SECOND-ORDER SCHEDULES: DISCRIMINATION OF COMPONENTS[1]

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Pigeons were exposed to a series of second-order schedules in which the completion of a fixed number of fixed-interval components produced food. In Experiment 1, brief (2 sec) stimulus presentations occurred as each fixed-interval component was completed. During the brief-stimulus presentation terminating the last fixed-interval component, a response was required on a second key, the brief-stimulus key, to produce food. Responses on the brief-stimulus key before the last brief-stimulus presentation had no scheduled consequences, but served as a measure of the extent to which the final component was discriminated from preceding components. Whether there were one, two, four, or eight fixed-interval components, responses on the brief-stimulus key occurred during virtually every brief-stimulus presentation. In Experiment 2, an attempt was made to punish unnecessary responses on the brief-stimulus key, i.e., responses on the brief-stimulus key that occurred before the last component. None of the pigeons learned to withhold these responses, even though they produced a 15-sec timeout and loss of primary reinforcement. In Experiment 3, different key colors were associated with each component of a second-order schedule (a chain schedule). In contrast to Experiment 1, brief-stimulus key responses were confined to the last component. It was concluded that pigeons do not discriminate well between components of second-order schedules unless a unique exteroceptive cue is provided for each component. The relative discriminability of the components may account for the observed differences in initial-component response rates between comparable brief-stimulus, tandem, and chain schedules.

Key Words: second-order schedule, brief-stimulus presentations, chain schedule, conditioned reinforcement, temporal discrimination, fixed-interval schedule, key peck, pigeons

CONTENTS

In second-order schedules, the completion of some subordinate, component schedule is reinforced according to a superordinate schedule. For example, on a fixed-ratio 4 (fixed-interval 30-sec) [FR 4 (FI 30-sec)] completion of the fourth FI 30-sec component results in primary reinforcement. Three types of second-order schedules are commonly used: tandem, brief-stimulus, and chain schedules. On a tandem

schedule, the same exteroceptive stimulus is present throughout the interreinforcement interval. A brief-stimulus schedule is the same as a tandem schedule, except that completion of each component is signalled by the brief presentation of a second stimulus. On a chain schedule, each component is associated with a different stimulus (frequently, different key colors). The use of second-order schedules in the analysis of various stimulus functions (e.g., discriminative and/or reinforcing) has been thoroughly reviewed by Kelleher (1966) and Kelleher and Gollub (1962). An important difference between the behavior maintained by these three procedures is that on an extended chain schedule (more than two component schedules), response rates in the initial components are usually depressed compared to those maintained by a comparable tandem schedule (Fantino, 1969; Gollub, 1958; Jwaideh, 1973; Kelleher and Fry, 1962; Thomas, 1964), or by a comparable brief-stimulus schedule (see Stubbs, 1971, for a review). This difference has been explained in terms of the conditioned reinforcing properties of the stimuli (e.g., Kel-

leher, 1966). For example, the terminal link of a chain schedule is presumably a conditioned reinforcer because it immediately precedes the delivery of food (an unconditioned reinforcer). However, the penultimate link is twice removed from food and would, if effective as a reinforcer, depend on pairings with a conditioned reinforcer. It may be that such higher-order conditioning does not produce effective conditioned reinforcers, and that this is why behavior is poorly maintained on extended chain schedules. In contrast, brief-stimulus presentations, which occur at the end of each component schedule, are intermittently paired directly with primary reinforcement and in principle are effective conditioned reinforcers.

Some doubt has been cast upon this explanation by Stubbs' (1971) finding that brief stimuli also facilitate responding when presented at the end of each component, *except* the one preceding primary reinforcement. These "unpaired" brief stimuli are presumably not conditioned reinforcers; consequently, their effectiveness in enhancing response rates weakens the conditioned reinforcement explanation outlined above. An alternative explanation of the difference in the effects of tandem, chain, and brief-stimulus schedules can be made in terms of what the animal learns when exposed to these schedules. There is considerable evidence from classical conditioning studies that the emission of a conditioned response is dependent on the context in which the conditioning occurs, and is not always a simple function of the relation between the conditioned and unconditioned stimuli (Dawson, 1970; Dawson and Grings, 1968; Grings, 1965; Grings and Lockhart, 1963). In a similar way, the relationship between responding and reinforcement on second-order schedules may not be the only determinant of response rate. Instead, the different stimulus conditions associated with these second-order schedules may result in the animal attending to different aspects of the situation and learning a different set of relations. On a tandem schedule [*e.g.*, FR 4 (FI 30-sec)], pigeons behave very much as they do on a simple FI 120-sec schedule, suggesting that they learn something similar in the two cases, *i.e.*, that responding is reinforced every 120 sec. Response rates are very low following a primary reinforcement, and temporal discrimination or temporal inhibition of responding is said to occur (*cf.* Staddon, 1972). In compari-

son, on a chain FR 4 (FI 30-sec) schedules responding is usually depressed in the initial link and elevated in the terminal link. This suggests that the pigeon has learned something different than on the tandem schedule, even though the relation between responding and reinforcement is the same. Presumably, on a chain schedule, the pigeon learns that responding in the presence of the initial-link stimulus does not produce food but responding in the presence of the terminal-link stimulus does. Comparing the chain and tandem schedules then, it appears that the visual stimuli associated with the components of the chain schedule more effectively control behavior than do the temporal cues of the tandem schedule; in particular, the visual initial-link stimulus is a more effective S^{Δ} than is the postreinforcement period of the tandem schedule. On an FR 4 (FI 30-sec) schedule of brief-stimulus presentations, responding is generally enhanced in the initial links relative to the previously described schedules. Thus, it may be that on the brief-stimulus schedule, the pigeon learns that responding is reinforced once every 30 sec with a probability of 0.25, *i.e.*, that the schedule is functionally the same as a VR 4 (FI 30-sec) schedule of brief-stimulus presentations. This account assumes that on brief-stimulus schedules, neither the temporal cues nor the number of brief-stimulus presentations is effectively controlling behavior. It also means that the effects of paired and unpaired brief stimuli should be similar. If this analysis is correct, pigeons should have difficulty discriminating among the components of brief-stimulus schedules. The following series of experiments was designed to test this explanation of the facilitative effects of brief-stimulus presentations on responding in second-order schedules.

EXPERIMENT 1.
DISCRIMINATION OF COMPONENTS IN BRIEF-STIMULUS SCHEDULES

If each of the components of paired brief-stimulus schedules is equivalent to the pigeon, due to the absence of temporal control of responding, then each brief-stimulus presentation may set the occasion for some response, such as approaching the food hopper. Food-hopper approach might then be used as a measure of the discriminability of the components. However, since such a response is likely to be quite var-

iable in topography and difficult to measure, Experiment 1 interposed the requirement of a discrete overt response during the last brief-stimulus preceding primary reinforcement: a peck on another response key. To the extent that one brief-stimulus presentation is discriminated from another, pecks on the second key should be confined to the last brief-stimulus presentation. However, if discrimination is poor, pecks might occur to earlier brief stimuli, even though these pecks are never reinforced.

