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Choice as a Dependent Measure in Autoshaping: Sensitivity to Frequency and Duration of Food Presentation

Mitchell Jon Picker
Western Michigan University

CHOICE AS A DEPENDENT MEASURE IN AUTOSHAPING: SENSITIVITY TO FREQUENCY AND DURATION OF FOOD PRESENTATION

by

Mitchell Jon Picker

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Mitchell Jon Picker, M.A.

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Previous investigations have shown that rate, latency, and percentage of trials with at least one response are somewhat insensitive measures of the strength of autoshaped responding. In two experiments, nine pigeons were exposed to an autoshaping procedure in which the successive presentation of three stimuli were followed by food on either 100%, 50%, or 0% of the trials. Choice testing involved the simultaneous presentation of the three stimuli. In Experiment I, all pigeons consistently directed their initial choice responses and the majority of subsequent responses to the stimulus always followed by food. In Experiment II, rate, latency, and percentage of trials with at least one response did not change appreciable as a function of duration of feeder presentations. However, choice responding was lawfully affected by duration of feeder presentations. These data suggest that choice is perhaps a more sensitive measure of the strength of autoshaped responding.

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CHAPTER I

Introduction

When response-independent food presentations are made conditional upon prior key illuminations, food deprived pigeons eventually approach, orient toward, and finally peck the illuminated key at moderately high rates. This phenomenon has been referred to as autoshaping (Brown and Jenkins, 1968). Since the initial observation of the autoshaped response, the variables affecting its acquisition and maintenance have been analyzed in several species (for reviews see Hearst and Jenkins, 1974; Locurto, Terrace and Gibbon, 1981; Schwartz and Gamzu, 1977). Although autoshaping paradigmatically resembles classical conditioning, specifying only the relation between a conditional stimulus (key illumination) and an unconditional stimulus (food delivery), a cursory review of the autoshaping literature clearly reveals Skinner's influence. For instance, numerous experiments have explored the role of response-food contingencies in the acquisition and maintenance of the autoshaped response (e.g., Hursh, Navarick and Fantino, 1974; Williams and Williams, 1969). In addition, response rate, the dependent measure strongly advocated by Skinner (1938, 1966), has been commonly used to index the strength of autoshaped responding, even though Nevin (1974, 1979) has recently questioned its value as a measure of response strength under schedules of operant reinforcement.

One independent variable that has been studied parametrically with respect to several dependent variables is the percentage of key

illuminations followed by food. Gonzalez (1974) reported that when pigeons were exposed to 0, 12.5, 25, 50, and 100% key light-food pairings, overall response rate was characterized by an inverted U-shaped function; rates were highest during the 50% condition and decreased slightly as the percentage departed from this value. The average latency to the first response varied inversely with the percentage of trials followed by food. The percentage of key illuminations during which at least one response occurred was directly related to the percentage of pairings, although almost all key illuminations evoked responding under both the 50% and 100% conditions. Subsequent investigations have confirmed Gonzalez' initial findings (Gibbon, Farrell, Locurto, Duncan and Terrace, 1980; Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger and Ricci, 1975; Poling and Thompson, 1977). Gibbon et al. (1980) also reported that the temporal distribution of responding across the period of key illumination was affected by the percentage of key light-food pairings. At the higher percentages (75 and 100%), responding was evenly distributed across the trial or decreased as the interval elapsed, while at lower percentages (19, 33 and 50%) responding gradually increased across the interval. Although this suggests that the different percentage pairings exerted differential effects, it does not indicate which condition was associated with the greatest response strength.

The results of these and other (Picker, Fath, Sobeck, and Malott, Reference Note 1) experiments suggests that the sensitivity of responding to changes in key light-food pairings depend crucially on

the aspect of behavior being considered and the range of probabilities compared. With respect to response rate, a 50% pairing seems to evoke stronger responding than a 100% pairing; this relation is reversed with respect to latency. However, when 25% and 100% pairings are considered, latency is shorter and response rate higher in the latter condition.

Beyond failing to covary in some instances, response rate and response latency in autoshaping paradigms, like key illuminations with at least one response, often are not highly sensitive to variables known to affect behavior under other circumstances. One of these is duration of food presentation. This parameter has been shown to influence the rate and pattern of operant responding under a range of conditions (e.g., Shettleworth and Nevin, 1965; Todorov, 1973) and might be expected to affect autoshaped responding in a similar manner. Further, if a classical conditioning model of autoshaping is accepted, changes in length of access to food alter the magnitude of the unconditional stimulus; such changes have been shown to strongly affect the strength of the conditional response in many conventional procedures (e.g., Mackintosh, 1974, p. 70-71). However, when response rate, latency, and key illuminations with a response are considered, the duration of food presentation exercises only weak control over autoshaped responding (Balsam, Brownstein and Shull, 1978; Balsam and Payne, 1979; Perkins et al., 1975).

The present studies examined several dependent variables in autoshaping procedures as a function of both the percentage of key

illuminations followed by food (Experiment I) and the duration of food presentations (Experiment II). As in earlier studies, response latency, rate, and distribution, and the number of key illuminations with a response, were recorded. Response duration, a variable known to be sensitive to some manipulations under autoshaping procedures (e.g., Schwartz, 1977) was also determined. However, in contrast to earlier studies, concurrent choice trials were occasionally arranged. During training, sequential key illuminations that differed in spatial locus and color were differentially associated with particular probabilities and durations of food delivery. During testing, these key illuminations were presented simultaneously. While choice is a commonly used and highly sensitive measure of behavior under operant reinforcement schedules (e.g., deVilliers, 1977), where response-stimulus (reinforcer) relations are prescribed, it is not clear whether choice is a sensitive dependent measure under autoshaping procedures. However, some data suggest it may be.

Williams and Williams (1969) first studied choice using an autoshaping paradigm. In their procedure, pigeons were exposed to two simultaneously illuminated keys. A peck on one key, designated the negatively contingent key, extinguished the key lights and prevented the delivery of food. Pecks on the other key, designated the irrelevant key, had no scheduled consequences. If pecks were directed at the irrevelant key or did not occur, food was delivered after 8 seconds. During the initial sessions, pecking occurred at equal rates on both keys. However, during subsequent sessions the frequency

of pecking the irrelevant key increased while pecking the negatively contingent key was eliminated. These results were systematically replicated in a latter study by Schwartz and Williams (1972).

Fisher and Catania (1977) also used choice as an index of response strength. These authors investigated the effects of feeder light color on the acquisition of pigeons' autoshaped pecking. In this study, pigeons were initially exposed to the simultaneous illumination of two distinctly colored keys followed by feeder presentations. The color of the feeder light was identical to one of the two key colors. For all subjects the initial autoshaped peck occurred to the key color that matched the feeder color, and subsequent pecks were also predominantly directed at this key. In this experiment, unlike that of Williams and Williams (1969) and Schwartz and Williams (1972), choice responding had no programmed consequences. Fisher and Catania's (1977) data suggest that choice responding may be lawfully related to environmental events even when such responding is without scheduled consequences. The present experiments further explore this possibility.

