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Pigeons were exposed to second-order schedules in which completion of a component fixed-interval schedule was reinforced according to a variable-ratio schedule. The completion of each component FI resulted in presentation of either a brief stimulus previously paired with food (paired brief stimulus), a brief stimulus not previously paired with food (unpaired brief stimulus), or no brief stimulus presentation (tandem). Three fixed-interval durations were employed in the study, with all birds exposed to the different durations in an ascending order (FI 15-sec, FI 30-sec, FI 1-min).

The results demonstrated both similarities and differences in effects produced by the paired and unpaired brief stimuli. The pause following a brief stimulus, whether paired or unpaired, increased as the component FI duration increased. However, for a particular FI duration, the longest pauses always followed the paired brief stimulus. The results are consistent with the suggestion that the brief stimulus functions as a discriminative stimulus, with the pairing operation serving to enhance the discriminative properties of the brief stimulus.

SECOND-ORDER SCHEDULES: A COMPARISON OF THE EFFECTS OF PAIRED AND UNPAIRED BRIEF STIMULI ON COMPONENT FIXED INTERVAL PERFORMANCE

by

William Irvin Witty

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Thesis Adviser

APPROVAL PAGE

This thesis has been approved by the following committee of the Faculty of the Graduate School at The University of North Carolina at Greensboro.

Thesis Adviser Richard L. Shull

Committee Members Aaron J. Brownstein

John M Pratt

May 7, 1974

Date of Acceptance by Committee

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CHAPTER I

INTRODUCTION

A conditioned reinforcer is a stimulus event that has acquired the ability to function in a manner similar to that of primary reinforcers. When presented according to some schedule the rates of responding and patterns of behavior are similar to those which occur when primary reinforcers terminate the schedule. Its effectiveness is dependent upon an experimental history of exposure to that stimulus and as such is a learned reinforcer, as opposed to a primary reinforcer.

The study of conditioned reinforcement has focused on the necessary and sufficient conditions for establishing a stimulus event as a conditioned reinforcer. Several experimental designs have been used and these have been discussed together with attendant difficulties by Kelleher and Gollub (1962). A recent research trend has involved the use of second-order schedules. These schedules overcome many of the problems discussed by Kelleher and Gollub (1962), and allow for the study of conditioned reinforcing effects over prolonged periods of time.

A second-order schedule has been defined as one in which the behavior specified by a schedule contingency is treated as a unitary response that is itself reinforced according to some schedule of reinforcement (Kelleher, 1966b). Second-order schedules may be broadly classified into two categories, depending upon the stimulus conditions employed to terminate the component schedule. These two procedures are chaining and brief stimulus procedures (Marr, 1969).

In chaining procedures primary reinforcement terminates a sequence of component schedules in which each component schedule is associated with a different exteroceptive stimulus. In brief stimulus procedures a brief stimulus is presented under a schedule and the behavior engendered by this schedule is treated as a unitary response that is reinforced according to some schedule of reinforcement. The brief stimuli terminating each component may, or may not, be temporally paired with primary reinforcement and responses in its presence have no programmed consequences (Marr, 1969). As an example, a FR 10 (FI 2:S) schedule of reinforcement specifies that primary reinforcement is available upon the completion of the tenth fixed interval (FI) component. At the completion of each component interval a response produces a brief stimulus that signals the completion of that component schedule. Thus, the completion of the tenth FI component will result in presentation of primary reinforcement.

In the brief stimulus procedures a paired stimulus is one that has been temporally associated with primary reinforcement, preceding by 0.5-sec to 1.0-sec and often accompanying primary reinforcement. An unpaired brief stimulus is one that has not been explicitly paired with primary reinforcement. It is separated from primary reinforcement by at least one component of the schedule. Studies of the function of brief stimuli usually employ unpaired stimuli as a control against which to measure the effects of paired stimuli. Because the explicit pairing is the only difference between the counter-balanced stimuli, any differences in behavior can be attributed to the effects of pairing.

A consistent research finding in the study of the function of brief stimuli is that paired stimuli produce patterns of responding similar to those that occur when food terminates the schedule while the result from the use of unpaired brief stimuli have been more inconsistent. Since the explicit pairing is the only difference between the two conditions, it has been proposed that pairing is a sufficient condition for producing a conditioned reinforcer (Kelleher and Gollub, 1962). This pairing proposal will subsequently be referred to as the temporal contiguity hypothesis. Presumably, the close temporal association functions to imbue the brief stimulus with properties similar to those of primary reinforcement through a classical conditioning process. Several studies have been performed which purport to demonstrate that pairing is sufficient to produce a conditioned reinforcer.

Kelleher (1966a) compared the effects of paired and unpaired brief stimuli on the rates and patterns of responding. The schedule used was a FR 15 (FI 4:S). In the paired condition each FI component was terminated by a 0.7-sec change in key color from blue to white. The last component terminated with a key-color change to white followed by primary reinforcement. In the unpaired condition each FI component, except the last, was terminated by a key-color change from blue to red for 0.7 sec. Termination of the last FI component resulted in the immediate presentation of primary reinforcement. A second unpaired condition was studied in which the response key was completely darkened for 0.7 sec. The pigeons were exposed to the paired condition for a total of 124 sessions. Preceding the last 56 sessions of the paired condition the birds were exposed to the unpaired condition in which the unpaired brief stimulus was the darkened key. This condition remained in effect for seven sessions. After the last 56 sessions of the paired condition the birds were exposed to the unpaired condition in which the brief stimulus was a change in key-color to red. This condition remained in effect for 17 sessions.

In those components terminated by a paired brief stimulus accelerated patterns of responding developed. In those components terminated by a darkened key (unpaired condition) low, constant rates of responding occurred.

When the unpaired brief stimulus was a red key-light, however, an accelerated pattern of responding developed for all birds. For two birds the rates of responding in the last half of each FI component in this condition were lower than in the paired condition, but the accelerated pattern was evident. For one bird, #128, there were no differences in performance between the paired and unpaired conditions, when the unpaired brief stimulus was a change in key-color to red.

Byrd and Marr (1969) examined, in two studies, the rates and patterns of responding engendered by second-order schedules using either paired, unpaired, or no brief stimuli (tandem). In the tandem control schedule there were no brief stimulus presentations and the same exteroceptive stimulus was associated with each component of the schedule. The paired brief stimulus was a 1-sec presentation of the food-hopper light. The unpaired brief stimulus was a 1-sec change in key-color from blue to red. Pigeons were exposed to the paired condition for 12 sessions, to the unpaired condition for 13 sessions, and to the tandem control for 27 sessions.

When the paired brief stimulus terminated components of the schedule, response rates were positively accelerated within individual FI components. When the unpaired brief stimulus terminated FI components, response rates tended to be more constant throughout each individual FI component.

However, one bird, P-33, did show occasional scalloped patterns of responding. Scalloped patterns did not develop in the tandem control. The tandem schedule produced the highest response rates while the paired condition produced the lowest. The unpaired condition produced rates intermediate to the two.

In their discussion of the results, Byrd and Marr conclude that the presentation of the paired brief stimulus was the event that maintained patterns of positively accelerated responding. This conclusion was based on the infrequent observation of scalloped patterns when unpaired brief stimuli terminated component FI schedules, or when there was no brief stimulus presentation.

De Lorge (1967) also compared the effects of paired and unpaired brief stimuli when FI schedules were used as component schedules. His schedule was a FI 18 (FI 3:2). The paired brief stimulus was 0.5-sec change in key-color from red to yellow. The unpaired brief stimulus was a 0.5-sec change in key-color from red to green. The single pigeon used in this study was exposed to the paired condition for 24 sessions and to the unpaired condition for 11 sessions. When a paired brief stimulus terminated components of the schedule, positively accelerated patterns of responding developed in most of the FI components. When an unpaired brief stimulus terminated FI components the accelerated pattern of responding was still frequently observed. The main difference between the two conditions was the effect on response rate. The paired condition produced higher response rates than did the unpaired conditions, and produced shorter pauses after primary reinforcement.

De Lorge (1967) also exposed the pigeon to an unpaired brief stimulus that had previously been paired with primary reinforcement. The unpaired stimulus was a change in key-color from red to yellow for 0.5 sec and accompanied each FI component except the component resulting in food presentation. When food was presented the red key-light remained on during food presentation. This condition followed the condition in which the yellow key-light was a paired stimulus. During this condition the accelerated patterns of responding were rarely observed in individual FI components. De Lorge reports that the yellow key-light continued to have some effect because short pauses did occur after presentation of the yellow light. The effect on responding was to decrease the rate relative to the paired condition.

These studies are often cited as evidence to support the suggestion that pairing is sufficient to generate a conditioned reinforcer. It is apparent from the results that the pairing produced patterns of responding similar to those which occur when food terminates a schedule. But when the differences in response patterns are attributed to the pairing, difficulties are encountered. Left unexplained is the occasional, and sometimes frequent, occurrence of accelerated patterns of responding in components terminated by unpaired stimuli. If the temporal contiguity hypothesis is to explain these discrepant results, then pairing must be viewed as occurring along either a temporal dimension that spans the FI component duration, or perhaps pairing occurs along some dimension of the brief stimuli employed (e.g., duration, color). The former assumption would be difficult to reconcile with the existing literature (Bersh, 1950; Jenkins, 1951) considering the FI component durations used in the above cited studies. This suggests that some other factor is responsible for producing the accelerated patterns of responding occasionally seen when unpaired stimuli terminate component performance.

It may well be that pairing functions to imbue the brief stimulus with properties of primary reinforcement, properties not shared by the unpaired stimulus. But the question remains as to the nature of these properties. Stimuli may have several functions in addition to a reinforcing function, and these other functions may be responsible for the differences in results between paired and unpaired stimuli. The conditioned reinforcement interpretation maintains that the paired brief stimulus is a reinforcing stimulus, but as mentioned, the temporal contiguity hypothesis can not easily account for the occasional observation of accelerated patterns in components terminated by unpaired brief stimuli. It seems likely that the brief stimulus serves a function other than that of a conditioned reinforcer when FI schedules are used as component schedules in a second-order schedule. It is suggested that this alternative function is that of a discriminative stimulus.