METHOD

Subjects

Six adult male White Carneaux pigeons served. Four (N-20, N-M, 6254, and 6498) had extensive histories in a variety of two-key experiments (Squires, 1972; Squires and Fantino, 1971). The other two (38 and N-N) were relatively naive but had some experience with simple reinforcement schedules.

Apparatus

The standard experimental chamber measured 15 by 15 by 18 in. (30 by 30 by 38 cm). The front wall of the chamber contained two translucent Gerbrands response keys mounted 3.75 in. (9 cm) apart and 8.5 in. (21 cm) above the floor. The left key could be illuminated from behind by a green bulb, the right key by an orange bulb. Responses emitted on an illuminated key produced auditory feedback (the click of a relay); responses on a dark key did not. A minimum force of approximately 0.15 N was required to operate either key. All effective responses were recorded. The chamber also contained a solenoid-operated hopper for grain presentation 2 in. (5 cm) above the floor of the chamber, and two 6-W miniature lamps for chamber illumination. White noise masked extraneous sounds. Standard relay control and recording equipment was located in an adjacent room.

Procedure

The following description applies to the second-order schedule FR 2 (FI 60-sec) of paired brief-stimulus presentation. The other paired brief-stimulus schedules differed only in the number of components and their duration. The left key was illuminated with green light and an FI 60-sec schedule was in effect. The

first response on the left key after 60 sec elapsed darkened that key and produced orange illumination on the right key for 2 sec. This sequence was repeated twice. Responses on the right key during the first brief-stimulus presentation had no effect, but the first right-key response during the second brief-stimulus presentation produced immediate access to grain for 3 sec. If in the last component the subject failed to respond on the right key during the 2 sec of orange illumination, the entire last component was repeated until a right-key response was made during the brief stimulus and a reinforcement delivered. However, the pigeons rarely failed to respond at the end of the last component. Responses on either key when it was dark had no effect and occurred infrequently.

Each pigeon was exposed to four schedules of brief-stimulus presentation in which the brief stimulus was paired with, *i.e.*, directly preceded, primary reinforcement. In each case, the total scheduled interreinforcement time was 120 sec, but the number of components and their duration varied inversely. One, two, four, or eight components were used, with durations of 120, 60, 30, and 15 sec respectively. The experimental procedures and the order of presentation for each subject are presented in Table 1. In addition to the four schedules of paired brief-stimulus presentation, the same schedules were presented with the brief stimulus unpaired. In this case, the 2 sec of orange illumination on the right key following completion of the last component was eliminated. Instead, the first left-key response occurring after the fixed-interval elapsed in the last component produced grain, and no right-key responses were required. The keys were dark during hopper presentations. Each session lasted until 40 primary reinforcements had been obtained and each of the eight schedules was in effect for 20 sessions.

Four pigeons (N-20, N-M, 6498, and 6254) were first exposed to the four paired brief-stimulus schedules, and then to the four unpaired brief-stimulus schedules. The other two pigeons (38 and N-N) were started with the unpaired brief-stimulus schedules (see Table 1). Following the unpaired-stimulus conditions, all six subjects were transferred to a condition in which the brief stimulus was paired with primary reinforcement, but no right-key responses were required. The last brief-stimulus

Table 1

Order of Experimental Conditions, Experiment 1

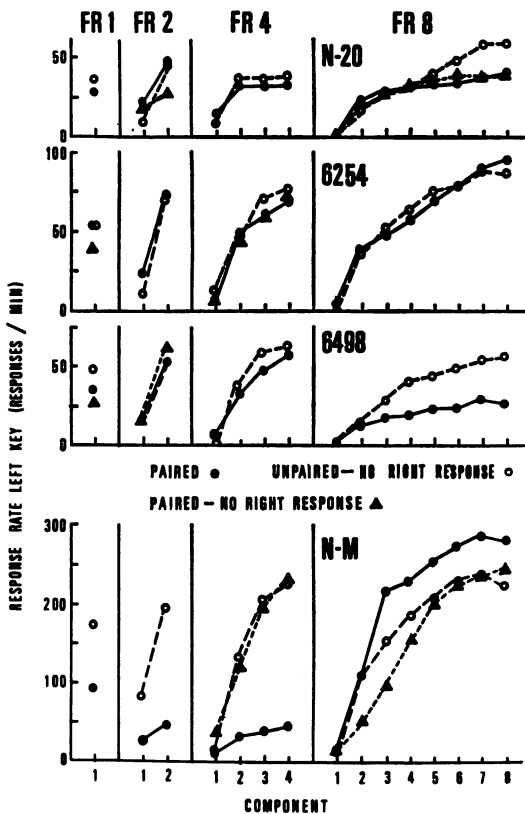| Brief-Stimulus Condition	Schedule	Subject					
		N-20	N-M	6254	6498	38	N-N
Paired	FR 1 (FI 120-sec)	3	4	2	4	—	—
	FR 2 (FI 60-sec)	1	1	4	3	—	—
	FR 4 (FI 30-sec)	4	2	1	2	—	—
	FR 8 (FI 15-sec)	2	3	3	1	—	—
Unpaired	FR 1 (FI 120-sec)	6	5	7	8	1	4
	FR 2 (FI 60-sec)	8	7	5	7	2	3
	FR 4 (FI 30-sec)	5	6	8	6	3	2
	FR 8 (FI 15-sec)	7	8	6	5	4	1
Paired, no	FR 1 (FI 120-sec)	—	—	9	9	—	5
right-key	FR 2 (FI 60-sec)	9	—	—	10	—	6
response	FR 4 (FI 30-sec)	—	10	10	—	6	—
required	FR 8 (FI 15-sec)	10	9	—	—	5	—

Fig. 1. Mean response rates on the left key over the last three sessions as a function of the FI component in effect, for all three types of schedules used in Experiment 1. The closed and open circles represent data from the procedures with paired and unpaired brief stimuli respectively. The triangles represent data from the schedules with paired brief stimuli with no right-key response required in the terminal brief stimulus. Each subject experienced the last type of schedule at only two fixed-interval values.

presentation lasted for 2 sec and ended automatically with grain presentation.