Experiment I: Rationale

This experiment investigated the effects of probability of food presentation on choice responding. In addition, this study contrasted the different dependent measures previously used as dependent variables in autoshaping paradigms, i.e., trials with a response, response latency, rate, and duration, and temporal distribution of pecking.

CHAPTER II

Method

Subjects

Nine experimentally naive barren-hen White Carneaux pigeons, approximately 6.5 years old, served as subjects. The birds were obtained from the Palmetto Pigeon Plant (Sumter, SC) and were maintained at 80% of their free-feeding body weights. Each bird was individually housed with free access to grit and water in a constantly illuminated room maintained at 23°C.

Apparatus

Three Lehigh Valley Electronics pigeon chambers measuring 32.5 cm long, 36 cm high, and 35 cm wide were employed. In each chamber, three keys 2.5 cm in diameter were located 26 cm from the bottom of the intelligence panel, approximately 7 cm apart. Each key could be illuminated in red, green, or a white cross. A minimum force of 0.2N was required for key operation. An aperture 6 cm in length and 5 cm in width horizontally centered on the intelligence panel 12.5 cm above the floor allowed access to a hopper filled with mixed grain when the hopper was raised. A 7.5-W white bulb illuminated the aperture when the hopper was raised. A 7.5-W white lamp centrally mounted 33 cm from the chamber floor provided continuous illumination, while a fan provided masking noise and ventilation.

Scheduling of experimental events, data collection, and data analysis were accomplished through the use of a Digital Equipment Corporation PDP-8/f minicomputer using interfacing and software (SUPERSKED) provided by State Systems Inc. (Kalamazoo, MI). Response durations were collected by Durpat software (Snapper and Inglis, 1981), also provided by State Systems Inc.

Procedure

Magazine Training. Prior to the start of the experiment proper, all subjects were exposed to an identical hopper training program. During the first session, each bird was placed in the experimental chamber for a 10-min habituation period, following which it was manually held directly in front of the illuminated hopper aperture with the hopper raised. After the subject ate from the hopper, the hopper was lowered and immediately raised again for 10 seconds, then lowered again. This procedure was repeated until the subject consistently ate from the raised hopper. After a subject did so, it was exposed to 40 food presentations programmed under a random-time schedule with a mean intertrial interval of 45 seconds (RT 45-sec). Initially, the hopper was presented for 10 sec which was reduced over 10 presentations to 4 sec. Each subject was then exposed to two additional training sessions each consisting of 40 4-sec hopper presentations under a RT 45-sec schedule.

Baseline. All subjects were exposed to a forward pairing auto-

shaping procedure (Brown and Jenkins, 1968). Each autoshaping trial consisted of a 6-sec illumination of one of the three keys in red, green, or with a white cross. The order in which the stimuli were presented, and the keys where they appeared, were truly random. The termination of each stimulus was followed by food delivery (4-sec) with a specified probability. The percentage of key illuminations followed by food was 100%, 50%, and 0% for the red, cross, and green stimuli, respectively. Presentation of each stimulus occurred under a RT 45-sec schedule which was not operative during key illuminations or food presentations. On the average, each stimulus was presented 20 times per session with a range across sessions of 8-32. After 60 trials the houselight was extinguished and the session terminated. Throughout all experiments key pecking had no scheduled consequences. These conditions remained in effect for 70 sessions, during which each bird received one session per day, six days per week.

Testing. All experimental conditions were identical to baseline sessions except choice trials were occasionally presented. For 10 consecutive sessions, 2-5 choice trials occurred each day. Each choice trial consisted of the simultaneous presentation of the three stimuli (red, cross, and green) in one of the six possible combinations of color and position. Prior to the testing phase subjects were randomly assigned to one of three groups, each containing three birds. The only difference between groups was the probability of food presentation following choice trials. For Group I, all choice trials

were followed by 4-sec access to grain. For Group II, half of the choice trials were followed by food, while for Group III, choice trials were never followed by food. Across the 10 test sessions the total number of choice trials for individual birds ranges from 42-50 with a mean of 45. Successive trial presentations continued during these sessions, as described above.

Data Collection and Analysis. During baseline sessions, response rate, latency (time from onset of a trial to the first response), duration, and temporal distribution data, as well as trials with at least one response, were recorded separately for the red, cross and green stimuli. Three rate measures were calculated: overall rate (total responses during all key illuminations/total time of all key illuminations), run rate (total responses during all key illuminations/ total time minus the total latency to the first peck during all key illuminations), and rate during trials with a response (total responses during all key illuminations/total time of all key illuminations in which at least one response occurred). Response distributions were calculated by recording the number of pecks emitted in each of the twelve 0.5-sec intervals (bins) from the onset to the offset of key illuminations; response durations, in milliseconds, also were recorded across 0.5-sec bins. During each simultaneous choice trial, the location and latency of the first response was recorded, as was the number of responses emitted to each stimulus. The number of instances in which a bird switched from one key to another also was determined.

Data similar to those recorded during baseline sessions (above) were collected for sequential stimulus presentations during sessions in which choice trials were arranged.

CHAPTER III

Results

Red (100% key light-food pairing) and cross (50% pairing) key illuminations consistently evoked responding; green key illuminations (0% pairing) did not. Thus, data for green illuminations are not presented. Figure 1 shows the overall response rate, run rate, and rate during trials with at least one response during red and cross key illuminations. Each data point represents the mean across the last five days of baseline (sessions 66 through 70). Five of the nine subjects consistently demonstrated higher overall rates during cross key illuminations (50% pairing), while four birds evidenced approximately equal overall rates during red (100% pairing) and cross key illuminations. With two exceptions, all birds emitted at least one response during virtually all red and cross illuminations (Table 1). Thus, for 7 birds overall response rate and response rate during trials with at least one response were nearly identical. Overall, in 7 of 9 birds, mean response rate during trials with a response was higher during cross illuminations (50% pairing) than during red (100% pairing) illuminations.

For eight of the nine subjects, mean latency to the first response was shorter during red illuminations than during cross illuminations. The largest differences in mean latencies were 1.7, 1.4, and 2.1 sec (P31, P32, and P33, respectively); the differences for the five other birds were less than 0.7 sec, as shown in Table 1.

Figure 1. Mean overall response rate, run rate, and rate during trials with at least one response for each bird during the final five baseline sessions (66-70) of Experiment I. Rates are graphed separately for red illuminations, always followed by food, and cross illuminations, followed by food 50% of the time. During Experiment I, all feeder presentations were 4-sec in duration. The vertical lines represent $\pm$1 standard deviation.

