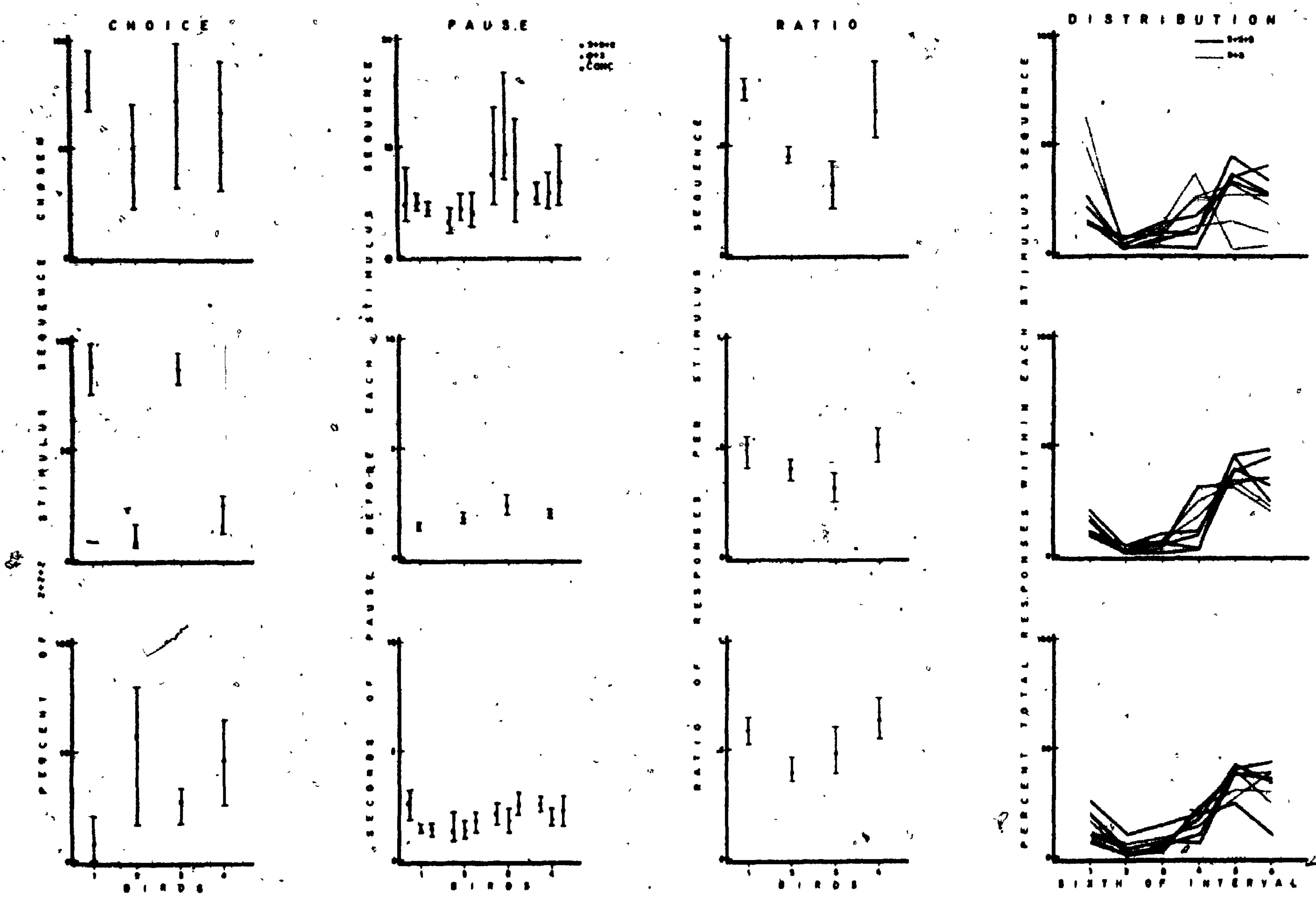
Phase I

Figure 10 presents the data for Phase I of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data indicated that sequence preferences were not maintained across the key reversal. The ratio calculation indicated that the relative amount of responding controlled by a sequence was maintained across the reversal.

The distribution data replicates the trend which had occurred in the other conditions. A high proportion of the responding occurred at the onset of the stimulus immediately preceding food and the proportion of

Figure 10. Data for Phase I of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 2+2+2 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the 2+2+2 sequence; the triangles represent the mean pause before the 3+3 sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 2+2+2 sequence. The ratio is formed by dividing the mean number of responses per 2+2+2 sequence by the mean number occurring per 2+2+2 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 2+2+2 sequence was greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 2+2+2 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
3+3+3
3+3
CONC
PERCENT OF 2+2+2 STIMULUS SEQUENCE CHOSEN
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
0
1
2
3
4
5
6
BIRDS
SIXTH OF INTERVAL

responding in subsequent two second blocks tended to decrease.

Phase II

Figure 11 presents the data for Phase II of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data indicated that there was not a consistent sequence preference across the key reversal in three of four birds. Pause times increased almost by a factor of 100 with the increase of the interval duration by a factor of ten.

The distribution data indicated that the sequences continued to generate substantially different response distributions during the alternative intervals. These distributions were similar to those generated in Phase I which had only a twelve second interval.

Phase III

Figure 12 presents the data for Phase III of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase.