RESULTS

Figures 1 and 2 give the rates of responding on the left key during each component of each schedule (FR 1 to FR 8). The data from the subjects exposed to all three sets of right-key contingencies are shown in Figure 1 and those of the subjects started with the unpaired brief stimulus are shown in Figure 2. In both figures, the open circles represent the data from the unpaired brief-stimulus conditions and the triangles represent the data from the schedules in which the brief stimulus was paired but no right-key response was required. In addition, in Figure 1, the filled circles represent the data from the original paired brief-stimulus schedules for the four subjects exposed to those conditions. These data are the means of the response rates from the last three sessions at each condition. In all cases, left-key responding was an increasing function of the time since the last primary reinforcement. For three of the four subjects exposed to all experimental conditions, there is no systematic difference in the response rates for the three procedures. For Subject N-M, response rates appear generally higher in the unpaired than in the paired conditions. However, most of this difference is accounted for by the very low response rates on paired FR 2 (FI 60-sec) and paired FR 4 (FI 30-sec). Since these were the first two conditions N-M was exposed to, and since response rates in subsequent paired conditions more than doubled, it is possible that the apparent
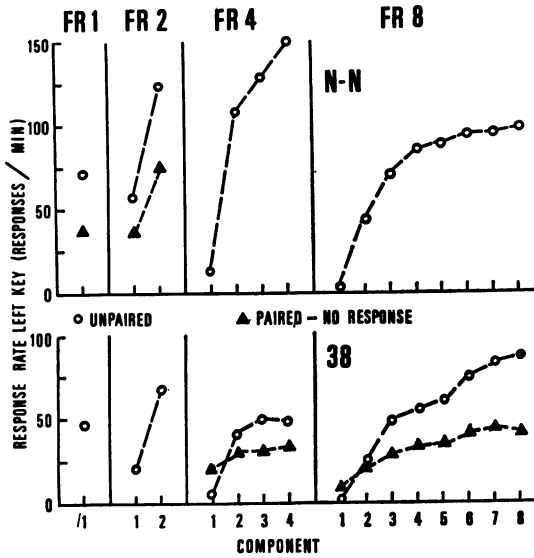
Fig. 2. Mean response rates on the left key as a function of the schedule component for Subjects N-N and 38. Unlike the subjects represented in Figure 1, these two subjects were not originally exposed to the paired brief stimulus with a right-key response required.
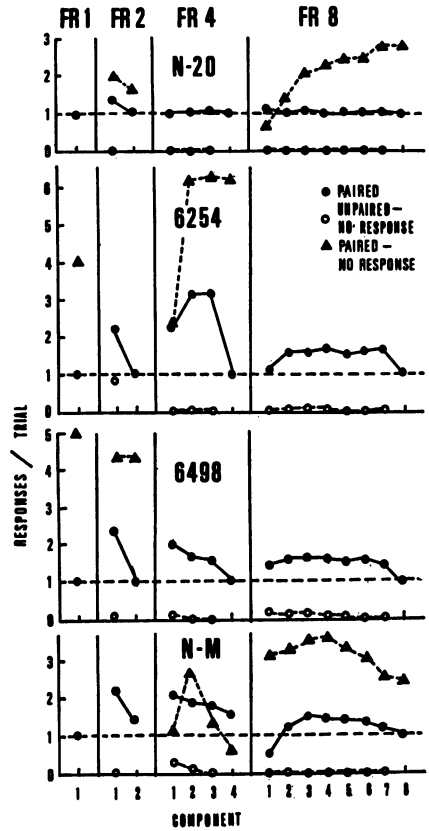

Fig. 3. Mean number of responses on the right key per brief-stimulus presentation as a function of the FI component that the brief stimulus terminated. The horizontal dashed lines indicate a mean of one response per brief stimulus. The closed circles represent the condition in which the final right-key response produced reinforcement. The open circles represent the case in which there was no brief stimulus at the end of the final component (unpaired), and the triangles represent the case in which the brief stimulus was paired with primary reinforcement but no right-key response was required.

advantage of the unpaired over the paired brief-stimulus schedules for this subject was simply a function of their ordinal position. For Subjects N-N and 38 (Figure 2), the unpaired brief-stimulus conditions maintained higher response rates than the paired brief-stimulus conditions with no right-key response required. The possible reasons for this are discussed below.

Figure 3 shows the data of principal interest with respect to the discriminability of components, i.e., the right-key responses during the brief stimulus. The data are for the subjects exposed to all three experimental conditions. The number of responses during each brief stimulus are shown by schedule (FR 1 to FR 8) and by components within those schedules. These data are the mean number of responses per brief-stimulus presentation over the last three sessions. When the brief stimulus was paired with primary reinforcement and a response was required on the brief-stimulus key at the end of the terminal component (filled circles), the number of responses per brief stimulus almost always averaged one or more. An average of one response per brief stimulus is indicated by the dashed horizontal line. The first response in the last brief stimulus produced the hopper, so the number of responses in this component was limited. (Some subjects,

for example N-M, occasionally emitted double pecks, even though only the first peck was effective. As a result, the average number of pecks in the last brief stimulus in the paired condition sometimes exceeded one.) The number of responses in earlier brief-stimulus presentations was free to vary. When no right-key response was required, but the brief stimulus was still paired with primary reinforcement (triangles), response rates during the brief stimulus were enhanced. This probably reflects the fact that in the original condition, a brief-stimulus key response that did not operate the magazine, provided information that no primary reinforcement would be forthcoming.

This was not the case when no brief-stimulus key response was required, because all brief-stimulus presentations lasted 2 sec. When the brief stimulus was unpaired (open circles), few brief-stimulus key responses occurred.

Figure 4 gives the per cent of the brief-stimulus trials containing right-key responses in the paired brief-stimulus condition (response required) for those subjects whose data are also shown in Figure 3. The data are presented in this additional form because it cannot be determined from Figure 3 whether every trial contained a response or whether some trials contained many responses and others none. Figure 4 shows that virtually every brief-stimulus presentation occasioned a response, except the first brief-stimulus presentation in the FR 8 (FI 15-sec) schedule, and even in that condition only one subject (N-M) responded less than 75% of the time.