FIGURE 1

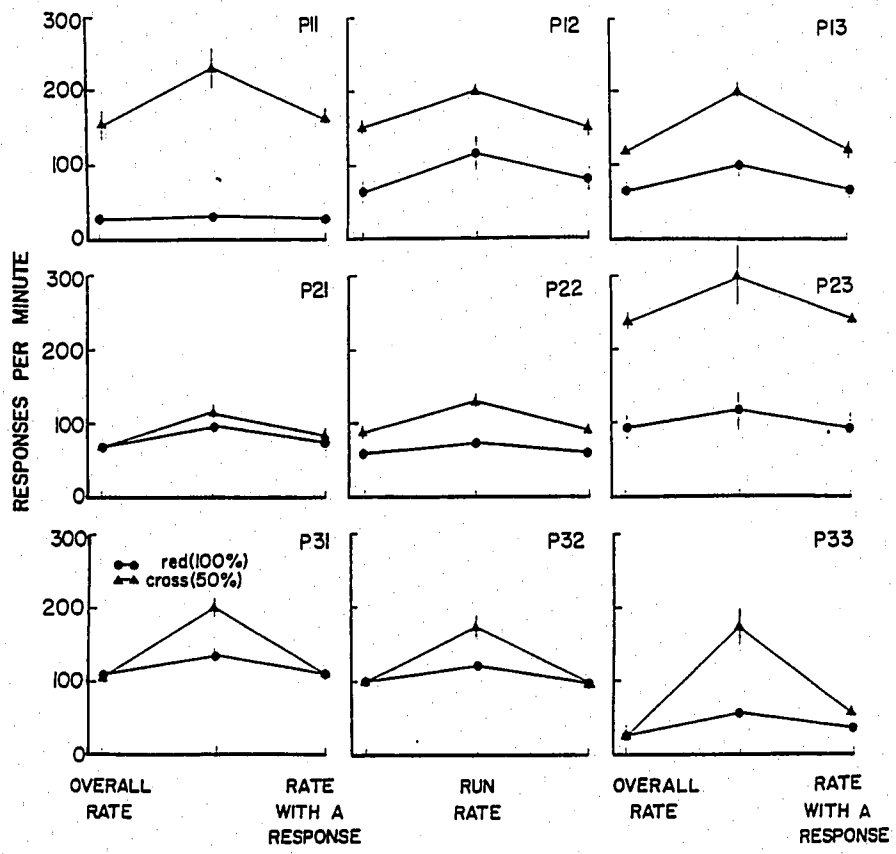


Table 1. Mean response latency and mean percentage of trials with a response during sessions 66-70 of Experiment I. Values under S.D. represent one standard deviation. Red illuminations were always followed by 4-sec access to food, while 50% of cross illuminations were followed by 4-sec access to food on half of the trials.

TABLE 1

	Latency (Sec)				Trials w/Response			
Subject	Red	S.D.	Cross	S.D.	Red	S.D.	Cross	S.D.
P11	1.5	0.2	1.7	0.1	89	6.7	96	3.7
P12	1.7	0.2	1.4	0.1	83	12.4	98	2.8
P13	2.0	0.3	2.4	0.2	95	6.6	100	0.0
P21	1.4	0.3	1.6	0.3	96	6.1	90	5.5
P22	1.2	0.1	1.9	0.2	100	0.0	98	2.2
P23	1.2	0.1	1.3	0.1	100	0.0	100	0.0
P31	1.1	0.1	2.7	0.4	100	0.0	100	0.0
P32	1.2	0.2	2.6	0.1	100	0.0	99	1.8
P33	2.3	0.4	4.4	0.5	76	14.0	65	3.7

As these latency data suggest, run rates for all birds were higher during cross illuminations (50% pairing) than during red illuminations (100% pairing).

The temporal distribution of responding during red and cross key illuminations is shown in Figure 2, which depicts the percentage of total responses emitted in 0.5-sec bins across the 6 sec of key illuminations. In this figure, a flat function would represent an even distribution of responses across the interval, while a positively accelerated function would indicate that rate increased as a function of time. During red illuminations, response rate peaked early in the trial and either remained constant or decreased as the interval progressed. Responding during cross illuminations was characterized by a positively accelerated function, i.e., rate increased across time. Differential response patterning during red and cross illuminations was evident in all subjects regardless of baseline response rate during the two stimuli. Median response durations were 6 milliseconds for both red and cross illuminations and did not change lawfully across the interval of key illumination.

Responding during sequential key illuminations was not affected by the introduction of simultaneous choice trials. Figure 3 shows the percentage of choice trials in which the first response was emitted to the red stimulus and the percentage of trials in which the first response was emitted to the cross stimulus. (Responses during choice trials were never directed toward the green stimulus, which was never followed by food.) During the first choice trial, all subjects made

Figure 2. Percent total responses emitted by each bird during successive twelths of the trial for red illuminations, which were always followed by food and for cross illuminations, followed by food 50% of the time. During Experiment I, all feeder presentations were 4-sec in duration. Each data point is based on the final five baseline sessions (66-70) of Experiment I.