Stubbs (1971) in a series of studies concluded that a discriminative interpretation was more consistent with his research findings than was a conditioned reinforcing interpretation. In one study he compared the effects of paired and unpaired brief stimuli in a second-order schedule. The component schedule in this study was either a FI 40-sec or a FI 60-sec schedule maintained by either a VI 360-sec or FI 600-sec schedule. Stubbs found that there were no systematic differences between the effects produced by the paired and unpaired brief stimuli. That is, appropriate FI patterns of responding developed in individual FI components under both the paired and unpaired conditions. In subsequent studies (1971) Stubbs concluded that the number and type of brief stimuli might well influence the results when comparing the effects of paired and unpaired brief stimuli, and that the same stimulus event must be used in the comparison. Furthermore, his results showed that appropriate FI patterns of responding was not the result of response-produced brief stimuli since response-independent presentations also resulted in appropriate FI patterning, and that FI patterns of responding did not develop when there was no systematic temporal relationship between the brief stimulus and food presentations.

The Stubbs (1971) study is the only direct evidence which suggests the functional similarity of paired and unpaired brief stimuli. However, Stubbs relied on responding in quarters of the component FI as the dependent measure for equating the function of the brief stimuli and did not determine if there were systematic differences between the duration of the pauses following a brief stimulus presentation, or if his results were restricted to the particular FI values used as component schedules.

The Stubbs (1971) study suggests that the brief stimuli function as discriminative stimuli which produce periods of no-responding. Additional evidence to support this contention comes from the studies previously discussed, from a consideration of the factors responsible for generating accelerated patterns of responding on FI schedules maintained by primary reinforcement, from the work of Staddon and Innis (1969) and from studies of percentage reinforcement schedules.

When FI schedules are used as component schedules it is assumed that the factors producing the pause-respond patterns of behavior, when they occur, are the same as those which operate to produce pause-respond patterns when food terminates a FI. Dews (1970) has made clear that the essential feature of FI schedules in producing pause-respond patterns is the constant interval of time between the onset of the discriminative stimulus associated with the schedule and the presentation of the next reinforcement. Food on FI functions to insure behavior, but it also functions as a discriminative event, as evidenced by the pause following food presentation (Staddon, 1970).

The constant interval of time between schedule onset and termination by food and the discriminative effects of food seem to account for the pause-respond patterns of behavior on FI schedules. When FI schedules are used as component schedules in brief stimulus procedures the occurrence of pause-respond patterns of behavior is attributed to the reinforcing effects of the brief stimulus. Nevertheless, the pause following the brief stimulus, like the pause following food on FI, would appear to result from the discriminative effects of the brief stimulus rather than a reinforcing effect. Evidence to support this comes from studies in which food on FI is replaced by a blackout.

Ferster and Skinner (1957) studied performance on FI schedules when food was intermittently replaced by a blackout. Initially, the presentation of the blackout had no effect on performance except to eliminate responding during the blackout period. Responding began immediately after termination of the blackout. With a longer duration of the blackout, however, a pause developed with a subsequent return to a high rate of responding. It is important to note that the blackout replaced rather than preceded food.

Staddon and Innis (1969) studied the effects of reinforcement omission on FI schedules. Their experimental variable was the occasional omission of food upon completion of a FI component. When food was omitted a blackout of equal duration to primary reinforcement was presented (3.2 sec). Their schedule was effectively a VR 1.5 (FI 2). They found that omission of primary reinforcement initially produced "running through" behavior in the following component. That is, pigeons began responding immediately after termination of the blackout and continued to do so until the next reinforcement, which always followed the omission condition. However, with continued exposure to the schedule a post-blackout pause did develop (personal communication) and response rates in the component following the omission condition were suppressed when compared to rates in the preceding component. Furthermore, as the blackout duration was increased from 3.2 sec up to 32 sec the pause after the blackout also increased such that at 32 sec the pause nearly equalled the post-food pause.

Staddon (1972) also reports that when birds are responding on a VI 2-min schedule for food, the presentation of a brief stimulus, followed by a FI 2-min schedule, will produce a pause and an accelerated pattern of responding. In this procedure the key-color was the same in the VI and FI schedules. The brief stimulus was the presentation of three vertical white bars upon a dark response key. Staddon also reports that he obtained the same results when a variety of brief stimuli were used to signal the beginning of the FI 2-min schedule.

These three studies demonstrate that when food is replaced on FI by a blackout, a pause after the blackout, or other brief stimulus, develops, followed by an accelerated pattern of responding. It is possible that the blackout was functioning as a paired brief stimulus in the Ferster and Skinner (1957) and Staddon and Innis (1969) studies because there were similarities between the blackout and the stimulus conditions prevailing at the moment of reinforcement. Nevertheless, the important point is that accelerated patterns of responding may occur under conditions where a reinforcing stimulus can not be identified. This point is more clearly made by Neuringer and Chung (1967) and without the possible confounding of stimulus conditions.

Neuringer and Chung (1967) studied performance under a percentage reinforcement schedule. On this schedule reinforcement is presented only a percentage of the time. At other times some stimulus event replaces food on the schedule. These investigators programmed food to occur on a VI 1-min schedule and then superimposed response-initiated FI 5-sec components onto the VI 1-min schedule. Food was presented on the average of once every minute and always occurred upon the completion of a FI 5-sec component.

If reinforcement had been set up by the VI programmer the completion of a FI 5-sec component resulted in food presentation; otherwise a blackout was presented in lieu of reinforcement.

Neuringer and Chung found that pause-respond patterns of behavior developed in individual FI components of the schedule and that the patterns were similar to those maintained by food. However, there were certain similarities between the blackout and reinforcement, e.g., all lights were off. To control for the similarity of conditions prevailing at the moment of reinforcement, the brief stimulus was changed to a tone while all lights remained on, and subsequently to a darkening of the response key while only the houselight remained on. The pause-respond patterns remained unchanged. After a series of manipulations they determined that the brief stimuli terminating individual components could become a "quasi reinforcer" if the stimulus is presented on a schedule that also produces primary reinforcement. In another study, Chung and Neuringer (1967) employing the same procedure, determined that the pause-respond patterns remained intact but that the pause after the brief stimulus lengthened in a linear manner as the FI component value was increased in steps from 1 to 30 seconds.

The evidence presented suggests that a stimulus event never explicitly paired with primary reinforcement may come to function similarly to a paired brief stimulus. If this is true then there exists some reason why unpaired brief stimuli did not function as well as paired brief stimuli in the Byrd and Marr (1969) and in the De Lorge (1967) study. If pairing is the critical event then it is not surprising that unpaired brief stimuli fail to produce pause-respond patterns in individual FI components. If, however, the brief stimulus functions as a discriminative stimulus, then it would be expected that pause-respond patterns would also occur in components terminated by the unpaired stimuli. Just why there are differences in patterns of responding obtained by paired and unpaired stimuli will be considered later in the present paper. It may well be that pairing is necessary at some FI values, or that pairing serves to make a stimulus event more salient, a quality likely to be obtained by increasing the brief stimulus duration (see Staddon & Innis, 1969).

The hypothesis that pairing of a stimulus event with primary reinforcement will generate a conditioned reinforcer is not applicable to the results obtained with unpaired stimuli, nor to the results obtained by Neuringer and Chung (1967), Staddon and Innis (1969), and Ferster and Skinner (1957) unless the parameters of temporal association are much larger than currently believed. It has been shown that the further removed a stimulus event is from primary reinforcement the less effective it is as a conditioned reinforcer (Jenkins, 1950; Bersh, 1951), and that maximum conditioned reinforcing effects result when the temporal association is either 0.5 sec or 1.0 sec, with sharp decreases in effectiveness after two seconds as measured by the number of responses emitted (Bersh, 1951). It is to be noted however that even when separated from primary reinforcement by ten seconds, the conditioned reinforcer maintained substantial amounts of behavior.

The results of the previous studies (Neuringer & Chung, 1967; Byrd & Marr, 1969) parallel the results of the Jenkins (1950) and Bersh (1951) results because they show that the further removed the brief stimulus is from primary reinforcement the less control is exerted by its scheduled presentation. For example, in the Neuringer and Chung (1967) study, when short FI 5-sec components were superimposed on a VI 1-min schedule for food, pause-respond patterns of behavior developed in individual FI components of the schedule. But when Byrd and Marr (1969) used FI 2-min schedules as component schedules, the pause-respond patterns were only occasionally observed.

There are several reasons why previous studies have shown that unpaired brief stimuli fail to function in the same way as paired brief stimuli. First, previous studies have used different brief stimuli when comparing the effects of paired and unpaired brief stimuli. Stubbs (1971) has discussed this point at length and concludes that when the brief stimuli are more similar physically, the effects produced by paired and unpaired brief stimuli are also more similar. Stubbs suggested that a blackout might be ineffective as a brief stimulus and his results support this conclusion. However, Shull, Guilkey, and Witty (1972) have shown that a blackout is an effective stimulus event when ratio schedules are employed as component schedules and maintained by a FI. Ratio schedules may have unique properties (Marr, 1969) however, and whether a blackout would be an effective brief stimulus when FI schedules are used as component schedules remains unclear.

Another possible reason that unpaired brief stimuli have failed to function similarly to paired brief stimuli concerns the duration of exposure subjects had under the different schedule conditions. When FI schedules are used as component schedules the events responsible for generating pause-respond patterns must be considered. When FI schedules are studied in isolation it is characteristic of performance to change as a function of the duration of exposure to that schedule. Initially, responding occurs immediately upon termination of primary reinforcement, but with continued exposure to the schedule a pause-respond pattern develops (Ferster & Skinner, 1957) and with longer exposure a pattern described as "break and run" (rapid transition to a terminal rate of responding) develops (Schneider, 1969). These same stages of pattern development are also observed to occur when paired brief stimuli terminate component schedules.