Figure 5 shows the brief-stimulus key responding for those two subjects first exposed to the unpaired brief stimulus. No right-key responses were made when the brief stimulus

was unpaired (open circles). When the brief stimulus was then paired with primary reinforcement, still with no response requirement on the brief-stimulus key (triangles), Subject N-N began to make brief-stimulus key responses with some regularity, although at a lower rate than the birds that had previously had a right-key response requirement. Subject 38 made no brief-stimulus key responses. However, when the paired brief stimulus was introduced, this subject began to respond at a high rate on the dark (left) key during the brief-stimulus presentations. Only the total number of left, dark-key responses was collected, so the distribution of these responses across components cannot be compared with the distribution of right-key responses of the other subjects. However, the average number of dark-key responses per brief-stimulus made by Subject 38 was similar to the average number of brief-stimulus responses for the other subjects, 5.2 on the FR 4 schedule, and 3.6 on the FR 8 schedule. In comparison, when the brief stimulus was unpaired, the average number of dark-key responses was only 1.2 on FR 4, and 1.1 on FR 8. This result is important for two reasons. First, it shows that subtracting (or removing) a stimulus (green light left key) when it is predictive of reinforcement can function much like the addition of a stimulus (orange light on right key), although some dif-
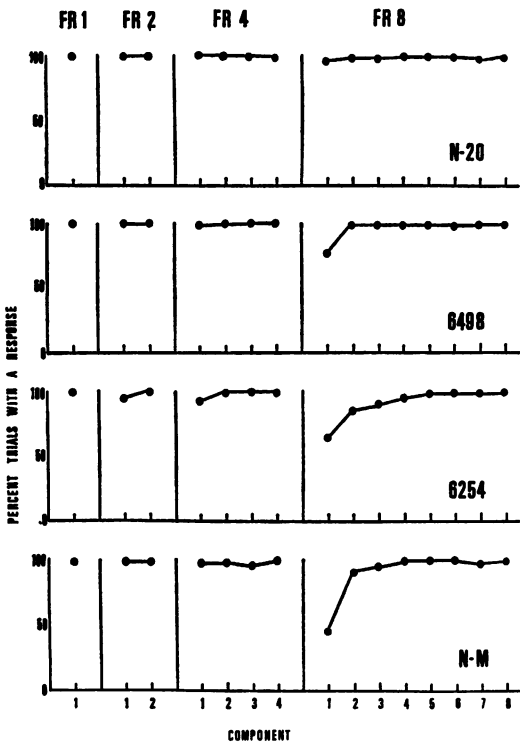

Fig. 4. The percentage of brief-stimulus presentations evoking at least one response, for the paired brief-stimulus schedules in which one response was required, for the same subjects represented in Figure 3.
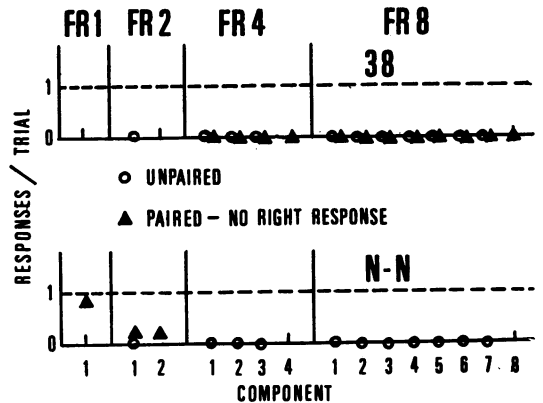

Fig. 5. Mean number of responses on the right key per brief-stimulus presentation as a function of the FI component that the brief stimulus terminated. The horizontal dashed lines indicate a mean of one response per brief stimulus. The open circles represent the condition in which there was no brief stimulus at the end of the final component (unpaired), and the triangles represent the case in which the brief stimulus was paired with primary reinforcement but no right-key response was required.

ferences have been reported by other investigators (Staddon, 1970, 1972; Stubbs, 1971). Second, a stimulus change (subtracting or adding a stimulus) must be predictive of, and not simply contiguous with reinforcement to control responding. This last point is crucial to the interpretation of the present results because in all conditions, left keylight off was contiguous with hopper presentation. Hence, it might be argued that in this sense of pairing, there was a paired brief stimulus in every experimental condition, i.e., keylight off was always contiguous with reinforcement and occurred at completion of each component schedule. However, dark-key pecks occurred only when the dark key preceded reinforcement and not when the dark key was contemporaneous with reinforcement. This result is consistent with the demonstrated relation between responding and the "information" value of a stimulus (cf., Bloomfield, 1972; Hendry, 1969). In the unpaired brief-stimulus conditions of Experiment 1, keylight off in the absence of the contemporaneous presentation of the food magazine signalled a period of nonreinforcement. On those occasions where keylight off and reinforcement were contemporaneous, the information provided by the keylight off was redundant.

The introduction of the paired brief stimulus for these two subjects did decrease left-key response rates (Figure 2), suggesting perhaps that the brief stimulus functioned as a delay of reinforcement or that the absence of the brief stimulus became an S△. This was generally not the case for the other subjects (Figure 1). The exact cause of these differences between the two groups is unclear, but is probably related to the strong control of responding exerted by the right-key stimulus for the first four subjects.

DISCUSSION

The data support the hypothesis, presented in the introduction, that pigeons do not discriminate well between components of brief-stimulus schedules: brief-stimulus key responses occurred at the end of all components, not just those in which primary reinforcement was scheduled. This conclusion rests on the assumption that if two stimuli are discriminable, and primary reinforcement is available in the presence of one stimulus (here, the terminal brief stimulus) and never available in the presence of the other (here, the earlier brief

stimuli), the first should become an S△ and the second an S△. However, all brief stimuli became S△s, suggesting that all brief stimuli were, in some sense, equivalent to the pigeon.

In addition to the fact that the brief-stimulus key responses were occasionally reinforced by the hopper presentation, another possible source of strength for the brief-stimulus key responses in the paired conditions may have to do with the tendency of stimuli that are differentially associated with food to elicit key pecking in pigeons (Gamzu and Schwartz, 1973; Gamzu and Williams, 1971, 1973). That this is the case is suggested by the fact that five of the six pigeons rapidly commenced pecking the right key in the condition in which the brief stimulus was paired with primary reinforcement but no right-key response was required, and by the fact that for one of these subjects (N-N), brief-stimulus key pecks had never previously been reinforced. All subjects had just experienced 80 sessions with the unpaired brief stimulus, which did not occasion brief-stimulus key pecks. The dark-key pecks emitted by the sixth pigeon are also consistent with this interpretation because the dark key was also predictive of food. This hypothesis also assumes that the subjects were not discriminating between components, since if the first brief stimulus were discriminable from the last, the first should not be predictive of food and should not elicit responding. Whether the right-key pecks are operant or elicited responses, the pairing operation was clearly necessary to induce responding, because almost no brief-stimulus key responses occurred in the unpaired-brief stimulus condition. Nonetheless, left-key responding was not enhanced by this pairing operation. This lack of any enhancement of left-key responding by paired brief-stimuli is consistent both with Stubbs' (1971) results showing no such enhancement in a variety of second-order schedules, and with the position that any facilitative effects brief stimuli may have in second-order schedules is not due to their conditioned reinforcing value, established by pairing of those stimuli with primary reinforcement.