FIGURE 2

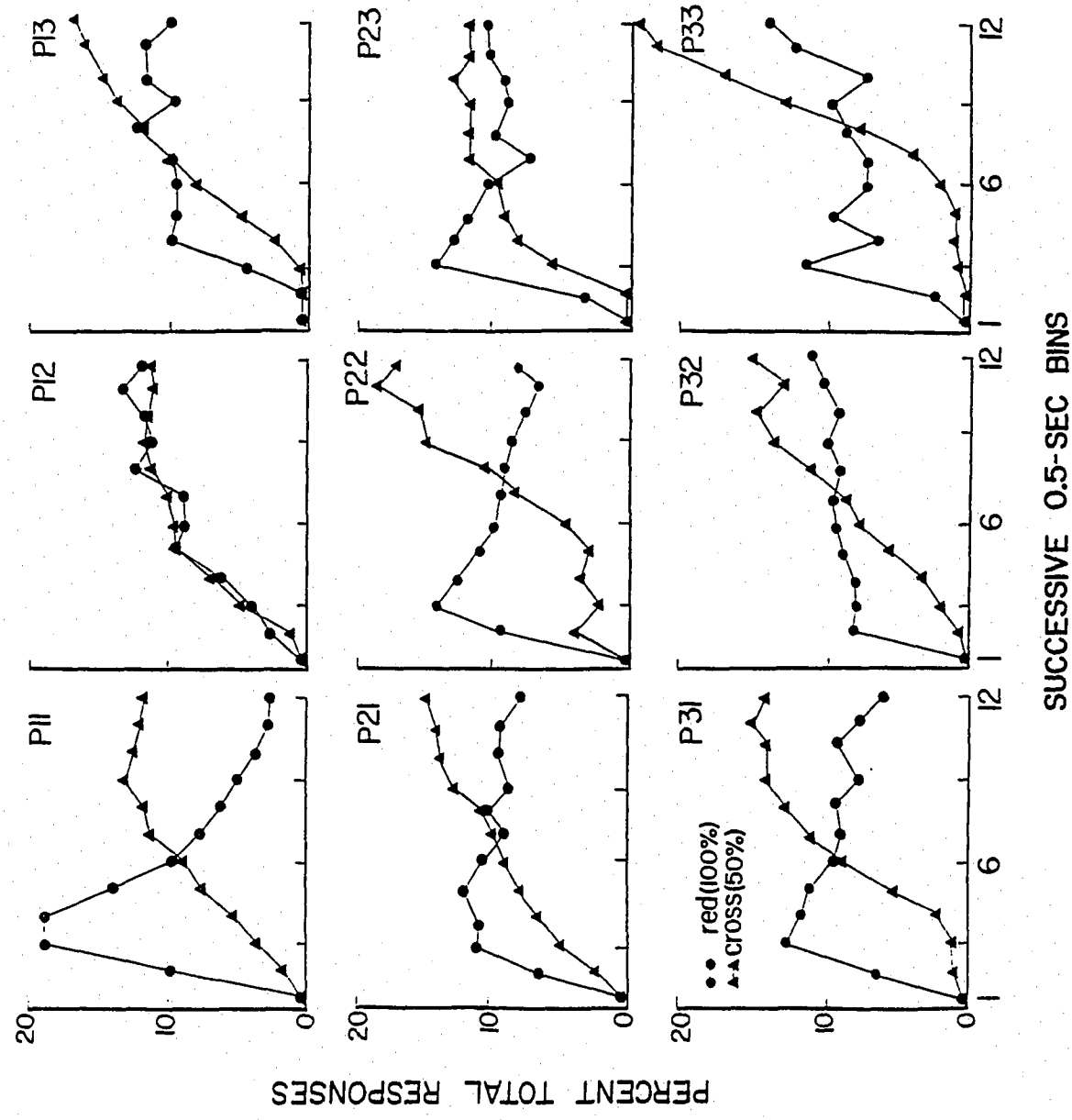
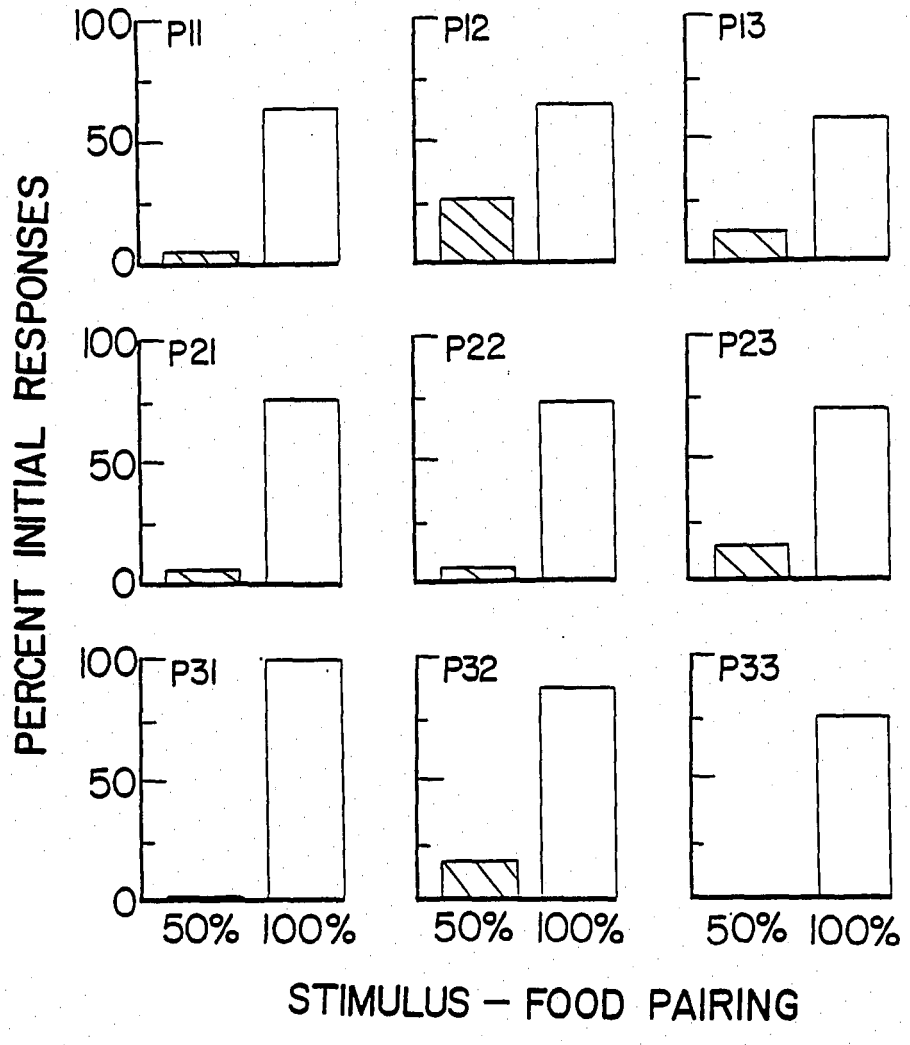


Figure 3. Percent of initial choice responses directed to the red and cross stimuli by each bird during the 10 test sessions (71-80) of Experiment I. These data represent only the first response during each choice trial. During training, the red stimulus was always followed by food (4-sec access), while the cross was followed by food (4-sec access) 50% of the time. Choice trials were never followed by food for P11, P12, and P13; were always followed by food for P21, P22, and P23; and were followed by food 50% of the time for P31, P32, and P33.