The choice data indicated that there was not a consistent sequence preference across the key reversal in three of four birds. Typically the 3+3

Figure 11. Data for Phase II of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 2+2+2 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of a sequence. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 2+2+2 sequence. The ratio is formed by dividing the mean number of responses per 2+2+2 sequence by the mean number occurring per 2+2+2 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than .5 as the amount of responding in the 2+2+2 sequence was greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 2+2+2 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.

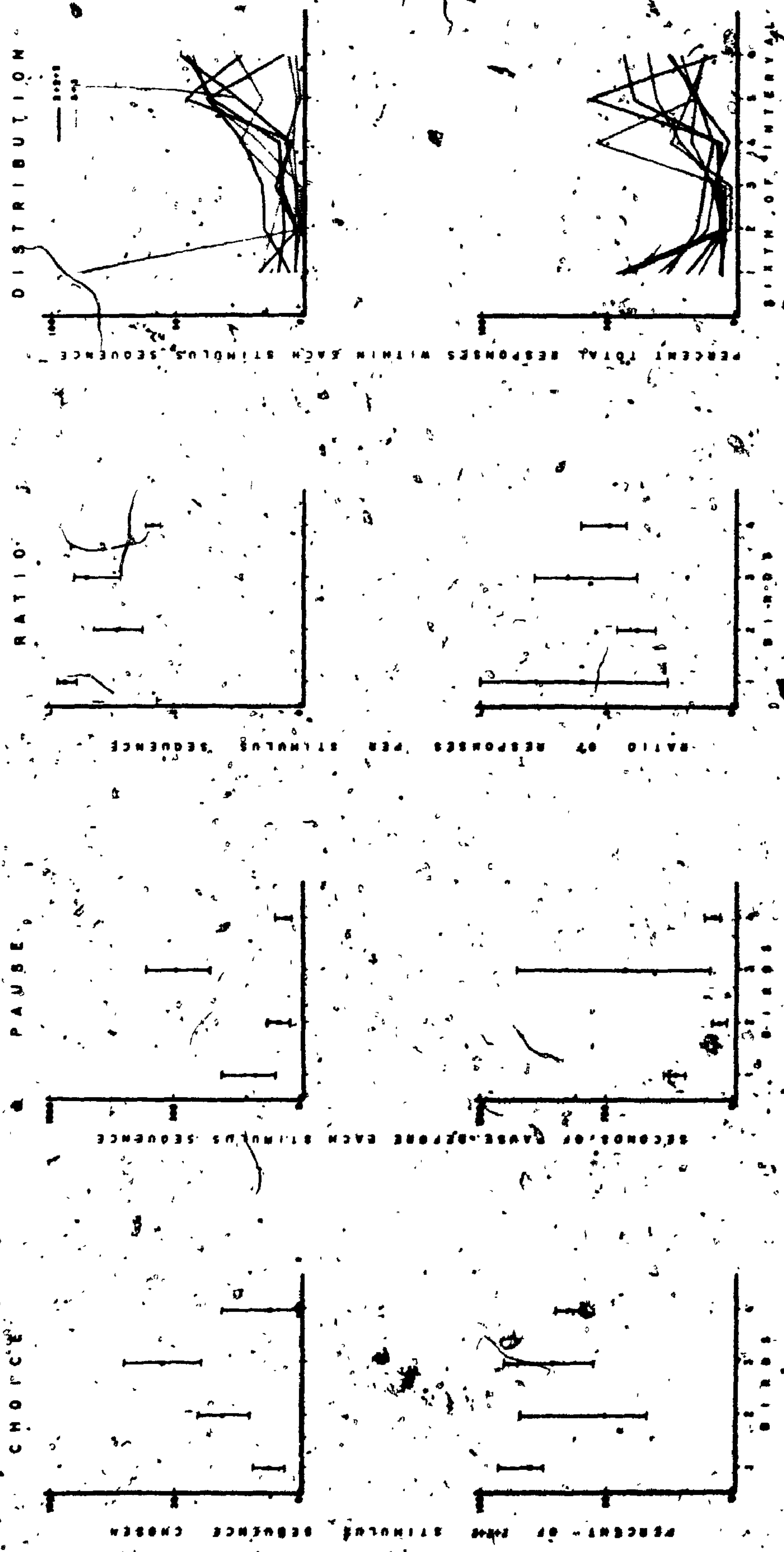
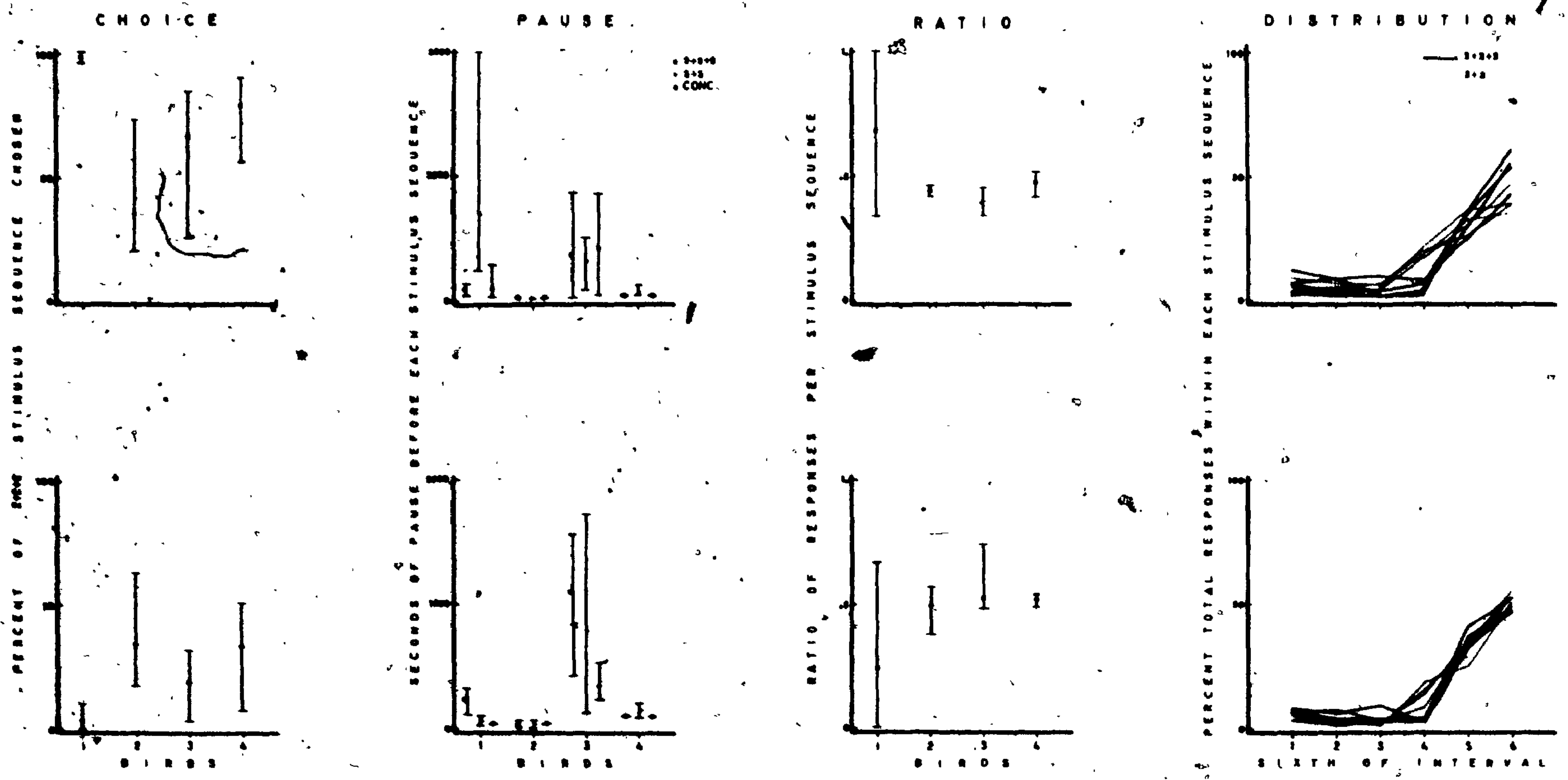