It should be noted that the procedure used here bears an interesting resemblance to a psychophysical procedure developed by Nevin (1970, Experiment 2). The major differences are that in Nevin's procedure: (a) the stimulus change (brief stimulus) occurred only on the

key on which the pigeon was responding (but a report of the stimulus change still consisted of a peck on a second key); (b) the probability of a brief stimulus at the end of each interval was 0.5 rather than 1.0; and (c) the brief stimulus was a threshold-level change in stimulus intensity. The results of that experiment, however, were quite different from ours (*cf.* Figure 10 of Nevin's experiment and Figure 4 of this experiment). First, the probability of reporting a brief stimulus (*i.e.*, of pecking the second key) was an increasing function of the number of intervals since the last primary reinforcement; second, the probability of a response during the last brief stimulus was less than 1.0. Of the procedural differences noted above, the one probably responsible for the differences in the results is the salience (intensity) of the stimulus change. Apparently, when the brief stimulus is a threshold-level signal it does not disrupt the simultaneous temporal control of responding.

EXPERIMENT 2.
DISCRIMINATION TRAINING; PUNISHMENT (BLACKOUT) FOR UNNECESSARY RESPONSES ON THE BRIEF-STIMULUS KEY

The results of Experiment 1 suggest that, on second-order schedules with brief-stimulus presentations, pigeons may not discriminate which component of the schedule is currently in force, since they respond similarly to all brief stimuli regardless of ordinal position. On the other hand, the "unnecessary" right-key response in no way decreased the pigeon's rate of reinforcement. Hence, it is possible that the unnecessary right-key responses were maintained simply because they had no negative consequences, not because of a failure to discriminate. Experiment 2 investigated whether or not an appropriate discrimination would be acquired when unnecessary right-key responses prevented delivery of primary reinforcement.

METHOD
Subjects and Apparatus

The same six subjects and the same apparatus described in Experiment 1 were used.

Procedure

A schedule of paired brief-stimulus presentations, as described in Experiment 1, was in effect for each pigeon for 20 sessions, *i.e.*, N-20: FR 8 (FI 15-sec); N-M: FR 4 (FI 30-sec); 6254: FR 2 (FI 60-sec); 38: FR 4 (FI 30-sec); N-N: FR 2 (FI 60-sec); 6498; FR 2 (FI 60-sec). After 20 sessions, the procedure was modified such that any right-key responses to the first brief stimulus produced a 15-sec blackout of the keys and the houselight, after which the schedule returned to the beginning of the first component. In other words, if the pigeon always pecked the right key during the first brief-stimulus presentation, no primary reinforcements would be obtained. If the subject reached the terminal component and failed to make a right-key response during the brief-stimulus presentation, that entire component was repeated until a primary reinforcement was obtained. It was planned subsequently to extend the contingency to later components (*e.g.*, the second brief stimulus of four), but the failure of the subjects to learn the initial discrimination precluded this. Sessions were terminated after 40 trials. Each trial consisted of either a response-produced blackout or primary reinforcement.

In a further attempt to reduce inappropriate responding to the brief stimulus, four subjects (6498, N-N, 38, 6254) were next exposed for 10 sessions to a schedule in which a blackout replaced the first brief stimulus in order to decrease responding to the right key at the end of the first component (*i.e.*, upon completion of the first component of the second-order schedule, the right key was dark for 2 sec, rather than being illuminated orange). Following these 10 sessions, the pigeons were returned to the preceding schedule for 10 additional sessions with right-key responses during the first brief stimulus producing a 15-sec blackout.

RESULTS

The probabilities of a right-key response during the first brief-stimulus presentation for each of the last three sessions with the paired brief stimulus are given in the first frame of Figure 6. (Only the results for 6498, N-N, 38, and 6254, which were exposed to all four conditions, are shown. There were no obvious differences in the data of the other two subjects). When punishment (blackout and return to the beginning of the first component) was introduced for right-key responses to the first brief stimulus (second frame), response probability did not decrease over the 20 sessions

that this procedure was in effect. Pigeon N-N did not respond every time to the first brief stimulus, and therefore received primary reinforcement for correct responding on 25 to 50% of the trials in some sessions, yet its behavior deteriorated over sessions, rather than improving.

The third frame of Figure 6 indicates that when a blackout of both keys replaced the first brief stimulus, all four pigeons ceased responding on the right key at the end of the first component, and thus obtained primary reinforcement at the end of every terminal component. However, this performance did not transfer to the punishment condition because all four pigeons again responded at their previous levels when the orange key color and the punishment condition were re-instated (fourth frame).

DISCUSSION

The results of Experiment 2 provide additional support for the assertion made in Experiment 1 that pigeons do not discriminate well between the components of second-order schedules of brief-stimulus presentation. During the punishment procedure, all six pigeons continued to emit right-key responses during the first brief-stimulus presentation, even though these responses prevented delivery of primary reinforcement. Further, the four pigeons that received 10 sessions of training on the appropriate response pattern all resumed responding on the right key during the initial-component brief stimulus when the right-key illumination in the first brief stimulus and the punishment condition were re-instated. The failure to respond differentially to brief stimuli terminating the first and last components of a second-order schedule under these conditions shows that pigeons not only fail to discriminate between components of second-order schedules of brief-stimulus presentation, but that they are unable to form such a discrimination even when failure to do so prevents delivery of primary reinforcement. The strength of this responding is suggested by its failure to extinguish even after 20 sessions with virtually no primary reinforcement. Finally, the behavior of Pigeon N-N is particularly instructive because this bird did not respond to the first brief-stimulus presentation on every trial, and therefore occasionally received terminal-component brief-stimulus presentations. Without these data it might be argued that the pigeons
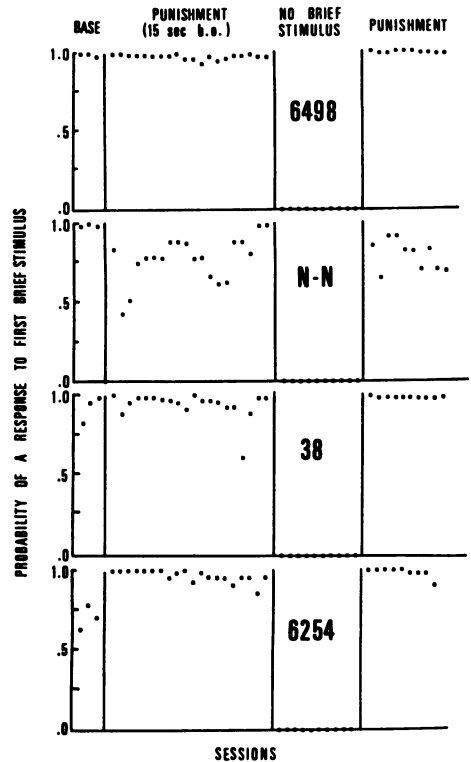

Fig. 6. Probability of a right-key response during the first brief stimulus following reinforcement for the last three sessions of the baseline procedure (paired brief stimulus), 20 sessions in which those responses were followed by a 15-sec blackout and return to the beginning of the first component, 10 sessions in which the right key was not illuminated during the first brief-stimulus presentation, and 10 sessions more of the punishment (blackout) condition.