FIGURE 3

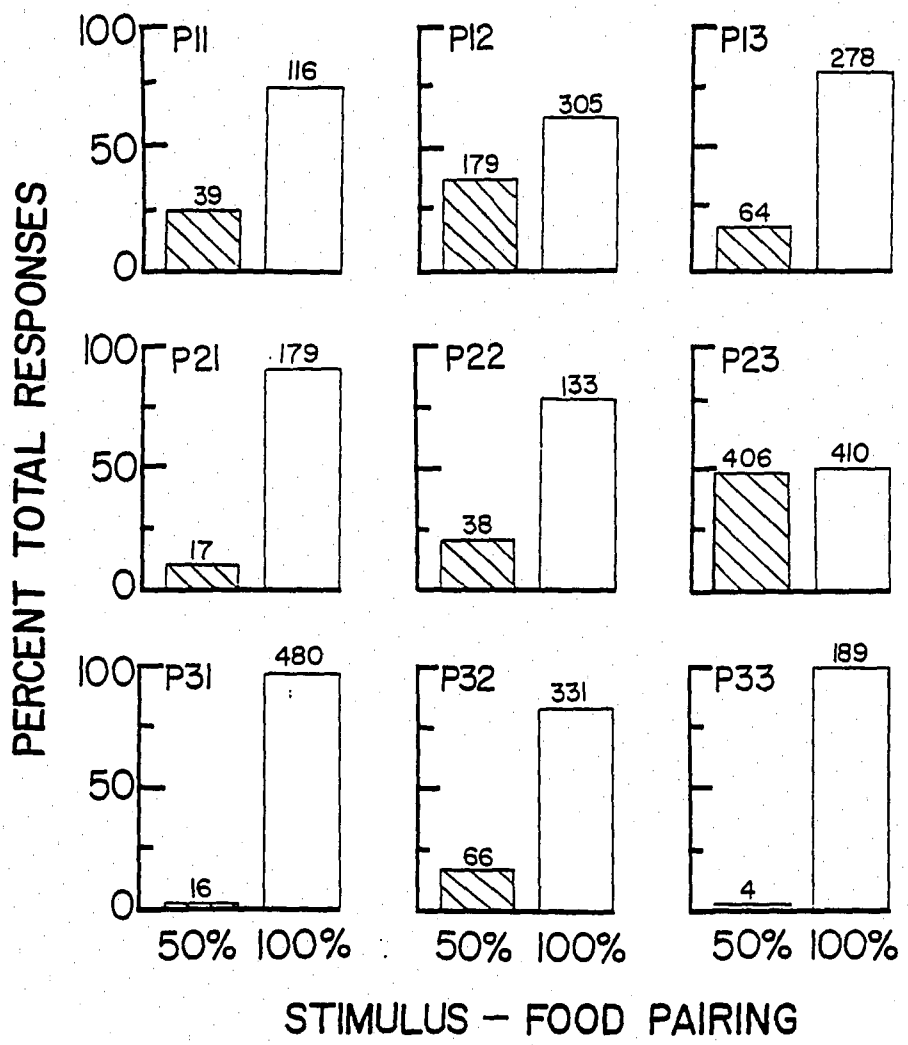


the initial response to the red stimulus. Across all choice trials in which at least one response occurred, the first response was emitted to the red stimulus in 299 of 357 instances. During all choice trials each bird responded more often to the red stimulus than to the cross; performance did not obviously differ in birds that received food following 100, 50, or 0% of choice trials. The preference for the red stimulus was evident in total response allocation, shown in Figure 4, as well as in the allocation of the initial response.

Interestingly, in 16 of 58 cases (28%) where the initial response was made to the cross stimulus, birds switched keys and began responding on the red stimulus. In contrast, of the 299 trials where the initial response was made to the red stimulus, the pigeons switched keys in only 16 instances (5%). On the average, the mean latency for a response to the red stimulus was one second longer on choice trials than on non-choice trials. Too few choice responses were made to the cross for a meaningful latency figure to be calculated.

Figure 4. Percent of total choice responses directed to the red and cross stimuli by each bird during the 10 test sessions (71-80) of Experiment I. Numbers directly above each bar represent the actual number of responses emitted. During training, the red stimulus was always followed by food, while the cross was followed by food 50% of the time. Choice trials were never followed by food for P11, P12, and P13; were always followed by food for P21, P22, and P23; and were followed by food 50% of the time for P31, P32, and P33.

FIGURE 4



CHAPTER IV

Discussion

The results of this experiment generally confirm previous findings (e.g., Gonzalez, 1974) indicating that key illuminations followed by food 50 and 100% of the time engender sustained pecking, while key illuminations never followed by food do not. Our findings also parallel previous data indicating that 50% key light-food pairings may evoke higher overall response rates than 100% pairings (Gibbon et al., 1980; Gonzalez, 1974; Perkins et al., 1975; Picker et al., Reference Note 1; Poling and Thompson, 1977). However, in the present study and in earlier investigations, these differences were small and not consistently evidenced by all subjects. For example, only five of our nine birds responded more rapidly during the stimulus paired with food on 50% of the trials.

Temporal distribution of responding differed as a function of whether key illuminations were always or intermittently followed by food, a finding consistent with data repoted by Gibbon et al. (1980). In both studies, key-pecking gradually increased across a stimulus intermittently followed by food. However, in contrast to our findings, those authors observed an inverted U-shaped gradient for the responding of birds presented with stimuli followed by food with a high probability. In attempting to account for this pattern, they suggested that, "the temporal distribution of reinforcement time in the higher probability groups may have 'released' a consummatory behavior pattern directed

at the hopper, which was ethologically more appropriate to the imminent consumption of grain (p. 55)." This consummatory behavior was assumed to be incompatible with key pecking. In the present study, pecking during the last 0.5 sec of red key illuminations decreased slightly in five birds relative to the preceding 0.5-sec bin, while four pigeons showed an increase in responding during this period. This suggests that the birds were not consistently emitting "consummatory" (e.g., hopper approach) responses incompatible with key pecking. However, Gibbon et al. reported data following only 15 sessions of autoshaping after acquisition of key pecking, while in the present study data are reported following 66 sessions of autoshaping. It is well established in the classical conditioning literature that responding often shifts toward the end of the conditional stimulus as a function of repeated exposure (Kimmel and Burns, 1975), and a retrospective analysis of our baseline data does in fact indicate the existence of an inverted U-shaped gradient early in training.

The results of primary interest are those from the simultaneous choice condition. Choice, as defined by percentage of initial choice responses, was lawfully related to the percentage of trials followed by food. A clear preference for the red stimulus, always followed by food, rather than the cross stimulus followed by food with a likelihood of 50%, was obvious for all birds both with respect to the total number of responses emitted and the allocation of the first choice response. On the average, the pigeons made the first response to the

red (100% pairing) stimulus during 80% of the trials in which a response was emitted; they also allocated 84% of their total pecks to this stimulus. These figures are well above those expected if birds matched choice responses in proportion to the total access to food associated with the two stimuli. If simple matching occurred, one would expect the birds to allocate 67% of their responses to the stimulus always paired with 4-sec access to food.

According to deVilliers (1977, p. 233), "The most persuasive argument for any measure of response strength is an orderly relation between that measure and the frequency, duration, or immediacy of reinforcement." This study demonstrated that choice in an autoshaping procedure is sensitive to frequency of food presentations, but it is an empirical question as to whether choice in this procedure, which specified no dependent relation between the autoshaped pecking and the delivery of food, is also sensitive to such parameters as duration of food presentations. Experiment II evaluated this possibility.