DISTRIBUTION
RATIO
PAUSE
CHOICE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
PERCENT OF STIMULUS SEQUENCE CHOSEN
SIXTH OF INTERVAL

Figure 12. Data for Phase III of Condition D. The four vertical columns present the choice, pause, ratio and distribution calculations. The horizontal rows depict the behavior following each subphase. The choice column gives the percentage of the free choice trials which were the 2+2+2 sequence. The mean and range is presented for each bird. The pause column presents the mean pause, in seconds, preceding the initiation of each type of sequence. The squares represent the mean pause before the 2+2+2 sequence; the triangles represent the mean pause before the 3+3 sequence; and the circles represent the pause during sessions in which either sequence could be initiated. The mean and range is presented for each calculation for each bird. The ratio column depicts the relative amount of responding during the alternative sequences in terms of the 2+2+2 sequence. The ratio is formed by dividing the mean number of responses per 2+2+2 sequence by the mean number occurring per 2+2+2 sequence plus the mean number per 3+3 sequence. A value of .5 indicates that an equal amount of responding occurred under both stimulus sequences. The ratio measure is greater or lesser than the 3+3 sequences respectively. The mean and range of the ratio measure is presented for each bird. The distribution column presents the relative amount of responding in each consecutive sixth of the interval for each sequence for each bird. The solid lines present the distribution of responding during the 2+2+2 sequence. The dotted lines present the distribution of responding during the 3+3 sequence.


CHOICE
PAUSE
RATIO
DISTRIBUTION
PERCENT OF ONE STIMULUS SEQUENCE CHOSEN
SECONDS OF PAUSE BEFORE EACH STIMULUS SEQUENCE
RATIO OF RESPONSES PER STIMULUS SEQUENCE
PERCENT TOTAL RESPONSES WITHIN EACH STIMULUS SEQUENCE
S+S+S
S+S
CONC
S+S+S
S+S
BIRDS
SIXTH OF INTERVAL
100
50
0
1
2
3
4
5
6

sequence controlled more responding than the 2+2+2 sequence.

The distribution measure indicated substantially different behaviors in the alternative intervals. Both sequences generated a steady increase in the percentage of responses occurring in succeeding sixths of the interval following the onset of the final stimulus.

Condition E

This procedure was used to assess the probability of a differential sequence preference generated by some mechanism other than the association or relationship of the stimuli with food presentation, such as differential sensory reinforcement (Kish, 1966).

Subjects

E1, E2, E3, E4, E5 and E6.

Apparatus

Chamber E, one of the larger boxes. It was fitted with a 102 by 102 mm square treadle beneath each key.

Procedure

Three birds were assigned to a control group and three birds were assigned to an experimental group. One hour sessions were conducted daily. The number of treadle depressions were recorded.

Phase I

Both groups were exposed to 22 sessions during which behavior had no programmed consequences.