discriminated the first-component brief-stimulus presentations from the last, but responses to the former were elicited much as they are said to be in the negative automaintenance procedure (Williams and Williams, 1969) or that the birds contacted the contingencies only infrequently. However, N-N failed to respond to the brief stimulus terminating the second component (which would produce primary reinforcement) with the same probability as it failed to respond to the brief-stimulus terminating the first component (which produced timeout). These data are shown in Figure 7 plotted as an ROC curve (Green and Swets, 1966). The probability of a response in the second brief stimulus (positive response contingency) is on the ordinate and the probability of a response in the first brief stimulus (negative response contingency) is on the abscissa.
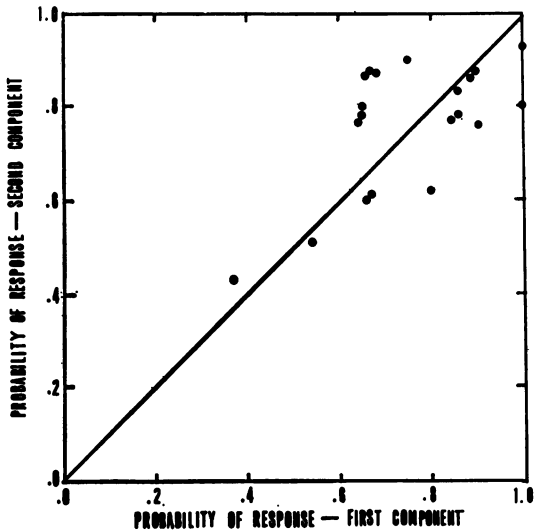
Fig. 7. Probabilities of a brief-stimulus key response for Subject N-N. The probability of a response during the first brief stimulus is given on the ordinate, and the probability of a response during the second brief stimulus is given on the abscissa. Each point represents the data from one session. The schedule was FR 2 (FI 60-sec) in which a right-key response during the first brief stimulus resulted in a 15-sec timeout, and a response during the second brief stimulus produced primary reinforcement.

According to the Theory of Signal Detection, the discriminability of the two events is indicated by the distance that the obtained data points are systematically displaced above the diagonal and the overall tendency to respond (response criterion) by the displacement of the data points toward the upper right-hand quadrant. Hence, the distribution of data points along the diagonal for Subject N-N indicates that while the probability of responding during a brief stimulus varied from session to session, there was virtually no discrimination of the first from the second brief-stimulus presentation.

EXPERIMENT 3.
DISCRIMINATION OF COMPONENTS IN CHAIN SCHEDULES

It was shown in Experiment 1 that on an FR X (FI Y) schedule of brief-stimulus presentations, pigeons do not respond differentially to the brief stimuli terminating the FI Y components; i.e., the number of responses per brief-stimulus presentation did not change systematically with the number of brief-stimulus presentations since the last reinforcement. In Experiment 2, punishment and special training were employed in an effort to enhance differential responding to successive brief-stimulus presentations, but both procedures were unsuccessful in this respect. These experiments indicate that discrimination of the ordinal position of successive components is poor when the components are signalled only by a brief-stimulus presentation at the end of each component. The inability of the cues associated with early components of chain schedules to maintain much responding, as compared to tandem and brief-stimulus schedules, suggests that the visual cues associated with these components more clearly signal the inaccessibility of primary reinforcement than do the temporal or numerical cues of the brief-stimulus schedules. Experiment 3 was designed to determine whether the addition of unique visual cues to each component would alter the pattern of brief-stimulus key responses.

METHOD

Subjects

Three different White Carneaux pigeons were used: N-J, 6448, and N-8. All had extensive experience with concurrent-chains schedules (e.g., Squires, 1972; Squires and Fantino, 1971).

Procedure

The response contingencies were identical to those in Experiment 1. Two- and four-component schedules were studied with paired brief-stimulus presentations, with a response to the brief-stimulus key required during the terminal-link brief stimulus. However, each component was signalled by a different color on the left key. During brief-stimulus presentations, the left key was dark and the right key was illuminated with yellow light. A change in the order of component colors was performed with both the two- and four-component schedules. Each condition was in effect for 20 sessions and each session consisted of 40 primary reinforcements. In one condition the final brief stimulus was removed, resulting in a schedule of unpaired brief-stimulus presentations with no right-key response requirement. Finally, all brief stimuli were removed for two subjects. The order of presentation of schedules and of stimuli is given in Table 2. Although each condition was to be in effect for 20 sessions,

Table 2

Order of experimental conditions, Experiment 3. The letters B, G, R, and O, under "stimuli" refer to blue, green, red, and orange respectively.

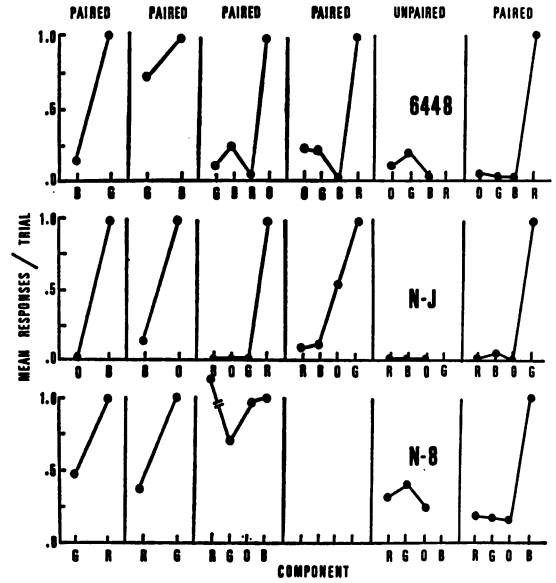| Subject	Schedule	Relation of Brief-stimulus to Food	Order	Stimuli
6448	FR 2 (FI 60-sec)	Paired	1	B, G
	FR 2 (FI 60-sec)	Paired	2	G, B
	FR 4 (FI 30-sec)	Paired	3	G, B, R, O
	FR 4 (FI 30-sec)	Paired	4	O, G, B, R
	FR 4 (FI 30-sec)	Unpaired	5	O, G, B, R
	FR 4 (FI 30-sec)	Paired	6	O, G, B, R
	FR 4 (FI 30-sec)	No brief stimulus	7	O, G, B, R
N-J	FR 2 (FI 60-sec)	Paired	1	O, B
	FR 2 (FI 60-sec)	Paired	2	B, O
	FR 4 (FI 30-sec)	Paired	3	B, O, G, R
	FR 4 (FI 30-sec)	Paired	4	R, B, O, G
	FR 4 (FI 30-sec)	Unpaired	5	R, B, O, G
	FR 4 (FI 30-sec)	Paired	6	R, B, O, G
	FR 4 (FI 30-sec)	No brief stimulus	7	R, B, O, G
N-8	FR 2 (FI 60-sec)	Paired	1	G, R
	FR 2 (FI 60-sec)	Paired	2	R, G
	FR 4 (FI 30-sec)	Paired	3	R, G, O, B
	FR 4 (FI 30-sec)	Unpaired	4	R, G, O, B
	FR 4 (FI 30-sec)	Paired	5	R, G, O, B

Fig. 8. Mean number of responses per brief stimulus over the last three sessions, for each link of the two- and four-component chains, presented in the order in which they were given. The components are indicated, in order, by the associated key color: blue (B), green (G), red (R), and orange (O). The headings at the top of each column indicate whether or not the stimulus was paired with primary reinforcement.