CHAPTER V

Experiment II: Introduction and Rationale

This experiment addressed the question of whether choice is affected by the duration of food presentation in an autoshaping procedure. Previous research not using choice as a dependent variable has indicated that duration of access to food exerts only weak control over autoshaped pecking (Balsam and Payne, 1979; Gibbon and Balsam, 1981). Balsam et al. (1978, Experiment IIIA) found that 2-, 4-, and 8-sec feeder durations did not differentially affect the rate of pigeons' autoshaped pecking, although latency to the first response was inversely related to feeder duration. This latter finding was corroborated by Perkins et al. (1975) and Balsam and Payne (1979). Nothing is known presently concerning the effects of duration of food presentation on choice under autoshaping procedures, where responses are without programmed consequences. However, this variable is known to lawfully influence choice under free operant (deVilliers, 1977, p. 248-251) and discrete-trial operant (Young, 1981) procedures.

CHAPTER VI

Method

Subject and Apparatus

Eight of the nine pigeons that served in Experiment I were used. Subject P13 stopped responding during session 99 and was eliminated from the study. The apparatus was the same as that used in Experiment I.

Procedure

At the start of this experiment the conditions were identical to the baseline phase of Experiment I. Following 33 sessions under these conditions, subjects were randomly assigned to one of two groups. The only difference between groups was the duration of access to food associated with the red stimulus (100% pairing with food) and the cross stimulus (50% pairing with food). For Group I, 4- and 8-sec durations of food delivery were associated with the red and cross stimuli, respectively. For Group II, duration of food presentation was decreased to 2-sec following red illuminations and increased to 10-sec following cross illuminations. Red and cross illuminations were 6-sec in duration throughout the study. After 17 sessions under these conditions, all subjects were exposed to simultaneous choice tests for 10 sessions. Choice tests were identical to those described in Experiment I except choice trials for all subjects were never followed by food delivery. At the completion of choice testing, the four subjects that demonstrated

a reversal in preference (P12, P21, P23, and P33) relative to Experiment I were reexposed to the original baseline conditions; both red and cross stimuli were followed by 4-sec access to grain. Reversal of preference was defined as the total allocation of at least 60% of the initial choice responses to the cross stimulus. This stimulus, paired with food 50% of the time in both experiments, never elicited the majority of initial choice responses in Experiment I. For the subjects who did not meet this criterion (P11, P22, P31, and P32), feeder durations were increased to 14-sec following cross illuminations and decreased to 2-sec following red illuminations. This phase continued for 20 sessions and was followed by a second series of 10 sessions in which choice was accessed.

Finally, following five baseline recovery sessions, all birds were run under an extinction procedure where successive key illuminations continued to occur, but food was never delivered. Extinction sessions were run seven days per week and continued for 17 sessions, or until an individual bird failed to respond for two consecutive sessions.

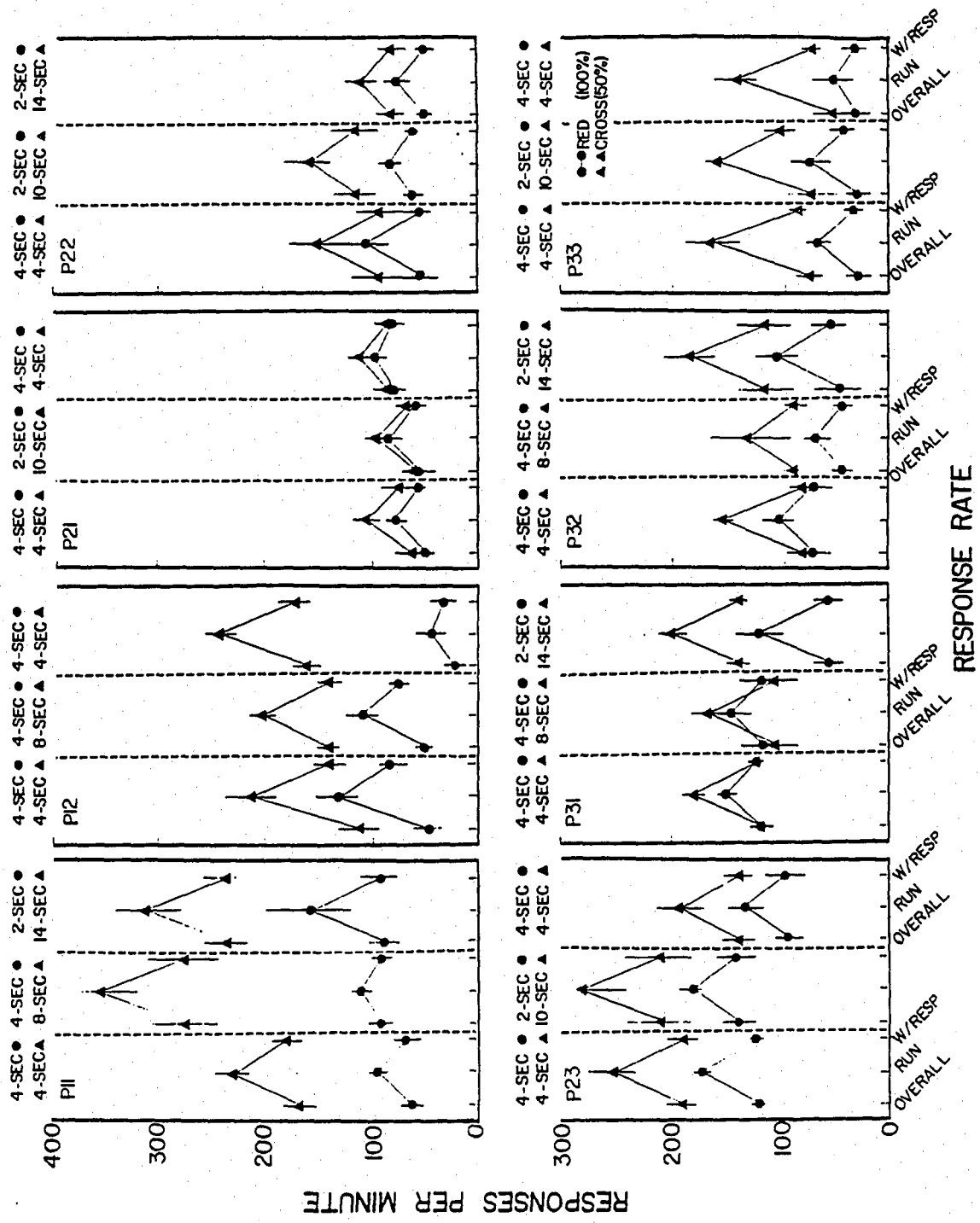
CHAPTER VII

Results

During baseline sessions of Experiment II, when feeder presentations remained at 4-sec following red and cross trials, no subject showed an appreciable change in overall response rate, run rate, or rate given a response relative to rates during baseline sessions (66-70) of Experiment I. However, latency to the first response when the red stimulus (100% pairing with food) was presented typically increased, while latency to respond when the cross (50% pairing) was presented decreased. By the final baseline session, three birds showed shorter latencies to the cross stimulus, a pattern evidenced by one of the nine birds in Experiment I. As the number of sessions increased, there was also a slight flattening of the temporal response gradients for both red and cross trials, although the two stimuli continued to produce different temporal patterns of responding. Response rates did not change for most subjects when the duration of feeder presentations following red and cross illuminations were changed to 2- and 10-sec or 4- and 8-sec, respectively. The absolute difference in latency to respond to the two stimuli continued to decrease, although for six birds latencies remained shorter during red illuminations. Response rates did not change appreciably in those subjects exposed to 2- and 14-sec feeder presentations, although latency was affected at these values. Figure 5 shows response rates for all birds as a function of feeder duration, while response