Thus, the patterns of responding are a function of the history of exposure to the schedule (Cumming & Schoenfeld, 1959; Sherman, 1959). Considering the length of time necessary for response patterns to stabilize when food terminates a FI schedule it must be asked whether pigeons exposed to FI component schedules terminated by unpaired brief stimuli have been exposed to the conditions for a time sufficient for response patterns to stabilize or even develop.

The number of food presentations may also be important. For example, in the Kelleher (1966b) study, pigeons received 372 food presentations in the paired condition, but only 21 food presentations when the unpaired brief stimulus was a blackout, and 51 food presentations when the unpaired brief stimulus was a change in key-color to red. A similar result obtains from the De Lorge (1967) study. In his study the single pigeon received 600 food presentations in the paired condition, but only 275 in the unpaired condition.

Two studies exist in which the number of food presentations was almost equal in both the paired and unpaired conditions (Byrd & Marr, 1969; Stubbs, 1971). In the Byrd and Marr study pigeons received 156 food presentations in the paired condition and 144 in the unpaired condition. In the Stubbs study the pigeons received 500 food presentations in each condition.

Thus, the duration of exposure to the brief stimulus conditions and the duration of exposure to the schedule conditions are likely to influence the results. The duration of exposure to the paired and unpaired brief stimulus conditions and the component FI schedules in the Byrd and Marr (1969) and De Lorge (1967) studies probably would not have insured stability of performance on a FI schedule terminated by food.

Another reason why unpaired stimuli have failed to function as paired stimuli is that the results obtained in comparison studies are a function of the FI value used in the study. That is, different FI values may yield different results because the unpaired brief stimulus is further removed from primary reinforcement, or perhaps for some other reason. Those studies concerned with the effects produced by paired and unpaired stimuli have not compared results across different FI values. Studies have typically compared the effects at one FI value and it has been assumed that the results are representative of those that would obtain at any FI value.

The purpose of the present study is to compare the effects of paired and unpaired brief stimuli while insuring equal amounts of reinforcement in both conditions, and while insuring nearly equal exposure to the stimulus conditions. In addition, several FI values will be studied and different stimulus events will be employed as brief stimuli to determine if the same stimulus event must be used before comparable results obtain between paired and unpaired brief stimuli.

CHAPTER II

GENERAL METHOD

Subjects

Four adult white Carneaux pigeons were maintained at approximately 80% of their free feeding weight. All birds had extensive exposure to various schedules of reinforcement and most recently were exposed to a concurrent chains procedure.

Apparatus

The experimental chamber was a modified ice chest. A translucent plastic response key was located 8.5 inches above the floor. When the key was transilluminated a force exceeding 25 g applied to the key activated an electrical contact that operated control and recording circuits and produced a feedback click. Feedback clicks were not produced for responses made during any brief stimulus presentation. White masking noise was present during sessions and a fan, located in the rear of the chest, provided air circulation. Relay, control and recording equipment was located adjacent to the experimental chamber.

A 33-position stepper was used to designate specific FI components to end in reinforcement (only 30 positions were used). Upon completion of each FI component the stepper moved to the next position and designated positions provided reinforcement upon completion of the FI component so that on the average, every fifth position provided reinforcement. The points on the stepper were changed daily. Each session began with food following completion of the first FI component and the session ended with food presentation.

Procedure

All birds had previous experience on schedules of reinforcement so preliminary key-peck training was not necessary. Each daily session began with all lights off in the experimental chamber and terminated after thirty reinforcements. Reinforcement consisted of 6 seconds of access to mixed grain. Sessions were conducted seven days each week. Throughout this study the basic schedule employed was a fixed-interval schedule. A fixed-interval schedule specifies that reinforcement is available, contingent upon the emission of the first response, after the completion of a fixed time since some preceding event, usually the presentation of reinforcement.

Baseline: Standard FI schedule. Initially, all birds were exposed to a mult FI 15-sec FI 15-sec schedule, with the response unit a single key peck. That is, the first key peck after a fixed time had elapsed since the termination of the preceding reinforcement produced food.

Each component of the mult schedule was associated with a different exteroceptive stimulus, either a blue or red key light. The birds were exposed to only one component of the mult schedule on any given day and the components were alternated on successive days. Whenever a mult schedule was used in the present study, the components were alternated on successive days. After an initial baseline period of 40 days the schedule was changed to a second-order schedule.

To compare the effects of a brief stimulus that was paired with food to the effects of a brief stimulus never paired with food, a different brief stimulus was associated with each component of the mult schedule. In one component a 0.75-sec blackout (darkening of the response key) was programmed to occur upon the completion of each FI, including the interval terminated by food (paired condition). The blackout preceded food presentation and accompanied food. In the other component the brief stimulus was a 0.75-sec change in key color from red to white that was presented upon the completion of each FI component except the one designated to end in reinforcement (unpaired condition). The blackout was associated with the blue key color and the white brief stimulus with the red key color, except as noted below. The schedule associated with the paired brief stimulus will be denoted VR 5 ($FI_x:S^P$) and the unpaired brief stimulus as VR 5 ($FI_x:S^{UP}$).

Second-Order Schedules

After stabilization of behavior in the baseline condition the schedule was changed to a second-order schedule [mult VR 5 (FI_x:S) VR 5 (FI_x:S)]. The response unit was now the behavior that occurred in each FI component. That is, the behavior in a FI component was now treated as a unitary response that was reinforced according to a variable ratio schedule. The first key peck occurring after the fixed interval had elapsed produced a brief stimulus on the response key and started the next fixed interval. On the average one in every five FI components ended with food presentation. Three different fixed interval values were studied in an ascending order (FI 15-sec, FI 30-sec, and FI 1-min). Once behavior had stabilized the FI component value was changed to the next higher value. Table 1 presents a summary of the conditions in the order studied and the number of sessions for each condition.

The FI 30-sec component value [VR 5 (FI 30-sec:S)] was reinstated after the FI 1-min condition to determine the recoverability of performance.

Controls

To determine if there was an interaction between the components of the mult schedule, all birds were exposed to each component for 16 consecutive days. The schedule during this condition was VR 5 (FI 30-sec:S). The

TABLE 1

Summary of Experimental Conditions in Order of Presentation

Number of Sessions	Schedule Conditions	Brief Stimulus Paired w/Food
40	mult FI 15-sec FI 15-sec	---
75	mult VR 5 (FI 15-sec:S)	BO
58	mult VR 5 (FI 30-sec:S)	BO
68	mult VR 5 (FI 1-min:S)	BO
20	mult VR 5 (FI 30-sec:S) (first redetermination)	BO
20	mult [Tandem VR 5 (FI 30-sec)]	---
16	VR 5 (FI 30-sec:S)^{UP}	---
16	VR 5 (FI 30-sec:S)^{P}	BO
20	Reversal of Key Colors mult VR 5 (FI 30-sec:S)	BO
20	mult VR 5 (FI 30-sec:S) (2nd redetermination)	BO
30	VR 5 (FI 1-min:S)^{UP}	---
30	VR 5 (FI 1-min:S)^{P}	W

unpaired-stimulus component was studied first, then the paired-stimulus component. To determine if the exteroceptive stimulus conditions associated with each component of the schedule was exerting any effect on performance, the key colors associated with the components were reversed. That is, in the reversal condition the blue key color was associated with the unpaired component and the red key color with the paired component. The brief stimulus conditions remained unchanged. Following this condition the original stimulus conditions were reinstated. Throughout these manipulations the FI component schedule was FI 30-sec.

To determine if pausing after a brief stimulus presentation was due to the brief stimulus or simply a time between responses the schedule was next changed to a mult [Tandem VR 5 (FI 30-sec)]. That is, all brief stimulus presentations were omitted from both components of the mult schedule, and the completion of one fixed interval initiated the beginning of the next fixed interval.

To determine the effects on performance of pairing a previously unpaired brief stimulus and to control for the physical properties of the brief stimulus, the schedule was changed to a VR 5 (FI 1-min:S^{UP}) following the tandem condition. The brief stimulus employed in this condition remained the change in key color from red to white for 0.75 sec. Once behavior had stabilized, the white brief stimulus was paired with food presentation and the schedule denoted VR 5 (FI 1-min:S^P). That is, the white brief stimulus preceded food presentation by 0.75 sec and accompanied food.

Data Analysis

The effects of different manipulations were assessed by measuring the post-food pause and post-brief stimulus change pause, by calculating running response rates and total response rates, and by cumulative records.

The pause following either food or a brief stimulus was measured from offset of that stimulus event until the first response occurring in the following fixed interval. Average post-food pause durations were determined for each session by dividing the total pause time by the number of food presentations, except the last. Average post-brief stimulus change pause durations were determined by dividing the total pause time after a brief stimulus by the number of brief stimulus presentations. In the paired condition of the brief stimulus presentations preceding food were not used in determining average pause duration.

The running response rates were calculated by dividing the total number of responses by the total session time, minus pause time following either food or a brief stimulus. Total response rates were calculated by dividing the total number of responses by the total session time by total session time minus the post-food pause.