Phase II

No programmed consequences followed any behavior of the control group. For the experimental group, a depression of the left treadle was followed by the transillumination of the left key with twelve seconds of white light. A depression of the right treadle was followed by the transillumination of the right key with two seconds each of yellow, orange, red, violet, blue and green light. Both groups were exposed to Phase II for 22 sessions.

Phase III

For the control group, no programmed consequences followed any behavior. For the experimental group, the treadle functions were reversed. A depression of the left treadle was followed by the transillumination of the left key with two seconds each of yellow, orange, red, violet, blue and green light. A depression of the right treadle was followed by the transillumination of the right key with twelve seconds of white light. Both groups were exposed to Phase III for 22 sessions.

Phase IV

Both groups were exposed to 22 sessions during which behavior had no programmed consequences.

Results

No consistent preference for either sequence developed. There was however a general increase in the overall number of treadle depressions in Phase III with a subsequent decrease in Phase IV. This effect occurred in both the experimental and control group, however, and therefore cannot be attributed to the reinforcing effects of the key stimuli. The mean number of treadle depressions per session for the last five days of each phase for each bird is given in Table 2.

Table 2. Mean treadle depressions per hour, for each bird during each phase of Condition E.

MEAN TREADLE DEPRESSIONS PER HOUR

Experimental Group

Phase	Bird 1		Bird 2		Bird 3	
	Six Stimulus Sequence	One Stimulus Sequence	Six Stimulus Sequence	One Stimulus Sequence	Six Stimulus Sequence	One Stimulus Sequence
I	2.6	3.4	2.2	3.6	15.4	9.6
II	0.4	0.4	4.2	0.8	5.6	3.2
III	2.0	2.2	14.4	18.0	27.0	25.0
IV	1.2	2.6	3.0	5.6	1.4	0.0

Control Group

Phase	Bird 1		Bird 2		Bird 3	
	Tred 1	Tred 2	Tred 1	Tred 2	Tred 1	Tred 2
I	4.8	2.2	3.0	2.8	9.0	4.6
II	1.2	0.2	0.6	1.0	7.6	0.4
III	4.8	3.2	13.0	13.6	23.0	6.8
IV	3.2	7.4	4.2	0.4	1.6	6.2

Summary of Results

The choice measure for the various phases of Conditions A through D indicated that a consistent sequence preference occurred in only the FI 120 second phase of Condition A, which opposed a six stimulus sequence with a single stimulus sequence. All four birds initiated the single stimulus sequence more frequently. The range of preference for one bird in one subphase was large however. In general throughout other conditions and phases there was a frequent occurrence of ranges of preference in the order of 40%.

During the FI phases of Conditions A, B, C, and D, the onset of the final stimulus typically occasioned a steady increase in rate. Preceding the onset of the final stimulus, few responses were emitted. However, during the FT phases (i.e., Phase I and II) of Conditions A, B, C, and D, onset of the final stimulus typically generated a sharp increase in the response rate followed by a subsequent decrease. This pattern occurred during both the 12 second interval and the 120 second interval.

There were two stimulus sequences which did not yield the otherwise typical increase in responding at the onset of the final stimulus during the FT phases; the six stimulus sequence and the 1 + 5 sequence. The six stimulus sequence generated an increasing rate through the first half of the entire stimulus interval followed by a decreasing rate to the end of the interval. The 1 + 5 sequence generated the highest rate of responding during the first stimulus.

Longer pauses often occurred preceding the sequence chosen most frequently, and often more responding occurred in the preferred sequence.

Condition E, the novelty control condition, which opposed a six stimulus sequence with a single stimulus, without primary reinforcement, indicated no evidence of a differential sequence preference.

CHAPTER III

DISCUSSION

The results of the test of the reinforcing effectiveness of timing stimuli did not support Hendry's hypothesis. The more informative stimulus sequence was not consistently preferred. It was found that timing stimuli evoke key pecking which varies in rate across the stimulus interval and differs in distribution across differing timing sequences. The response requirement at the end of the stimulus sequence in the FI procedure altered these distributions of responding during the sequence and may have influenced a preference for the less informative stimulus sequence.

Hendry and Dillow (1966) investigated the reinforcing effectiveness of timing stimuli in interval schedules. In their procedure a fixed interval schedule under a single stimulus was in effect on one key, while timing stimuli correlated with consecutive sixths of the interval were intermittently available on a separate key. In general they found that response contingent stimuli which were correlated with the passage of time during interval schedules could reinforce the response which produced them (i.e., timing stimuli were reinforcing). They concluded that "all clock stimuli, not just the stimulus closest to reinforcement, became reinforcing."

The present investigation, however, indicated that not only was there no consistent preference for the various informative sequences, the only reasonably consistent preference was for a non-informative sequence. The present data therefore contrast with Hendry and Dillow's findings as well as their hypotheses.

Differential Reinforcing Effectiveness

Conditions A and D allowed investigation of timed intervals which opposed different numbers of timing stimuli. In Condition A, a single stimulus interval was compared to a six stimulus interval. In Condition D, a three stimulus interval was compared to a two stimulus interval. The six stimulus interval in Condition A and the three stimulus interval in Condition D provided more information, less uncertainty, more opportunity for preparation, more precise control over behavior during the interval, and the stimulus which had the highest density of reinforcement. The alternatives were very different in Condition A, while the alternatives were more similar in Condition D.