Figure 5. Mean overall response rate, run rate, and rate during trials with at least one response for each bird during the three phases of Experiment II. Rates are graphed separately for red illuminations, always followed by food, the cross illuminations, followed by food 50% of the time. Successive phases are separated by dotted lines, and duration of feeder presentations following the red and cross stimuli are noted above each frame. The first set of data points are means for sessions 109-113, the middle set means for sessions 126-130, and the final set of means for sessions 166-170. The vertical lines represent ± 1 standard deviation.

FIGURE 5



latencies and the percentage of trials with a response are presented in Table 2.

Figure 6 shows the percentage of choice trials in which the first response was directed to the red stimulus and to the cross stimulus under all conditions of Experiment II. In contrast to other measures, choice was quite sensitive to the duration of feeder presentations. In choice trials in which at least one response was emitted, the subjects with exposure to 4- and 8-sec feeder presentations directed the initial response to the cross stimulus in 84 of 181 instances (46%). Subjects exposed to 2- and 10-sec feeder presentations made the initial choice response to the cross stimulus in 119 of 169 instances (70%). When 4-sec feeder presentations were associated with the red stimulus and 8-sec presentations with the cross, one subject showed a preference for the cross, one chose both stimuli on an equal number of occasions, and two made more initial choice responses to the red stimulus, which was always followed by food. Note that all birds preferred the red stimulus in Experiment I, when all feeder presentations were 4-sec. In 5 of 94 cases (5%) where the initial response was made to the cross the birds switched keys; they did so in 9 of 87 instances (10%) where the first response was made to the red stimulus. Figure 7 shows the percentage of total responses allocated to each stimulus during choice trials. Using total responses an as indicator of preference, two birds preferred the stimulus that provided longer (8-sec) but less frequent feeder presentations, while two subjects preferred the stimulus

Table 2. Mean response latency and mean percentage of trials with a response as a function of the duration of feeder presentations following red and cross illuminations in Experiment II. Values under S.D. represent one standard deviation. Red illuminations were always followed by food, while 50% of cross illuminations were followed by food. The duration of feeder presentations appear in the final two columns.

TABLE 2

Sessions 109-113	Latency (Sec)				Trials w/Response				Feeder Duration (Sec)	
Subject	Red	S.D.	Cross	S.D.	Red	S.D.	Cross	S.D.	Red	Cross
P11	1.4	0.2	1.4	0.2	95	5.1	96	2.3	4	4
P12	2.2	0.2	2.2	0.4	58	12.3	83	13.7	4	4
P21	1.5	0.1	1.8	0.4	90	6.3	89	8.0	4	4
P22	1.4	0.2	2.2	0.7	97	2.4	98	1.8	4	4
P23	1.6	0.3	1.5	0.2	99	2.2	99	1.8	4	4
P31	1.2	0.1	2.1	0.5	100	0.0	100	0.0	4	4
P32	1.4	0.1	2.7	0.3	100	0.0	99	3.1	4	4
P33	1.9	0.2	3.0	0.4	83	10.0	91	11.9	4	4
Sessions 126-130										
P11	1.3	0.2	1.4	0.2	99	1.8	98	4.9	4	8
P12	2.0	0.4	1.7	0.2	72	7.3	99	3.1	4	8
P21	1.4	0.2	1.6	0.3	93	6.1	91	5.2	2	10
P22	1.3	0.2	1.5	0.3	100	0.0	100	0.0	2	10
P23	1.3	0.3	1.5	0.2	97	4.8	100	0.0	2	10
P31	1.2	0.4	2.5	0.8	100	0.0	100	0.0	4	8
P32	2.2	0.6	2.8	0.4	95	3.7	96	6.1	4	8
P33	2.3	0.4	2.0	0.2	75	18.3	69	31.5	2	10

Table 2
Continued

Sessions 166-170										
P11	2.4	0.7	1.6	0.5	95	3.9	97	2.7	2	14
P12	2.3	0.3	1.6	0.2	68	17.2	96	4.1	4	4
P21	1.1	0.2	1.4	0.2	98	3.0	07	7.6	4	4
P22	1.7	0.2	1.9	0.6	100	0.0	98	1.8	2	14
P23	1.7	0.4	1.7	0.8	96	2.7	100	0.0	4	4
P31	2.9	0.5	1.7	0.2	98	3.0	98	1.8	2	14
P32	2.6	0.9	2.2	0.5	80	15.1	98	3.0	2	14
P33	2.3	0.3	2.9	0.2	96	3.7	80	20.7	4	4

Figure 6. Percent of initial choice responses directed to the red and cross stimuli by each bird during the two test phase of Experiment II. During training, the red stimulus was always followed by food presentations of the listed duration, while the cross was followed by food presentations of the listed duration 50% of the time. For all subjects, choice trials were never followed by food.