CHAPTER III

RESULTS

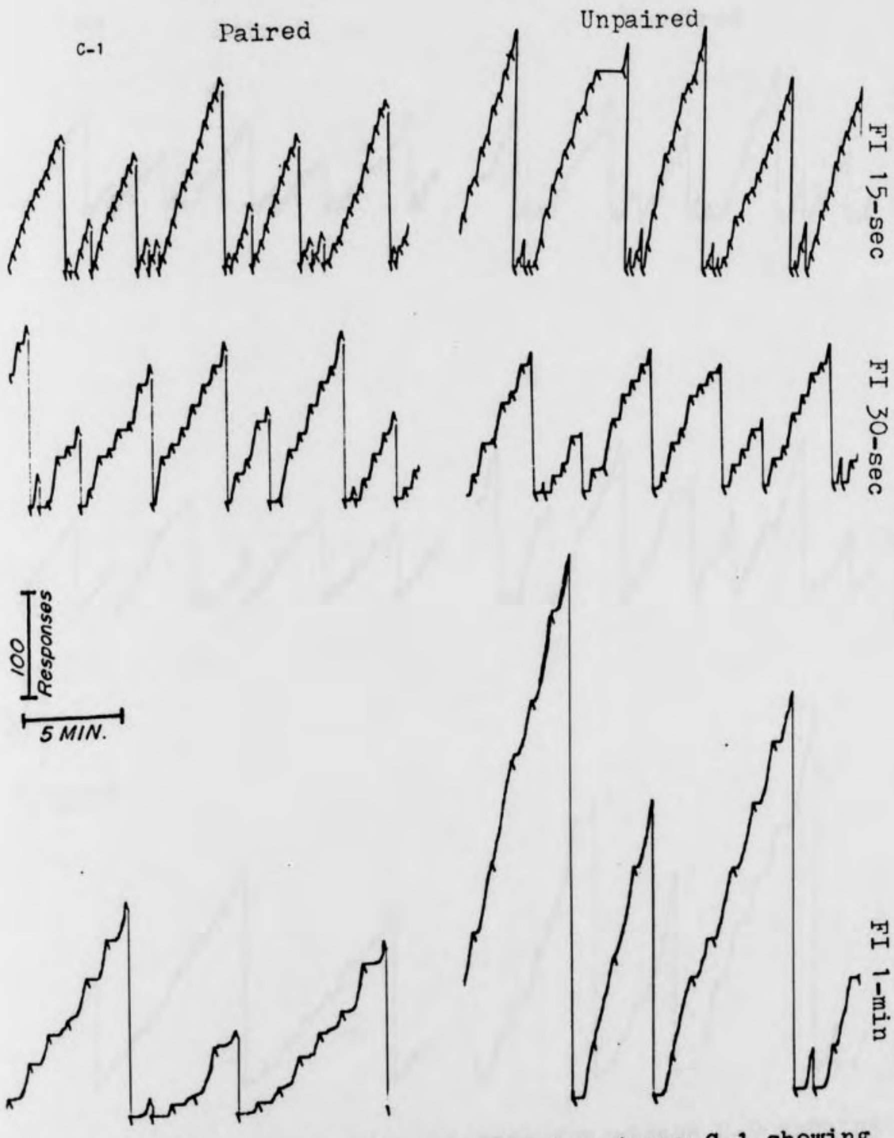
Cumulative Records

Fig. 1 presents representative cumulative records showing performance comparing the effects of the paired and unpaired brief stimuli for the three fixed-interval durations studied (Figs. 1, 1a, 1b, 1c), for the tandem condition (Fig. 1d) and for the last condition in which the previously unpaired brief stimulus was paired (Fig. 1e).

Figs. 1, 1a, 1b, and 1c show that presenting a brief stimulus upon completion of a FI component resulted in a pause-respond pattern of behavior. That is, a pause followed the brief stimulus and the pause was terminated by an accelerated rate of responding. The records also show that the pause length increased as the FI component value increased. This pause-respond pattern was evident in both the paired and unpaired conditions. A comparison of the cumulative records showing performance when component FI schedules were terminated by a brief stimulus with performance under the tandem schedule (Fig. 1d), where all brief stimulus presentations were omitted, shows that the brief stimulus presentations generated the pause-respond pattern of behavior within the FI components.

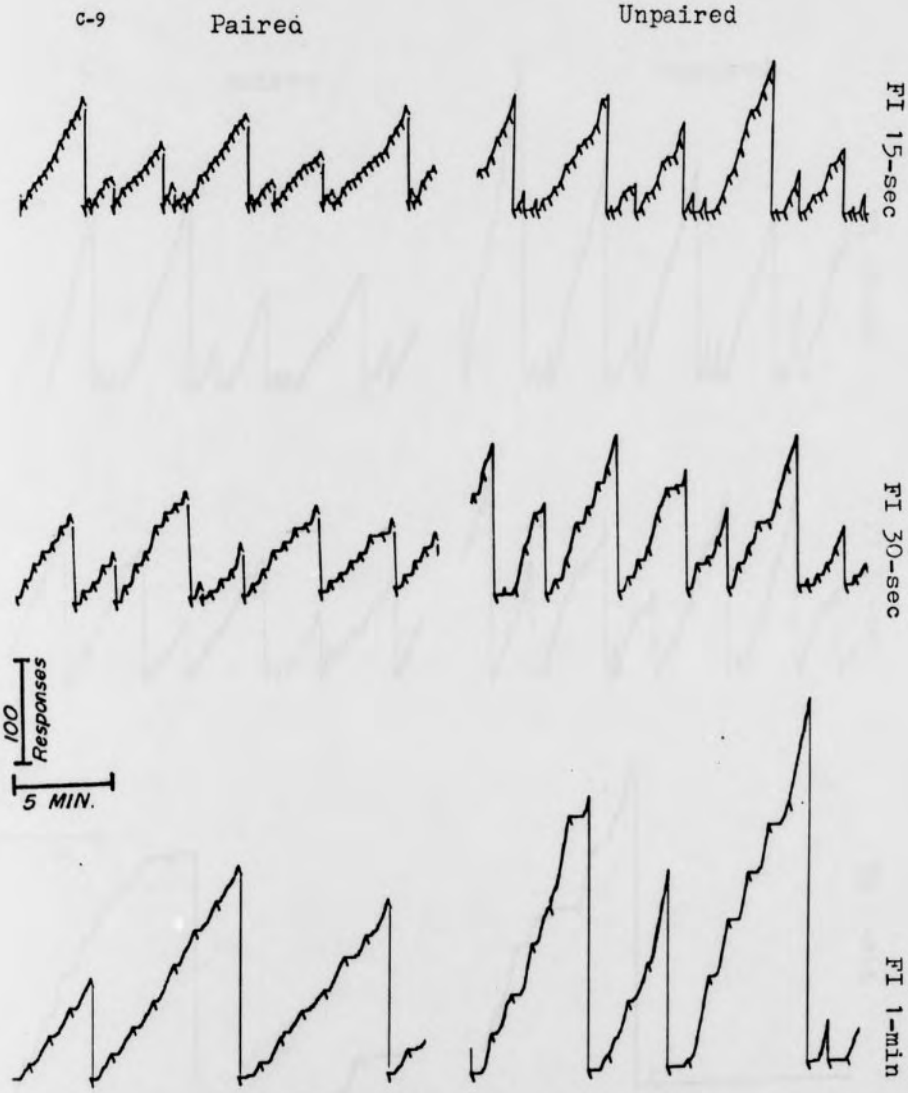
Occasionally, pauses did not follow a brief stimulus. This "running through" behavior was observed to occur more often in the unpaired component of the mult schedule, or whenever an unpaired brief stimulus was used. This behavior

Fig 1



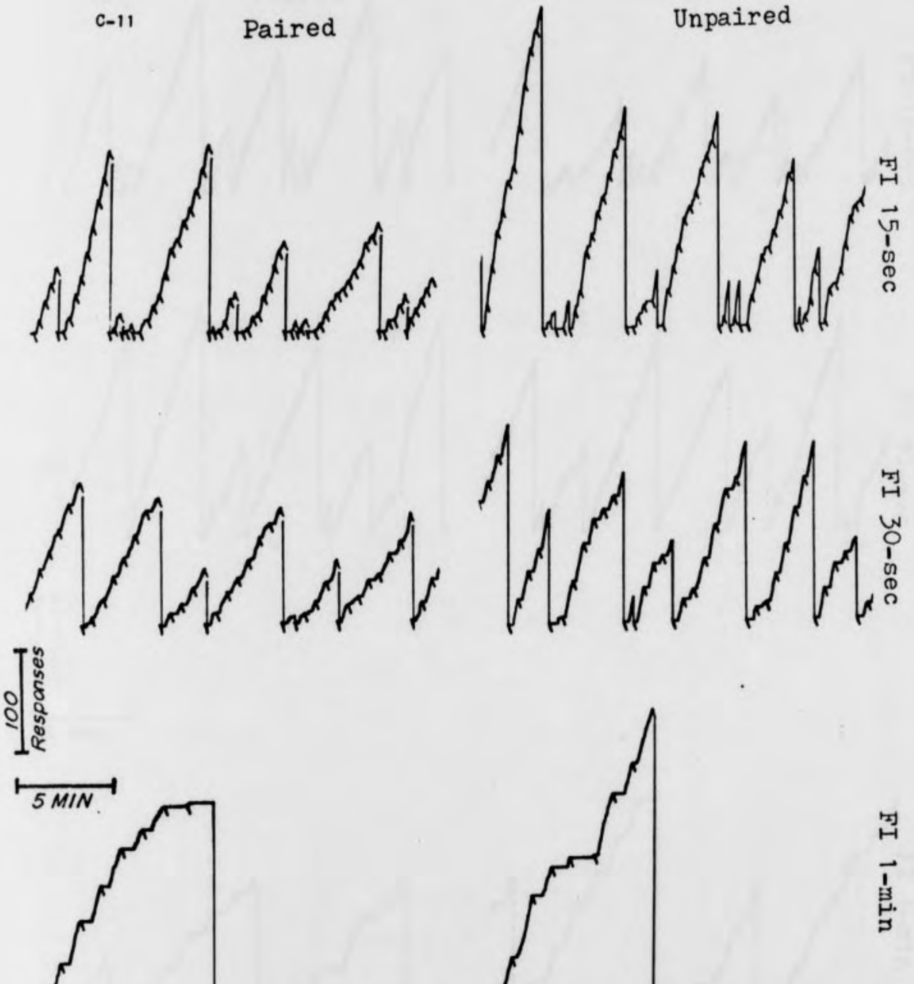
Representative cumulative records for pigeon C-1 showing performance from the paired and unpaired conditions and for each of the three fixed-interval durations studied.