Subject N-8's behavior was unstable at the end of this period in some conditions, so extra sessions were conducted. For this reason, this subject completed fewer conditions.

RESULTS

Figure 8 shows the number of responses per brief stimulus at the end of each component of the chain schedules for each of the three subjects, presented (from left to right) in the order in which the conditions were presented. These are the means over the last three sessions at each condition. These data are analogous to those from the paired and unpaired brief-stimulus schedules (Experiment 1) presented in Figures 3 and 5. It is evident that the components of the chain schedule were well discriminated, since the subjects responded on all brief-stimulus presentations at the end of the terminal component but not in the earlier components, particularly in the four-component chain. The one exception was for Subject N-8 in the first four-component chain (third panel), but there is no obvious explanation for this exception. In the four-component chains, the unavailability of primary reinforcement appeared to be equally well discriminated across the first three components. Brief-stimulus key responding in the unpaired brief-stimulus condition was similar to that in the paired brief-stimulus conditions.

Figure 9 gives the left-key response rates as a function of the component of the chain schedule, for each of the three subjects. Control of responding by the visual and/or temporal stimuli is indicated by the fact that high response rates were usually maintained only in the terminal component. Subject 6448, however, sometimes responded at a high rate in the third component of the four-component chains also. (The decrease in rate from the third to the fourth component for this subject in one condition was due to the fact that it was making numerous unrecorded responses around the key during the fourth component.) The reason for the high third-component response rates is unclear, because these responses were not followed by brief-stimulus key responses, indicating that the unavailability of reinforcement was detected. This pattern was not observed in other subjects. For all subjects, response patterning on the left key was similar
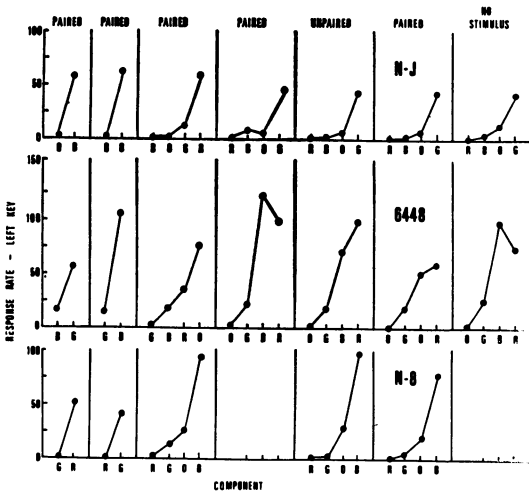
Fig. 9. Mean left-key response rates over the last three sessions for each component of each chain schedule. In the final condition (far right), there was no brief-stimulus presentations.

for the paired and unpaired brief-stimulus conditions, and for the condition in which there were no brief-stimulus presentations.

DISCUSSION

When exteroceptive cues were added to distinguish one component from the others, inappropriate brief-stimulus responses seldom occurred. Clearly, a conditional discrimination was being made so that the probability of a brief-stimulus key response was under the control of the preceding left-key color. This result weakens any explanation of the brief-stimulus responding in Experiment 1 on the basis of the density of reinforcement for these brief-stimulus key responses. In other words, it is not the case that the strength of these brief-stimulus key responses derived only from the fact that one of every four, for example, was reinforced, since this fact applies equally well to the chain and the brief-stimulus schedules; yet brief-stimulus key responding was maintained only in the latter.

The Discussion of Experiment 1 suggested that the pairing of the brief stimulus with primary reinforcement may well have elicited right-key responding, as in automaintenance procedures. The findings of Gamzu and Williams (1971, 1973) and Gamzu and Schwartz (1973) suggest that only stimuli signalling an increase in the probability of reinforcement will elicit responding. Since in the present ex-

periment, right-key responses were confined mainly to the terminal link, it appears that the brief stimuli at the end of earlier components of the chain did not signal an increase in reinforcement probability, and thus did not induce responding.

GENERAL DISCUSSION

These experiments strongly suggest that the pigeon does not accurately discriminate the reinforcement contingencies on brief-stimulus schedules (i.e., the availability of primary reinforcement only in the terminal component and not in earlier components) because the probability of a brief-stimulus key response was virtually constant over components (Experiments 1 and 2). The only problem with this conclusion is that it is obvious from Figures 1 and 2 that response rates on the left key increased somewhat as a function of the ordinal position of the component in the second-order schedule, suggesting the contrary conclusion that the pigeons discriminate between the components. Thus, the left- and right-key behaviors appear to be in conflict. There is evidence in the literature to suggest, however, that such acceleration may not be indicative of temporal (or nominal) discrimination at all. Byrd and Marr (1969) studied the behavior of pigeons on a variable-ratio (fixed interval) schedule of brief-stimulus presentations. Since on a variable-ratio schedule neither the number of components nor the time since the last primary reinforcement is predictive of food, response acceleration across components would not be expected if acceleration is solely a function of temporal or nominal discrimination. And yet their data (Figure 2) clearly suggest acceleration across the first few components. In fact, the amount of acceleration in the present experiments is quite comparable, supporting the statement in the introduction that these schedules might be functionally equivalent to VR (FI) schedules. (Interestingly, Byrd and Marr obtained less acceleration with the paired than with the unpaired brief stimulus and more suppression in later components, probably because their paired stimulus involved the hopper light. For a discussion of the effects of different types of brief stimuli see below.) It appears, then, that successive omissions of reinforcement, signalled by the brief stimulus, will result in higher and higher response rates even

in the absence of a dependency of primary reinforcement probability upon time since the last reinforcement. This effect is reminiscent of Amsel's theory of frustrative nonreward (e.g., Amsel and Roussel, 1952) and of Staddon's theory of the discriminative aftereffects of stimuli presented in lieu of primary reinforcement (Staddon, 1970, 1972).[2] Staddon's analysis is particularly relevant here. According to Staddon, stimuli that signal reinforcement omission have the same effect as primary reinforcement, but to a lesser degree, so that if the effect of primary reinforcement is a long postreinforcement pause, the effect of signalled reinforcement omission will be a shorter pause. In one particularly interesting experiment (Staddon, 1972) in which the probability of being reinforced at the end of a fixed-interval was conditional on whether or not the immediately preceding interval was terminated by reinforcement (R) or brief blackout (N), Staddon found that the pause following reinforcement was longer than the pause following blackout, even when the probability of successive reinforcements, $P(R/R)$, was 0.9, and the probability of reinforcement following blackout, $P(R/N)$, was 0.1. This suggests that it is the properties of the preceding stimulus, rather than the probability of a subsequent reinforcement, that controls responding. Hence, it seems reasonable to assume that the increase in response rate on the left key in Experiment 1, as a function of ordinal position of the component, was due to the omission of reinforcement at the end of successive components, rather than a discriminated increase in the probability of reinforcement. As in the Byrd and Marr (1969) study, the amount of disruption was inversely proportional to the ongoing response rate.