Conditions B and C investigated timed intervals which all contained two stimuli but which were qualitatively different. In Condition B, a stimulus change which occurred after one-sixth of the interval elapsed was compared to a stimulus change which occurred following five-sixths of the interval. Condition C opposed an interval with a stimulus change in the middle, with an interval with a stimulus change following five-sixths of the interval. The alternatives were very different in Condition B, while the alternatives were more similar in Condition D.

Of Conditions A through D, a consistent sequence preference occurred only in the condition which opposed a six stimulus sequence with a single stimulus sequence. This preference occurred during the 120 second response contingent or FI phase and the single stimulus sequence was preferred. One bird had a wide range of preferences, however. These findings indicate that timing stimuli which are correlated with the presentation of primary reinforcement are not reinforcing, relative to a non-timing stimulus condition.

Alternative interpretations for the obtained results in the present study can be generated, but do not appear compelling. Poor stimulus control or "inattention" would not seem to be an adequate explanation for the lack of consistent preferences for a particular informative sequence. The distribution measures indicated a very consistent difference between alternatives (this is discussed in more detail below). It would also seem unlikely that stimulus factors unrelated to food presentation, such as "sensory reinforcement" or "novelty" (Kish, 1966) could account for the present findings. The results of Condition E indicated no dominant differential preference for a particular stimulus sequence when primary reinforcement was absent.

An appeal to such factors as key or side preferences also seems unwarranted. The frequent occurrence of a wide range of sequence

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preference within and between pigeons suggests an absence of any preference. Furthermore, pigeons are not usually known to form strong key, color, or side preferences (Hendry, 1969b; Ricci, 1973). In any event, if the reinforcing effectiveness of temporal information is not relatively stronger than a position bias, then it would seem to have little predictive usefulness. This argument is not to say that the data in the present experiment indicate no key bias, however. All choice factors were equated except the stimulus sequences; therefore, if the stimuli were not differentially reinforcing, key bias could be the only factor controlling choice.

Explanations of the present results which rely upon the competition of contiguity and information factors are inappropriate, in that Hendry subsumed contiguity as a procedure which provided information. Stimuli are postulated to be reinforcing only because of their information content. Thus, controlling for contiguity while testing Hendry's hypothesis is unwarranted, in addition to having possible confounding effects.

Differential Controlling Effectiveness ("Evoked" Responding)

The effectiveness of information in differentially controlling behavior provided dramatic differences in response distributions. A differential effect of information was demonstrated between all alternative pairs of timing sequences. In addition, the controlling effect that a particular timing stimulus had on behavior was also dramatically different depending upon whether or not a response was required at the end of the stimulus sequence (i.e., between fixed time and fixed interval schedules).

The most notable characteristic of the distribution of responding within the fixed time intervals was the sharp increase in response rate at the onset of the final stimulus. This increase was usually followed by a subsequent decrease in the cases where the final stimulus was more than one-sixth of the interval in duration. This finding was somewhat similar to those reported by Farmer and Schoenfeld (1966) and Zeiler (1970).

Farmer and Schoenfeld (1966) found that a stimulus associated with the occurrence of food in a fixed interval schedule, when presented at other portions of the interval, would substantially increase the response rate during its occurrence. Zeiler (1970) investigated the effects of a stimulus which was terminally associated with primary reinforcement and which unpredictably changed keys in successive quarters of a fixed interval schedule. He reported that a burst of responding followed by a pause frequently occurred to the positive stimulus immediately after a position change.

The distribution of responding in the six stimulus sequence, during both the 12 and 120 second fixed time schedules was similar to Hendry and Dillow's (1966) finding. Maximum responding occurred in the middle portion of the interval. Hendry and Dillow had suggested that the stimuli in the middle portion of the interval were more reinforcing because of the high observing rates during that portion of the interval. In the present experiment timing stimuli were in effect without a response requirement other than the initial choice response however. The obtained response distributions could not be used to indicate reinforcing effectiveness, nor could they be labeled observing behavior. This finding would suggest that the rate change obtained by Hendry and Dillow could be due to factors of stimulus control rather than reinforcement properties.

The similarity of the various response distributions during the 12 second and the 120 second phases indicated that the response rates were controlled by the relative pattern of the timing stimuli rather than the absolute time to food presentation. These results systematically replicated and extend to fixed time schedules the finding that explicit stimuli in fixed interval schedules exert a greater control over the patterning of behavior than the absolute duration of the interval (Ferster and Skinner, 1957; Segal, 1962; Zeiler, 1970). They also suggest that responding is controlled by relative time or information more than by absolute time or contiguity.

The source and the maintenance of the behavior in the timing interval is subject to several interpretations. Responding in the fixed time intervals was initially high, most likely as a result of the concurrent variable interval shaping procedure. Continued responding could have been maintained by an adventitious correlation of food presentation with a response occurring at the end of the interval (Skinner, 1948; Herrnstein and Morse, 1957) or by the extended strengthening effect of the reinforcer on responses occurring earlier in the interval (Dews, 1966; 1970). The rate decrease at the end of the stimulus interval would then have to be interpreted as reflecting an increase in adventitiously maintained behavior, other than key pecking, immediately prior to the onset of food (Shull, 1970). However, some additional mechanism would then have to be postulated to explain why that behavior so reinforced did not predominate throughout the interval. The subsequent decrease in response rates following the onset of the final stimulus suggests that most likely key pecking during the sequences was not maintained entirely by a superstitious contingency. This is further supported by the difference in the behavior generated by the fixed time and the fixed interval phases. The fixed interval (response dependent) procedure could be thought of as the limiting case of a superstitious contingency.