Fig 1a



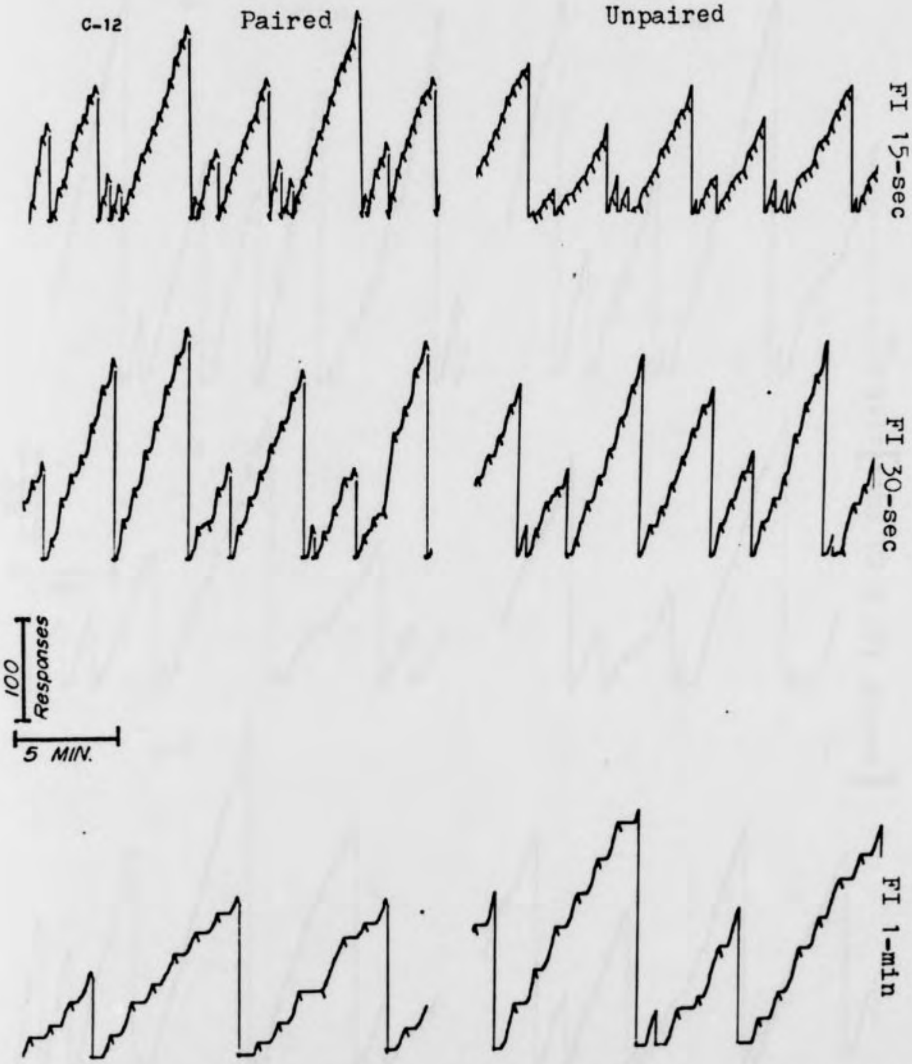
Representative cumulative records for pigeon C-9 showing performance from the paired and unpaired conditions and for each of the three fixed-interval durations studied.

Fig 1b



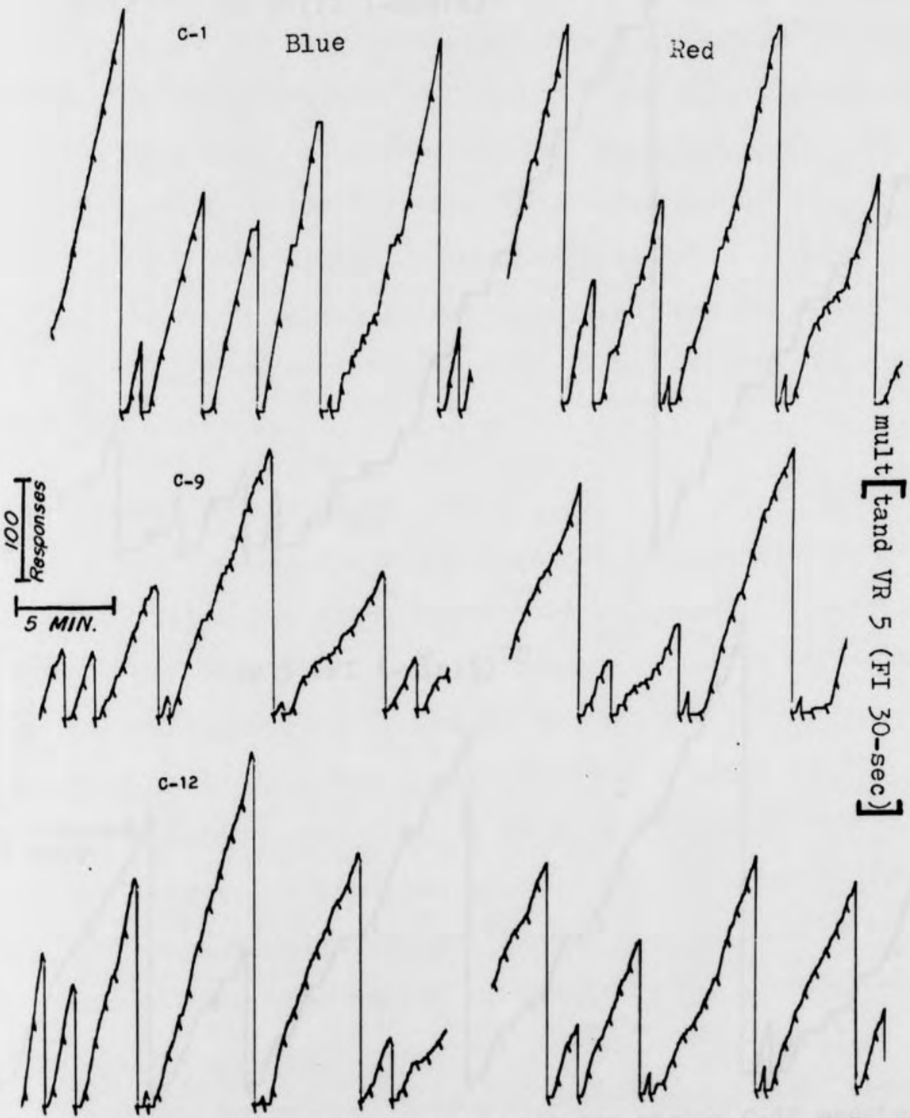
Representative cumulative records for pigeon C-11 showing performance from the paired and unpaired conditions and for each of the three fixed-interval durations studied.

Fig 1c



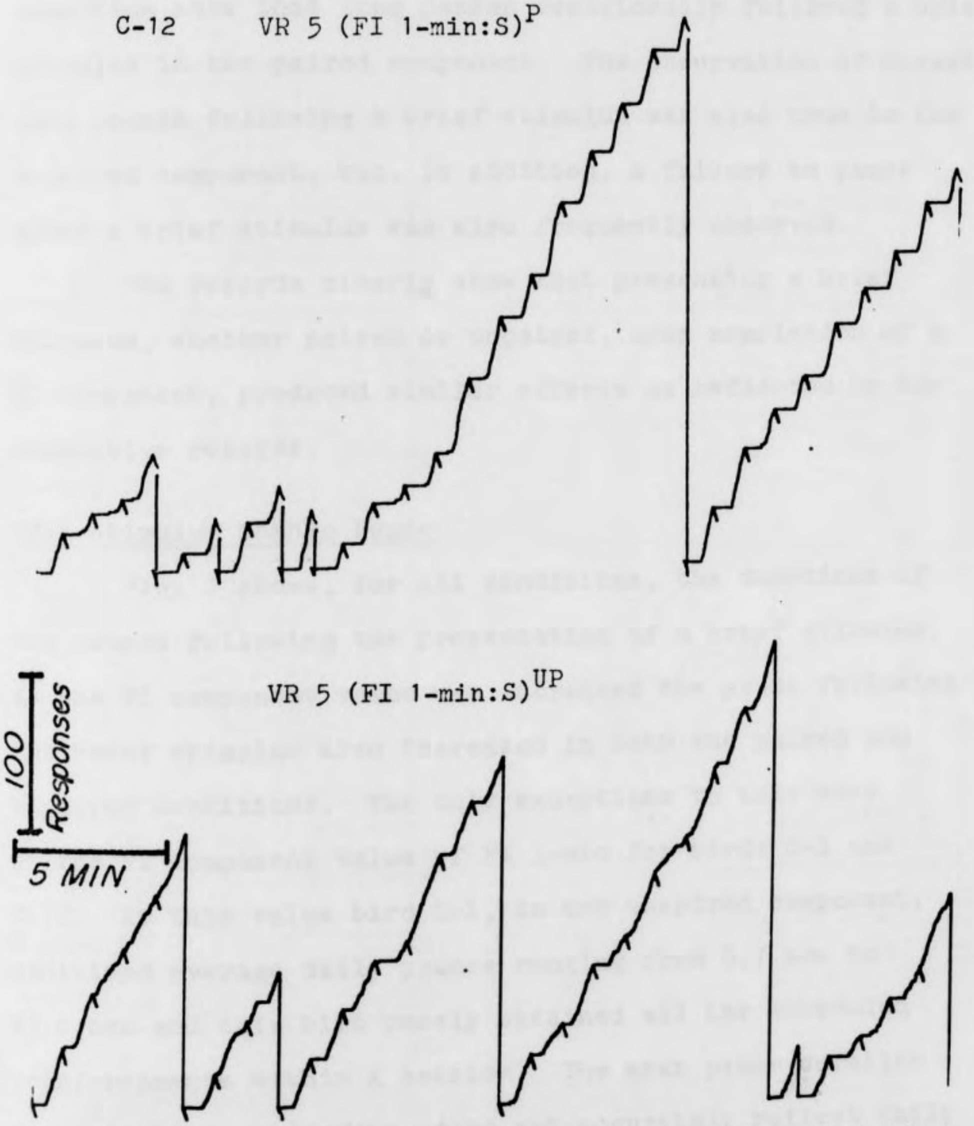
Representative cumulative records for pigeon C-12 showing performance from the paired and unpaired conditions and for each of the three fixed-interval durations studied.