The present analysis is also closely related to the concept of "overshadowing". In the prototypic experiments on blocking and overshadowing, Kamin (1968, 1969) showed that control by a weak stimulus may be eliminated or "overshadowed" by a strong stimulus. Thus, in one of his experiments, only the light in a compound CS composed of a light and a weak noise gained control over responding. By analogy, one could argue that in the present experiments there are two types of stimuli available in the FR X (FI Y) second-order schedules: temporal stimuli, the amount of time that has elapsed since the last primary reinforcement, and visual stimuli, the brief-stimulus presentations. If it is assumed that temporal stimuli are less salient than visual stimuli for the pigeon, then the addition of brief stimuli (paired or unpaired) to the tandem schedule may overshadow the temporal (inhibitory) control and produce an apparent rate enhancement.[3] The effectiveness of the stimuli in the chain schedules in suppressing response rates in the early components further attests to the prepotency of visual over temporal stimuli (although in this case their effects work in concert rather than in opposition).

The failure to find any enhancement in responding due to the pairing of the brief stimuli with food contradicts several theories of conditioned reinforcement. First, it is clearly inconsistent with the pairing hypothesis, which states that the necessary and sufficient condition for the establishment of any arbitrary stimulus as a conditioned reinforcer is the pairing of that stimulus with primary reinforcement (Kelleher, 1966). Instead, the present results confirm those of Stubbs (1971), who also found no facilitation of response rates by paired as compared to unpaired brief stimuli, and they further extend those results because the failure to find any difference is even more striking under the present circumstances. The brief stimuli in the present experiment were longer (2 sec as opposed to 0.75 sec), probably more salient because they consisted of darkening one key and illuminating the other, and the paired brief stimulus, but not the unpaired, was an S^D for a second response. Be-

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[2]The authors wish to acknowledge fully the similarities between the present analysis and that of Staddon (1972). On the other hand, they also want to caution readers not to view the present account as a condensed or simplified version of Staddon's position and instead refer them to Staddon's full 53-page manuscript.

[3]In another experiment using these same subjects, performance on tandem and brief-stimulus schedules was compared. The most reliable effect of adding brief stimuli to a tandem schedule was a decrease in PRP. General rate increases across components occurred only to the extent that a decrease in PRP was accompanied by a decrease in the average interreinforcement interval. This is in agreement with previous experiments with FR X (FI Y) schedules and indicates that there is nothing anomalous about the present procedure, such as brief-stimulus duration, or the response requirement, that would make the present analysis inapplicable to all brief-stimulus schedules, (cf. Stubbs, 1969, 1971; Kelleher, 1966).

cause of this last fact, these results are also inconsistent with the discriminative-stimulus hypothesis of conditioned reinforcement, which states that any stimulus that is an effective discriminative stimulus for some response will also be a conditioned reinforcer. This would predict a clear superiority of the paired stimuli in these experiments, something that was not found. Finally, these data may have some bearing on the information hypothesis of conditioned reinforcement. The regularity with which the paired brief stimulus evoked a right-key response suggests that its occurrence signalled an increase in the momentary probability of primary reinforcement, *i.e.,* it provided "information" that reinforcement was momentarily more likely. Presumably, the unpaired brief stimulus provided only negative information, since its occurrence precluded the possibility of primary reinforcement for another fixed-interval cycle. The observing-response literature suggests that positive cues are conditioned reinforcers but negative cues are not (for a review, see Fantino, *in press*). The present results do not support that conclusion from the observing-response literature because the "positive" cues did not enhance left-key responding compared to the "negative" cues.

A fourth possibility suggested by Neuringer and Chung (1967) and by Stubbs (1971) is that any stimulus that occurs on the same schedule as the primary reinforcer (the FI schedule in this case) may become a conditioned reinforcer. Thus, it may be that both the paired and unpaired brief stimuli are conditioned reinforcers. However, if this were the case, one would expect that the presence of the brief stimuli would have enhanced behavior on the chain schedules, which they did not. Another possibility is that the mechanism underlying conditioned reinforcement is stimulus generalization, so that the more similar are the conditioned and primary reinforcers, the more effective will be the conditioned reinforcer. Since the paired and unpaired stimuli were identical in their similarity to primary reinforcement, their effects should have been the same. When the paired stimulus more closely resembles the primary reinforcer than does the unpaired stimulus it will, by this hypothesis, differentially enhance response rates. In support of this hypothesis, a study by Malagodi, DeWeese, and Johnston (1973) demonstrated the clear superiority of paired brief stimuli over unpaired

brief stimuli (each added at the end of each component of a chain schedule as in our Experiment 3) when the paired brief stimuli were brief hopper presentations. J. Zimmerman and his co-workers (Zimmerman, 1969; Zimmerman and Hanford, 1966, 1968) have also maintained considerable responding when the consequence of responding was production of a short hopper presentation (too short to allow eating) and delay of longer hopper presentations. The apparent superiority of a brief hopper presentation to other paired brief stimuli may be attributed to its resemblance to the primary reinforcer. This effectiveness may either be due to the consequent conditioned reinforcing effects of those stimuli, or due to the failure to discriminate whether the hopper presentations will be short or long. The latter explanation would be similar to the failure-to-discriminate hypothesis suggested above (the "conditioned confusion" theory, Fantino, *in press*). The differences in these two explanations (conditioned reinforcement *versus* generalization) is crucial because the latter explanation obviates any need for a separate *conditioned* reinforcement concept under these circumstances. The utility of the concept of conditioned reinforcement lies in the prediction that an arbitrary stimulus may become a conditioned reinforcer. If only those stimuli that cannot be discriminated from primary reinforcement are effective, a separate concept is no longer required.

These experiments suggest the importance of addressing the question of what the organism learns on a given schedule of reinforcement, and how this is determined by the particular stimuli employed. Although it may still be possible to invoke conditioned reinforcement as an explanatory mechanism for the behavior on different second-order schedules, at the present time we feel it is more parsimonious to explain the behavior in terms of the discriminative properties of the stimuli and of the salience of the stimuli for the particular organism.

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