An alternative interpretation of the controlling factor of the behavior during the sequences could be that it represented some type of adjunctive behavior (Falk, 1972) such as autoshaping. Brown and Jenkins (1968) found that pigeons would peck a key which was temporarily illuminated immediately preceding the onset of food, with no response contingencies having been programmed. Williams and Williams (1969) found that this behavior was maintained even when the key pecking eliminated the presentation of food for that trial. It should be noted that with respect to the Williams and Williams procedure, responding which eliminates the possibility of food presentation can in no way be reinforced by food presentation.

Additional Findings

The present results suggest that a least effort analysis of the preference is not appropriate. The present findings also indicate that choice in general is not necessarily determined by least effort as measured by relative number of pecks. There was frequent choice of the sequence which generated the greater amount of responding during the interval. The choice and ratio measures therefore appear inconsistent with this frequently proposed interpretation of the possible determinants of observing behavior (Steiner, 1967; Baum, 1973). Baum suggested that observing behavior may be maintained because it decreased the amount of non-reinforced behavior, and therefore lowered the overall response cost.

Longer pauses often occurred preceding the initiation of the sequence chosen most often. This finding supports the contention that pause and choice are not necessarily equivalent measures (Skinner, 1950). The pauses were not differentially related to the stimulus sequence either however. If pause and choice are considered as alternative measures of preference or reinforcing effectiveness, the pause measure adds additional support to the present choice finding that timing information is not sufficient to establish conditioned reinforcing effectiveness.

Wyckoff (1959) had suggested that conditioned reinforcing effectiveness was related to "cue strength". Cue strength was presumably related to the ability of the stimulus to either control a differential distribution, differential rate, or differential pause. The present data indicate that none of these measures reliably predict differential reinforcing effectiveness of a stimulus.

Theoretical Implications

Hendry's Information Hypothesis

There are two alternatives for accounting for the present findings within Hendry's information hypothesis. First, "timing information" may be used in the more restrictive sense of being a necessary but not a sufficient condition for conditioned reinforcement. This would imply that although timing stimuli are not necessarily reinforcing relative to a situation which is not explicitly timed (such as the present findings); it could still be argued that all conditioned reinforcers are reinforcing because they provide temporal information. Secondly, it could be argued that only the first stimulus in the sequence was in the appropriate position to reinforce the choice response. Subsequent stimuli, although conditioned reinforcers by virtue of being temporally informative, may not have affected choice because they were separated from the choice response by a delay.

Neither of these interpretations could adequately handle the finding that the single stimulus was preferred in an FI 120 second schedule. In terms of the immediate consequence of the choice response, there would be no reason to predict beforehand that the first of six twenty second stimuli had less informative value than the initial portion of the single stimulus. If timing information were a necessary condition for conditioned reinforcement, it would have to be proposed that in some cases a single stimulus contains more timing information than a six stimulus sequence or that other factors easily override the effectiveness of the temporal information. In either case such a hypothesis would be difficult to utilize.

Weyant (1957), Killeen (1971), Duncan and Fantino (1972) and Schneider (1972) utilizing choice designs; and Hendry (1965), Palya (1968) and Kendall (1972) utilizing concurrent designs have presented data from situations somewhat similar to the present procedures. These findings could be taken as critical of a proposal which suggests a reinforcing effec[illegible]f timing stimuli. Neuringer (1969) has even suggested that the second link of a concurrent chains procedure is established as a reinforcer primarily on the basis of the overall time to primary reinforcement and is not affected by even procedural modifications.

Additional findings (Ayres, 1966; Seligman, 1966; Thomas, Berman, Serednesky and Lyons, 1968; Scheuer and Keeter, 1969; Rescorla, 1972) have been presented from designs similar to Egger and Miller's (1962, 1963) original procedure. These results do not support the notion that conditioned reinforcers are the result of temporal priority. A review of the literature does not seem to provide equal substantiation for the notion that timing stimuli are reinforcing. The primary advocates seem to be only Hendry and Dillow (1966).

General Contiguity Hypotheses

Although the present study did not assess various contiguity hypotheses, the data may be interpreted within a framework of that type.

Contiguity interpretations could emphasize a direct primary reinforcement mechanism or alternatively a frequency of reinforcement mechanism.

Originally, the contiguity position emphasized close temporal pairing of the response and the reinforcer to account for the effect of reinforcement. However, behavior could also be maintained in situations in which the occurrence of the reinforcer did not immediately follow the effective response. Mechanisms were therefore postulated to account for the reinforcer functioning with a delay interval. Hull (1932) proposed that reward was maximally effective on responses which immediately preceded it, but was also capable of directly reinforcing earlier responses to a lesser extent. Dews (1970) and Perkins (1968) have recently advanced somewhat similar notions.

According to this type of approach the choice behavior of the present experiment could have been maintained directly by primary reinforcement. The alternative choice responses would have been equally reinforcing in that they were followed with a reinforcer following equal delays. This approach could be invoked to account for the absence of preference in the present design, however it would have difficulty accounting for the obtained preference for the single stimulus sequence.