Fig 1d



Representative cumulative records for pigeons C-1, C-9, and C-12 from the mult [tand VR 5 (FI 30-sec)] condition.

Fig 1e



Representative cumulative records for pigeon C-12 showing the effects of pairing a previously unpaired brief-stimulus.

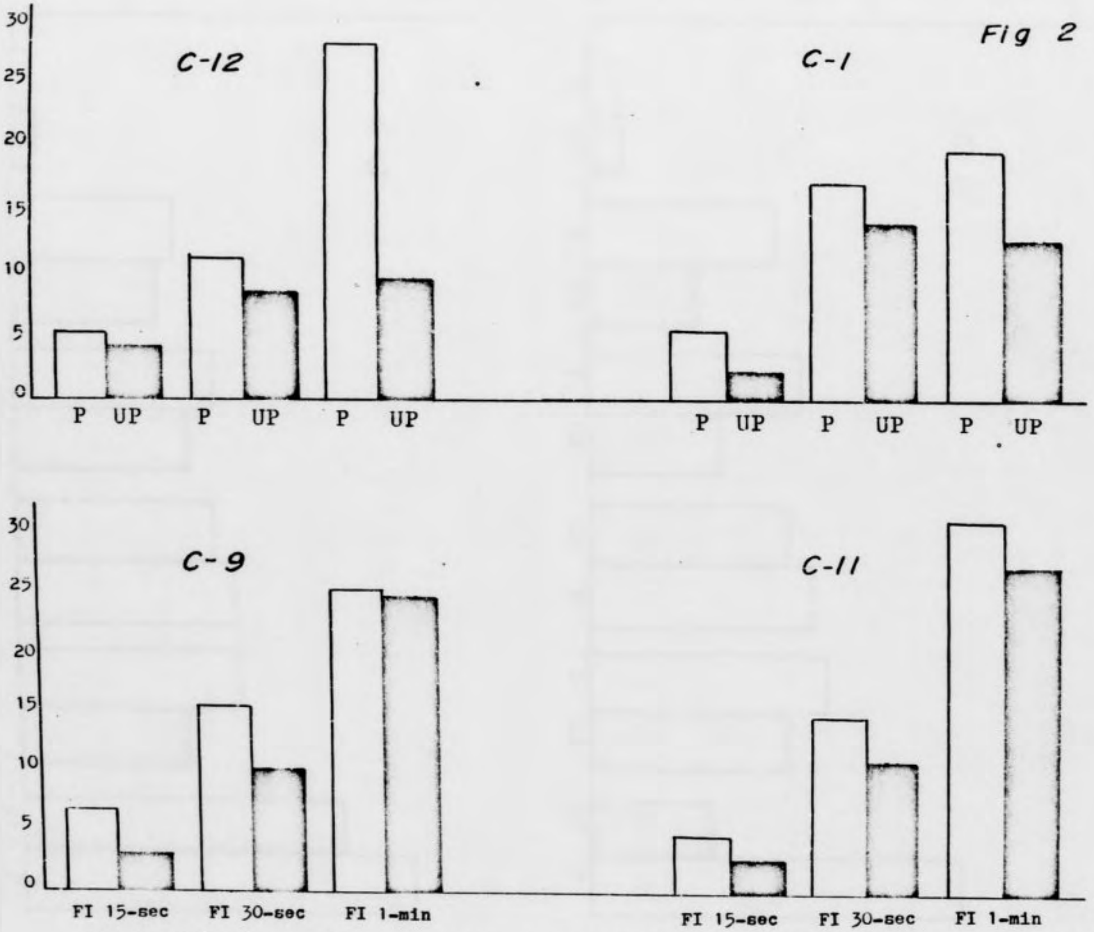
was especially noticeable in the next to last condition VR 5 (FI 1-min:^{UP}), for all birds.

The records for pigeon C-11 in the mult VR 5 (FI 1-min:S) condition show that long pauses occasionally followed a brief stimulus in the paired component. The observation of occasional long pauses following a brief stimulus was also true in the unpaired component, but, in addition, a failure to pause after a brief stimulus was also frequently observed.

The records clearly show that presenting a brief stimulus, whether paired or unpaired, upon completion of a FI component, produced similar effects as reflected by the cumulative records.

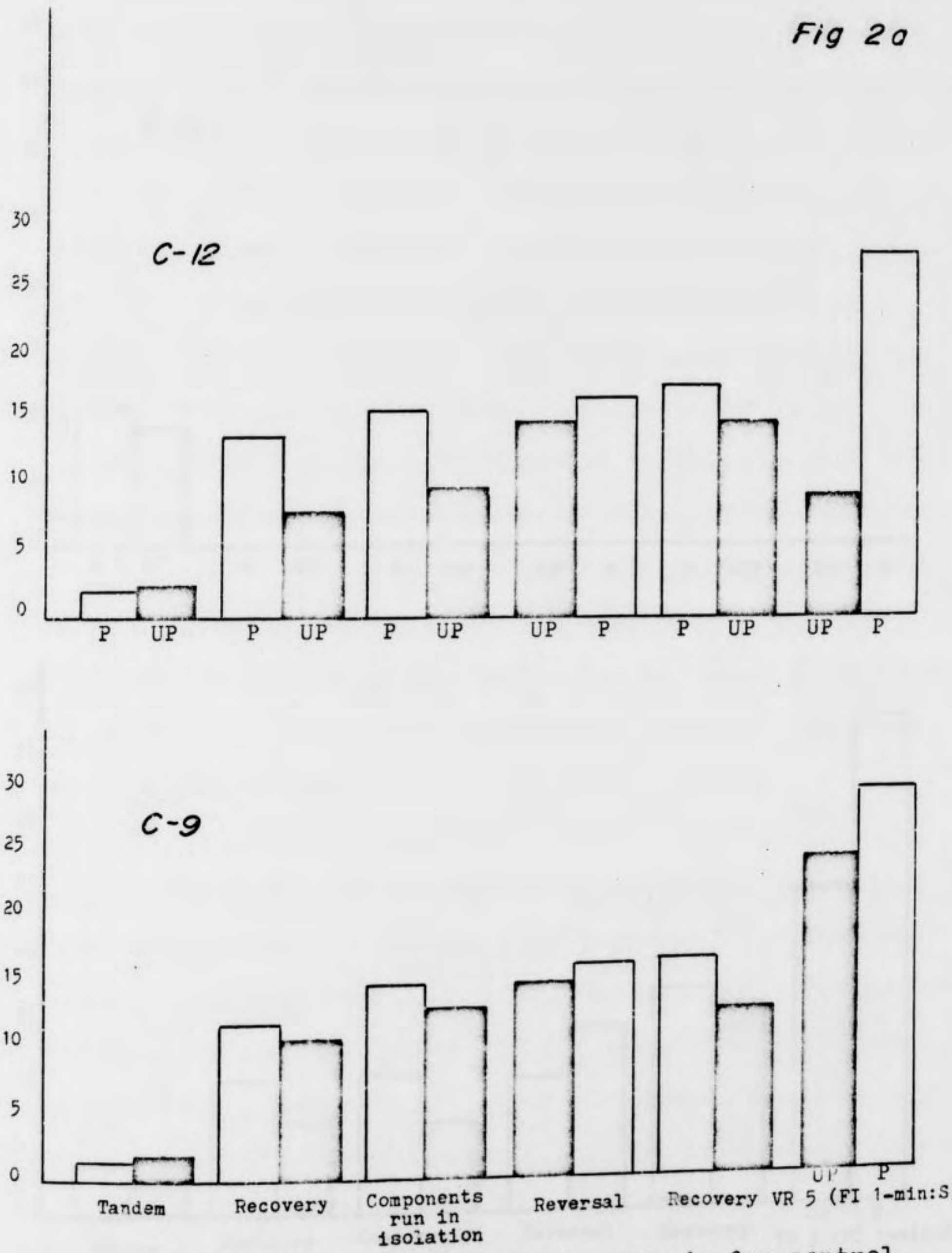
Post-Stimulus Change Pause

Fig. 2 shows, for all conditions, the durations of the pauses following the presentation of a brief stimulus. As the FI component value was increased the pause following the brief stimulus also increased in both the paired and unpaired conditions. The only exceptions to this were at the FI component value of FI 1-min for birds C-1 and C-12. At this value bird C-1, in the unapired component, exhibited average daily pauses ranging from 8.7 sec to 93.6 sec and this bird rarely obtained all the scheduled reinforcements within a session. The mean pause duration for this bird, therefore, does not accurately reflect daily performance in the unpaired component. Performance in the paired component was more systematic and did not show the



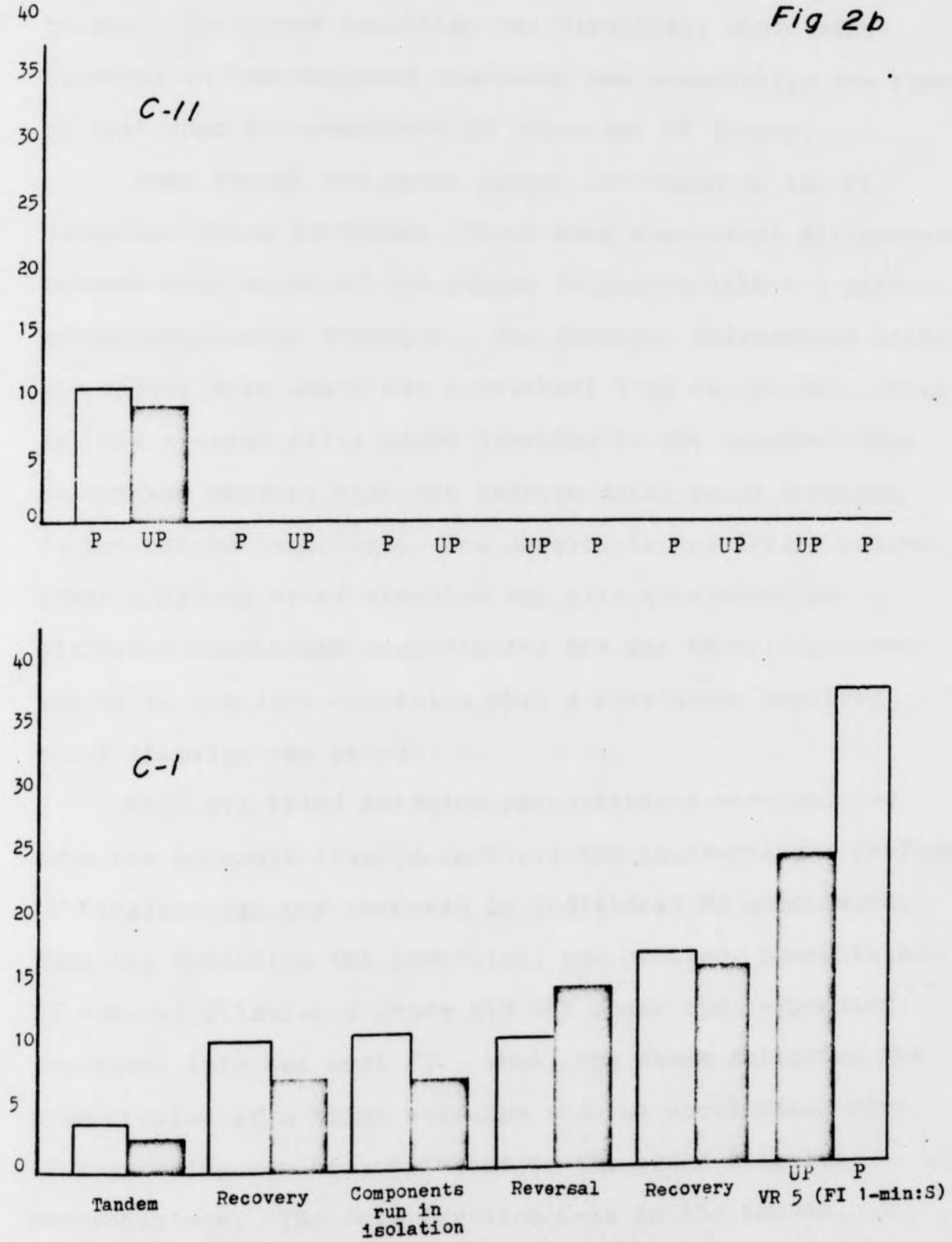
Post-stimulus change pause in seconds as a function of component fixed interval duration.

Fig 2a



Post-stimulus change pause in seconds for control conditions for pigeons C-9 and C-12.

Fig 2b



Post-stimulus change pause in seconds for control conditions for pigeons C-11 and C-1.

wide range of pause values observed in the unpaired component. The other exception was bird C-12, whose pause duration in the unpaired component was essentially the same as that when the component FI value was FI 30-sec.

Even though the pause length increased as the FI component value increased, there were consistent differences between the length of the pauses following either a paired or unpaired brief stimulus. The absolute differences between the values were small but consistent from day to day. That is, the average daily pause duration in the unpaired component was shorter than the average daily pause duration in the paired component. The observation of longer pauses after a paired brief stimulus was also consistent as different conditions were studied and was especially noteworthy in the last condition when a previously unpaired brief stimulus was paired.

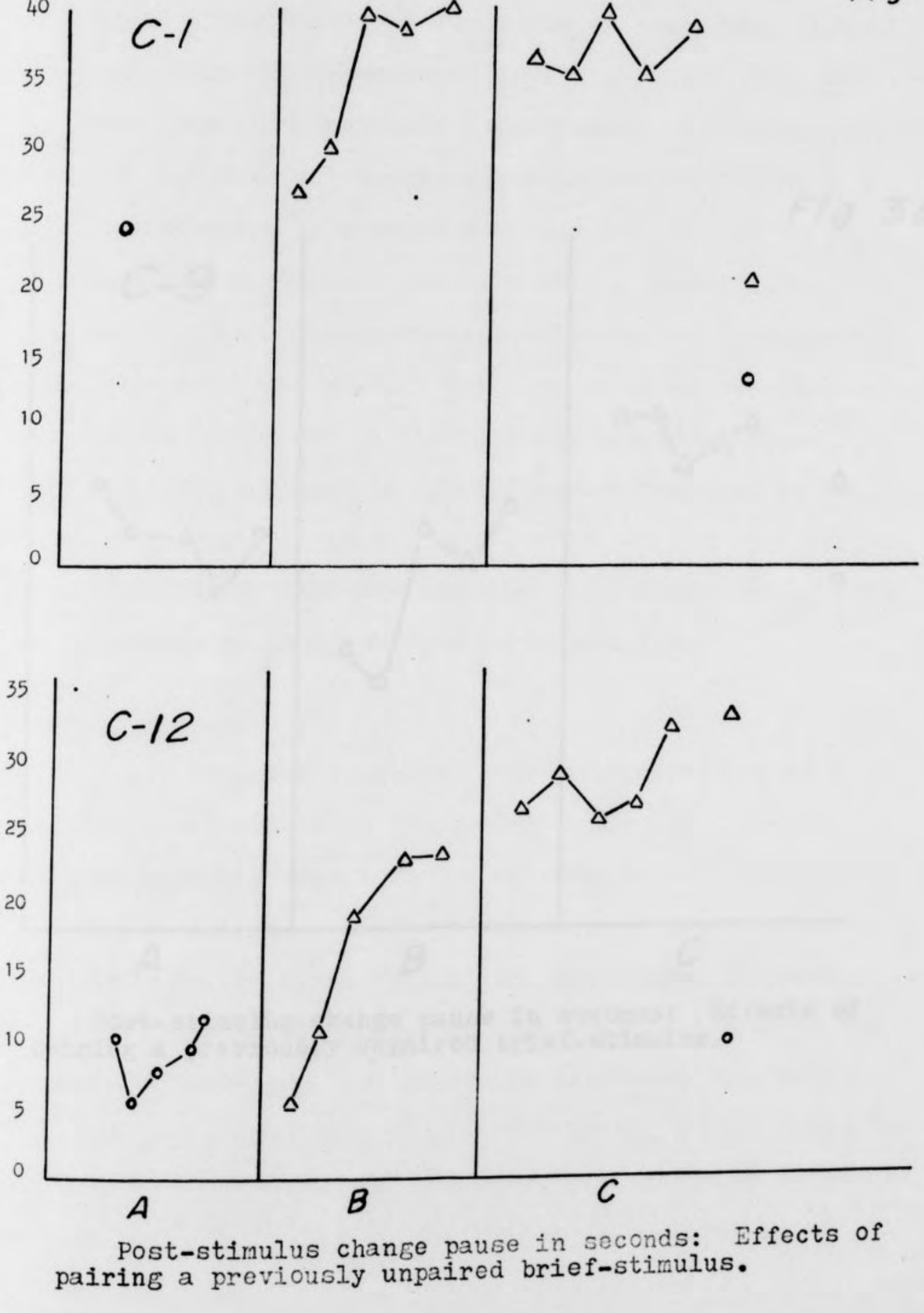
When all brief stimulus presentations were omitted from the schedule (tandem control) the pause-respond pattern of behavior was not observed in individual FI components. That is, following the scheduled, but omitted, presentation of a brief stimulus a pause did not occur and responding continued into the next FI. Thus, the pause following the presentation of a brief stimulus and the accelerated rate of responding can be attributed to the brief stimulus presentations. The data for bird C-11 in the tandem condition suggest that this bird was pausing after the scheduled presentation of a brief stimulus. However, the lengthy pauses resulted from random pausing throughout the component FI, some of which followed the scheduled brief stimulus presentation. Pigeon C-11 died following completion of the tandem condition.

Increasing pause duration as a function of FI component value was not the result of an interaction between the mult schedule components. When the birds were given extended exposure to each component of the mult schedule the longest pauses continued to occur after a paired brief stimulus. The absolute values of the pauses did change somewhat, however. Neither were the similarities the result of the specific key colors associated with the paired and unpaired components of the mult schedule. When the key colors associated with the paired and unpaired components of the mult schedule were reversed the longest pauses continued to follow the paired brief stimulus. During the reversal condition the absolute values of the pauses in the unpaired component did increase, relative to the values obtained in the original stimulus conditions. This might suggest that the blue key color did exert some control over pauses in its presence. However, since the longest pauses continued to occur after the paired brief stimulus, regardless of key color, the explicit pairing operation would seem to be the variable responsible for generating the longest pauses.

The influence of the pairing operation is made more clear by considering the last condition. In this condition the influence of pairing a previously unpaired brief stimulus was studied, as well as controlling for the differences in physical properties between the brief stimuli used in the comparison part of this study. In this condition all birds were exposed for 30 days to the unpaired component of the mult schedule [VR 5 (FI 1-min:^{UP})]. Then, the brief stimulus was paired with food presentation; i.e., it preceded food by 0.75 sec and accompanied food. The brief stimulus was the same as that employed throughout this study, a change in key color from red to white. Fig. 3 shows the average daily pause for the last five days when the brief stimulus was unpaired (A), the first five days after the brief stimulus was paired (B), and the last five days of the paired condition (C). Fig. 3 shows that following the pairing operation the pause duration increased for all birds over the value obtained in the unpaired condition.