An alternative contiguity approach, and one which is more consistent with a broader range of findings, suggests that conditioned reinforcing effectiveness is related to the frequency of reinforcement associated with that stimulus. This hypothesis has been substantiated using numerous procedures such as chain (Kelleher and Gollub, 1962) and second order (Kelleher, 1966) schedules. This approach could suggest that the sequences were equally positive in that the overall frequency of reinforcement was the same in both of the available timing intervals. This overall frequency of reinforcement position could draw additional support from studies utilizing concurrent chains designs. Schneider (1972) assessed preference for various two component chain schedules and found no preference as long as the overall reinforcement densities remained equal. Neuringer (1969) found relatively equal preferences for temporally equal interval schedules even when those intervals contained different response contingencies.

The equal overall frequency of reinforcement could be advanced to account for the lack of preference in the present experiment. However, like the direct primary reinforcement approach this position would have difficulty accounting for the obtained preference for the single stimulus interval. An alternative frequency of reinforcement interpretation which could account for a preference for the single stimulus would emphasize the reinforcement frequency of the stimulus which immediately followed the choice response.

An analysis of this type is supported by the data presented by Kendall (1972). He found that withholding the availability of the final stimulus in an optionally timed fixed interval schedule decreased timing behavior, while unavailability of the initial stimuli did not substantially decrease timing behavior. This data indicated that the possibility of obtaining the final stimulus was primarily responsible for maintaining the timing behavior.

In both Kendall's (1972) and Hendry and Dillow's (1966) procedure the stimulus most closely associated with food presentation could occasionally follow and therefore directly reinforce the observing response. In the present study the pigeons had an option of initiating the interval with one of two timing sequences. Once initiated the interval and sequence remained in effect until food presentation. The particular stimulus which invariably followed a choice response was correlated with maximum separation from food presentation except in the case of a choice of the single stimulus sequence. This sequence provided a stimulus which was also in effect immediately preceding food presentation.

An explanation based on these factors would suggest that the choice was typically between two stimuli which were not [illegible]sociated with food and were therefore both functionally negative and equal (Ferster and Skinner, 1957; Segal, 1962). The case in which the single stimulus was chosen over the six stimulus sequence could be taken as evidence for this position. This interpretation, would have difficulty accounting for the lack of preference for the single stimulus in the fixed time schedules and the relatively small degree of preference in the fixed interval schedule however, in that the choice was between a positive and a negative stimulus in those cases.

The obtained results are not entirely compatible with either the direct primary reinforcement or the frequency of reinforcement explanations. Consistency of the present findings with those contiguity mechanisms could be established by either of two approaches.

One approach would question the results obtained in Condition A, which compared the reinforcing effectiveness of a single stimulus and a six stimulus sequence. Preference for the single stimulus sequence in the fixed interval phase could in some way be aberrant. Support for this notion could be obtained by contrasting that single obtained preference with the lack of preference under a wide variety of alternative procedures in the present experiment. This analysis would assume that it is not meaningful to consider the six stimlus versus single stimulus procedure as different than any of the other sequence comparisons.

Alternatively, the absence of preference for the single stimulus in the fixed time phases of Condition A could be questioned. Support for this notion could be obtained by pointing out that two of four birds preferred the single stimulus sequence in the 120 second fixed time phase.

Corroborative evidence for the present findings however, suggests that the single stimulus preference was not aberrant. Duncan and Fantino (1972) presented data which indicated a preference for a fixed interval schedule with a single stimulus over an equivalent two stimulus chain FI FI schedule. Both the fixed interval and the chain schedule had equal programmed reinforcement densities. They also found an increased preference when longer overall intervals were used. Hershiser and Trapold (1972) also utilized alternatives with equal reinforcement frequencies. They found a preference for a stimulus directly associated with food presentation over a situation which provided a signal which was different than the stimulus preceding food presentation.

The alternative approach for integrating the obtained results with a contiguity analysis would suggest that both frequency mechanisms interact in some way to produce the results of the single stimulus condition or that an additional factor is responsible for that effect. It could be pointed out that the preference was obtained during the fixed interval phase. During that phase the single stimulus was a discriminative stimulus and its relatively greater reinforcing effectiveness could be due to its discriminative properties alone (Keller and Schoenfeld, 1960). It is also possible that requiring a key peck at the end of the interval ensured that exposure to the single stimulus was more closely and consistently paired with primary reinforcement.

Although the contiguity approach fares much better than the information approach in providing an explanation for the results of the present investigation, it has not proven to be a necessarily more testable mechanism (Herrnstein, 1969) nor as a necessarily more predictive framework (Egger and Miller, 1962, 1963; Baum, 1973). All in all both existing theoretical hypotheses (i.e., contiguity and information) for the empirical process of conditioned reinforcement appear to lack necessary predictive power.

Theoretical Insufficiency

A strict interpretation of a contiguity or pairing hypothesis would suggest that the efficacy of the pairing operation was determined by the temporal separation of the stimuli. This is not the case however. The magnitude of the effect from a strictly simultaneous, forward, or backward Pavlovian procedure is not ordered in terms of temporal separation. Typically the CS must precede the UCS. In addition, results have been obtained from both operant (Hendry and Coulbourn, 1967) and Pavlovian (Seligman, 1966) procedures which indicate that a stimulus need not be directly contiguous with a primary reinforcer to establish it as a conditioned reinforcer or as a conditioned stimulus.

A simple contiguity notion would also suggest that a continuously presented stimulus would become a conditioned reinforcer or conditioned stimulus. This is not the case (Terrace, 1966; Rescorla, 1968). A simple contiguity approach is not adequate to account for these findings. They do suggest an analysis in terms of some informational construct however, in that to be effective the stimulus must precede and be associated with an increased probability of the primary reinforcer.