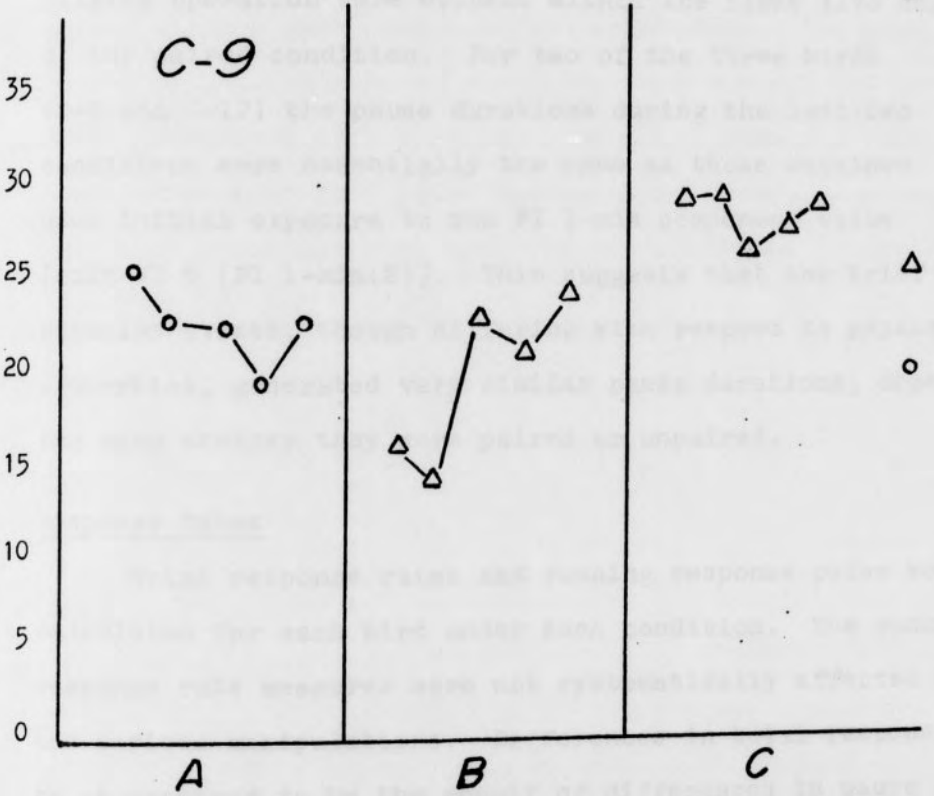
The effect of the pairing operation was especially dramatic on the behavior of birds C-12 and C-1. Fig. 3 shows only one data point for bird C-1 in the unpaired condition. The range of average daily pause durations varied to such an extent that they could not be fitted to the graph. The single point represents a mean of the last five days but does not accurately reflect daily performance. When the brief stimulus was paired, the behavior

Fig 3



Post-stimulus change pause in seconds: Effects of pairing a previously unpaired brief-stimulus.

Fig 3a



Post-stimulus change pause in seconds: Effects of pairing a previously unpaired brief-stimulus.

of this bird changed dramatically. Pauses occurred after each brief stimulus and the duration of the pauses varied much less than in the unpaired condition. For bird C-12 the pause duration increased significantly after the brief stimulus was paired. Longer pause durations following the pairing operation were evident within the first five days of the paired condition. For two of the three birds (C-9 and C-12) the pause durations during the last two conditions were essentially the same as those obtained upon initial exposure to the FI 1-min component value [mult VR 5 (FI 1-min:S)]. This suggests that the brief stimulus events, though differing with respect to physical properties, generated very similar pause durations, depending upon whether they were paired or unpaired.

Response Rates

Total response rates and running response rates were calculated for each bird under each condition. The running response rate measures were not systematically affected by the various manipulations. Differences in total response rates appeared to be the result of differences in pause durations. The total number of responses increased as the FI duration increased but each bird exhibited very similar responses per minute across all conditions, though there were differences between birds. Response rate measures were not systematically affected by the paired or unpaired brief stimuli. Higher rates were observed to sometimes occur in the paired component and sometimes in the unpaired component within a condition

Post-Food Pause

The average pause following food presentation was determined for each bird over all conditions. The results showed that average pause durations were essentially the same, regardless of the schedule or brief stimulus conditions. The post-food pause increased in duration as the component fixed-interval schedule was increased in duration.

CHAPTER IV

DISCUSSION

This experiment was concerned with comparing the effects of paired and unpaired brief stimuli on patterns of responding and pause durations following a brief stimulus, in an attempt to elucidate the function of the brief stimulus. The main results of this study were: 1) pause durations after a brief stimulus, in both the paired and unpaired conditions, was an increasing function of the FI duration; 2) in both the paired and unpaired conditions, very similar pause-respond patterns of behavior were observed and the pause durations after a brief stimulus were also very similar. However, the longest pauses always followed the paired brief stimulus, and 3) the observed differences in pause durations were not the result of any physical property of the brief stimulus.

Previous explanations about the function of the brief stimulus have focused on a conditioned reinforcement interpretation (Byrd & Marr, 1969; Kelleher & Gollub, 1962) and more recently a discriminative interpretation (Stubbs, 1971). The conditioned reinforcement hypothesis has stressed the importance of the pairing procedure in producing a brief stimulus that functions similarly to food.

The discriminative hypothesis stresses the contingency of food signalled by the brief stimulus. These hypotheses seem to predict quite different effects. If pairing is necessary for a brief stimulus to function similarly to food, then the response patterns during the unpaired condition should not be similar to those produced during the paired brief stimulus condition. A discriminative interpretation would predict that the paired and unpaired brief stimuli should function similarly, given that both stimulus events are equally discriminable, since the signalled time to food is the same.

The results of this study provide some support for both interpretations, but also present some difficulties for these hypotheses. The fact that longer pauses always followed the paired brief stimulus seems most consistent with a conditioned reinforcement view. However, the observation that pause durations increased in both the paired and unpaired conditions as the component FI value increased is consistent with a discriminative role.

The conditioned reinforcement hypothesis has difficulty accounting for the increasing pause durations in the unpaired condition unless additional assumptions are incorporated into the hypothesis. For example, it might be assumed that the unpaired brief stimulus was functionally a paired brief stimulus: the pairing may have occurred because of common dimensions shared with the brief stimuli.

Similarly, the signaling hypothesis has difficulty accounting for the fact that the longest pauses always followed the paired brief stimulus unless additional assumptions are made. For example, it might be assumed that the pairing affected the discriminative potential, or salience, of the brief stimulus.

The results of the Stubbs (1971) study and the results of the present study suggest that an interpretation of the function of the brief stimulus must incorporate the procedural aspects emphasized by both the conditioned reinforcement hypothesis and the discriminative hypothesis. The observation that pairing did affect pause durations dictates that the pairing procedure be considered one way of producing pause-respond patterns of behavior. Nevertheless, it was also demonstrated that pairing is not necessary to produce pause-respond patterns of behavior.

The most parsimonious explanation, and one consistent with the results from studies in classical conditioning, would be that the brief stimulus functions as a discriminative event, with the discriminative effectiveness of the brief stimulus affected by the pairing procedure (see Black & Prokasy, 1972). For example, Staddon (1972) has suggested that the salience of a stimulus event is an important factor in controlling behavior. Presumably, salience could refer to the ability of a stimulus event to elicit, or set the occasion for, some behavior, as a result of a previous history of conditioning. The observation that longer pause durations always followed the paired brief stimulus suggests the possibility that the paired brief stimulus was a more salient stimulus event. Considered in this way the importance of the pairing operation is recognized and the discriminative interpretation remains a plausible explanation. That is, the brief stimulus events were functioning as discriminative stimuli with the discriminative properties of the brief stimulus enhanced by the pairing operation.

The pairing procedure may make a stimulus more salient in one, or several ways. For example, the paired and unpaired brief stimuli are associated with different events. The paired brief stimulus with the presentation of food and the unpaired brief stimulus with the non-occurrence of food. The paired brief stimulus, because of its association with food, may produce food-hopper oriented behavior, while the unpaired brief stimulus may produce some other kind of behavior, perhaps emotional behavior. The observation that stimulus events control different kinds of behaviors in a classical conditioning paradigm has been made by Moore (1973).

A related possibility is that interoceptive stimuli are available to the pigeons. Because the paired brief stimulus is associated with food presentations in a classical conditioning paradigm, it would not be surprising if the paired brief stimulus elicited physiological responses similar to those that occur when a conditioned stimulus is presented before an unconditioned stimulus (e.g., food).

It is possible that the longer pause durations following a paired brief stimulus results from an interaction of behavior produced by the pigeon, physiological responses elicited by the paired brief stimulus and the FI duration. Any or all of these events may contribute to the salience of a brief stimulus and its ability to produce pause-respond patterns of behavior.

This study also considered the possibility that duration of exposure to the schedule and brief stimulus conditions might be an important factor when FI schedules are used as component schedules. To determine if duration of exposure was important, the average pause after a brief stimulus was determined for the tenth through the fourteenth day of each condition and compared to the average pause duration for the last five days in each condition. The data were inconclusive. When the FI component was either 15 sec or 1 min the average pause duration was essentially the same, indicating that after fourteen days of exposure to the conditions the pause durations changed very little. However, when the component FI was 30 sec there were large differences in pause durations for three of the four birds. That is, the average pause duration for the last 5 days was considerably longer than the average pause duration for days ten through fourteen. Because of the inconsistency across conditions, no conclusions can be made regarding duration of exposure as a factor influencing pause durations.

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