Information theory suggests that information is determined by the degree of contingency of one event on another, and that a negative prediction is equivalent to a positive prediction in terms of information. It also suggests that additional or subsequent stimuli which are equally correlated with the previously predicted event do not provide information or are redundant. Obtained data cannot be explained in terms of simple information as such, however. Alternative informative stimuli do not have the same reinforcing effectiveness (Bower, McLean and Meacham, 1966; Dinsmoor, Flint, Smith and Viemeister, 1969; Kendall, 1973b) and redundant stimuli can be reinforcing (Hendry, 1969c; Kendall, 1973a).

The predictions generated by the strictly formal interpretations of contiguity and information are distinct but unfortunately neither are completely supported by the data. Intuitive notions of information and contiguity are equally distinct but also equally strained when compared to the available data. A reliable conditioned reinforcing effect can occur with a stimulus in the signaled absence of primary reinforcement. It is difficult to see how the stimulus in that case would provide relevant information. This effect has been demonstrated in procedures such as maintained conditioned reinforcement designs and in higher order Pavlovian conditioning. Alternatively, behavior can be maintained without any contiguous explicit stimulus changes, most notably in unsignaled avoidance procedures. It is obvious therefore that qualifications must be added to either position in order to account for the available data.

Various positions have been advanced. Bloomfield (1972) has proposed a mechanism based entirely on information, while Rescorla (1972) has advanced a basic contiguity position. Schuster (1969) suggested a strictly functional atheoretical perspective, whereas Bolles (1972) has advocated an entirely different theoretical structure.

It is difficult to assess at this point a clear undisputed differentiating issue separating information and contiguity which would lead to an experiment verifying all varieties of one position and refuting all possibilities of the other. At present neither the formal nor the intuitive predictions of the contiguity and information approach are sufficient to account for the currently available data. Considering the complex effects as well as the negligible effects information can have on behavior, it may be more appropriate to establish a much broader and systematic data base before hypotheses are advanced.

Conclusions

Two conclusions seem warranted from the present investigation of the reinforcing effectiveness of timing stimuli.

1. Timing information (in terms of procedurally correlated stimuli; procedurally correlated stimuli which control different behaviors; or procedurally correlated stimuli which control differential behaviors and set the occasion for a specific required operant) is not a sufficient property to establish that stimulus sequence as a differential conditioned reinforcer.
2. Timing information has a dominant effect on behavior occurring in its presence and appears to be capable of reliably and systematically controlling complex behaviors such as key pecking in both fixed time and fixed interval schedules.

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GLOSSARY

Autoshaping. A procedure which correlates a stimulus with a primary event; usually a visual stimulus, grain presentation, and with pigeons. This typically results in responding directed at the stimulus.

Adventitious. Not programmed, accidental, seemingly causal.

Choice Response. A response which enables one of a set of mutually exclusive events.

Clock Stimuli. Stimuli which have a fixed temporal relationship with the occurrence of some event, usually the reinforcer.

Component. A unit of a complex schedule, usually a schedule itself.

Concurrent Schedules. Schedules of reinforcement which are in effect simultaneously. The requirement for both schedules cannot be met by the same response.

Condition. The set of procedures which utilized the same stimulus sequences and the same birds.

Conditioned Reinforcer. A stimulus which functions as a reinforcer only after some specific training history.

Contiguity Hypothesis. A term used to group conditioned reinforcement theories which explain the reinforcing properties of the observing stimuli or timing stimuli as a result of stimulus-reinforcer "pairings". This approach implements simple conditioning procedures and stresses the reinforcing effects of the positive or most favorable stimulus.

Contingency. Causal dependency, such as if X then Y; where X is typically a response or some temporal delay and Y is frequently food presentation.

Discriminative Stimulus. 1. A schedule correlated stimulus which sets the occasion for the reinforcement of an explicit response. 2. A stimulus which is consistently related with a schedule of reinforcement.

Effective Response. A response which could satisfy the primary reinforcement contingency.

Fixed Interval (FI) Schedule. A schedule which specifies that the first response following the elapse of a fixed interval is followed by the reinforcer.

Fixed Time (FT) Schedule. A schedule which specifies that the "reinforcer" (e.g. food presentation) follows the elapse of a fixed time regardless of behavior occurring in the interval.

Information. Value of a stimulus which reliably and selectively precedes a schedule of events, especially food presentations. A stimulus is said to be informative if its occurrence enables a better prediction of a subsequent event.

Information Hypothesis. A term used to group conditioned reinforcement theories which stress the predictive relationship of the stimulus to the primary event to account for the reinforcing effectiveness of both the negative and positive stimuli.

Observing Response. A response which may be followed with a stimulus which is correlated with some property of the schedule in effect and which cannot differentially satisfy the primary reinforcement contingency.

Preparatory Response. A response which modifies the effects of the reinforcer.

Reinforcement. A stimulus change which is followed by an increase in the probability of the response class which immediately preceded its occurrence.

Session. One continuous exposure to the experimental procedures, usually fifty reinforcements.

Stimulus Control. The covariance of an antecedent stimulus property and a subsequent response property.

Stimulus Sequence. The order of the stimulus units in a particular trial stimulus, such as six seconds of red followed by six seconds of green.

Superstitious. A term applied to a behavior which is maintained by adventitious reinforcement.

Timing Stimuli. Stimuli which have a fixed temporal relationship with the occurrence of some event, usually the reinforcer.

Uncertainty. A postulated drive state generated in situations in which two or more mutually exclusive behaviors are appropriate.