FIGURE 6

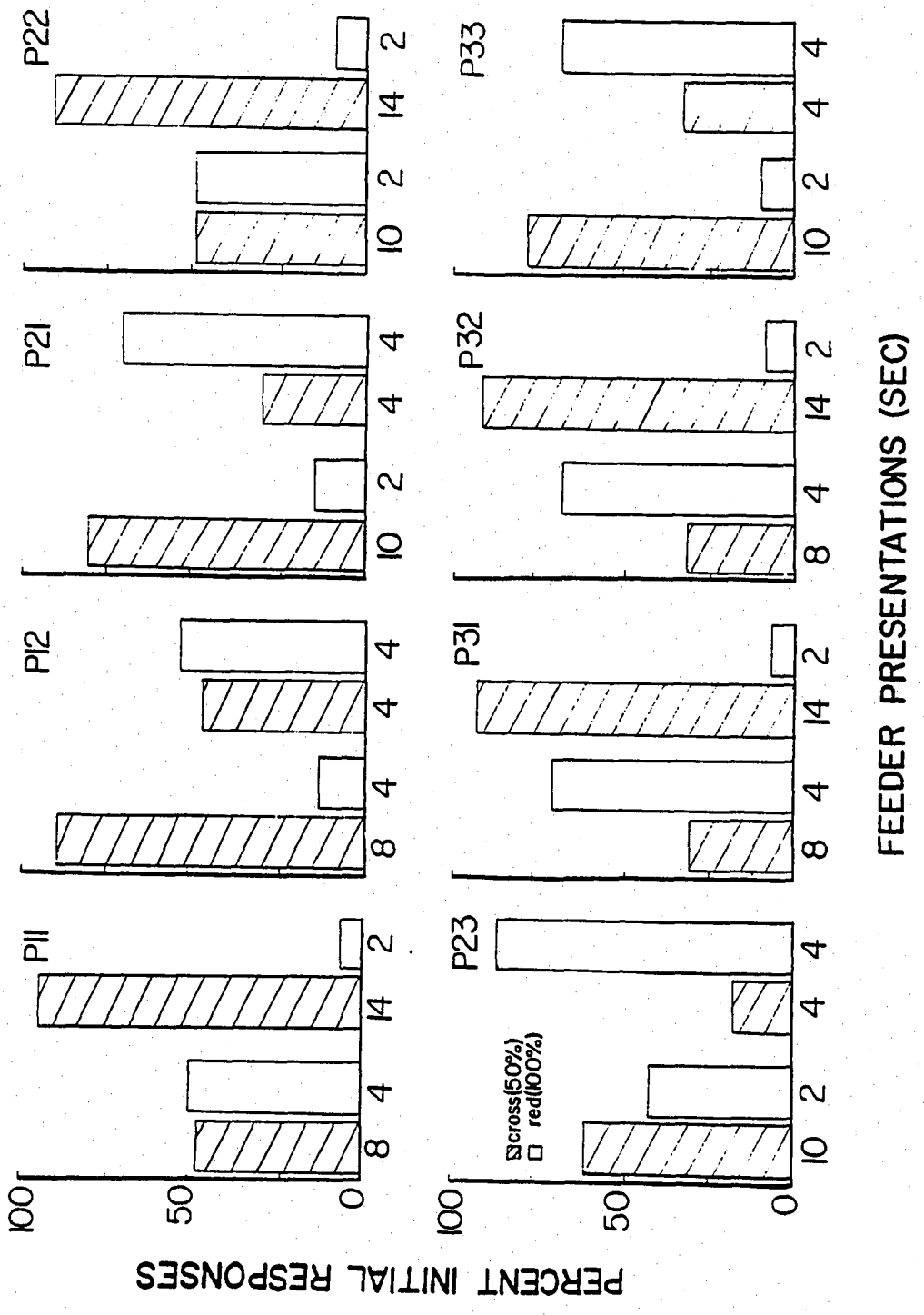
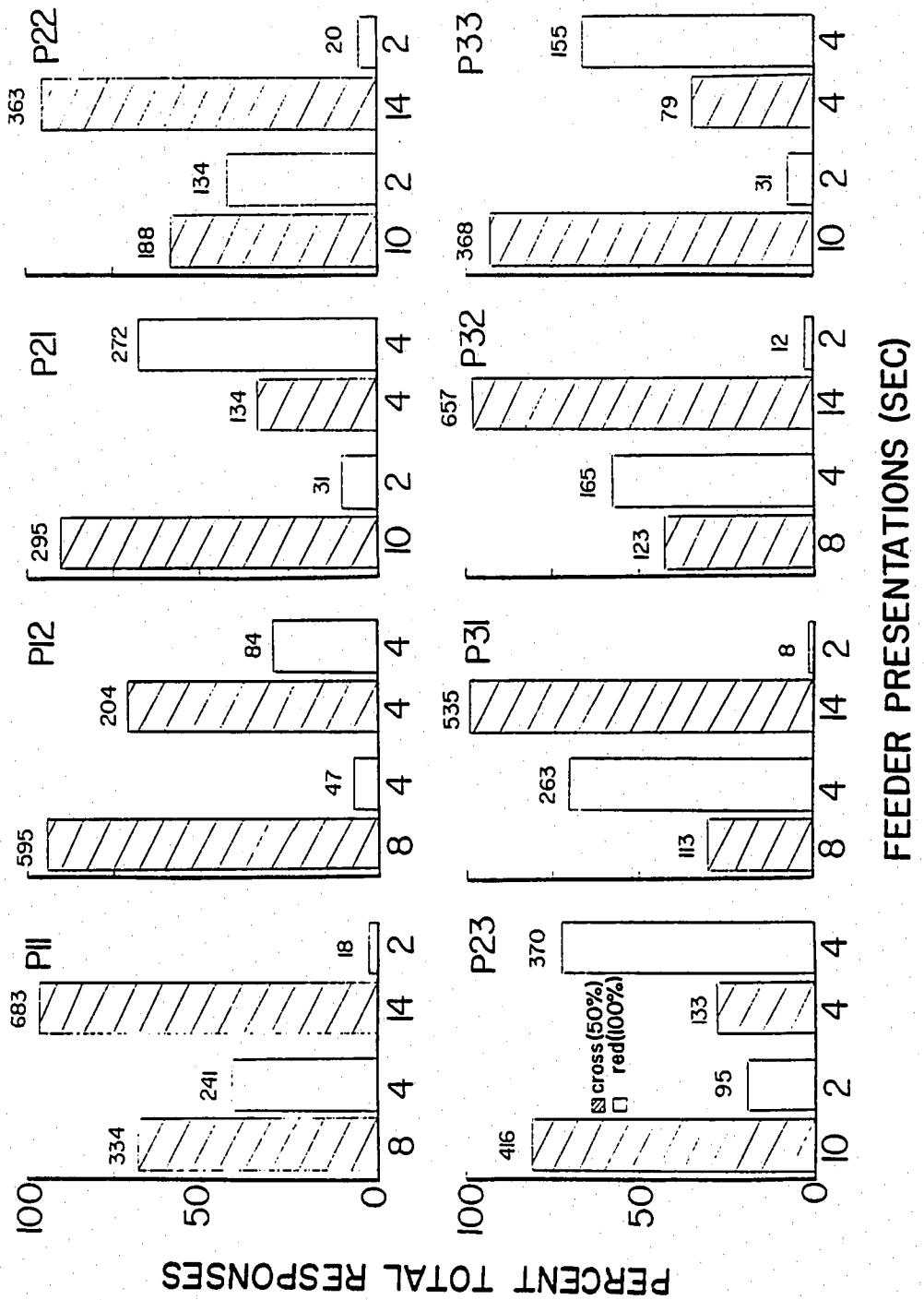


Figure 7. Percent of total choice responses directed to the red and cross stimuli by each bird during the two test phases of Experiment II. Numbers directly above each bar represent the actual number of responses emitted. During training, the red stimulus was always followed by food presentations of the listed duration, while the cross was followed by food presentations of the listed duration 50% of the time. For all subjects, choice trials were never followed by food.

FIGURE 7



paired with shorter (4-sec), more frequent, food deliveries.

Three subjects exposed to the 2- and 10-sec feeder presentations demonstrated a clear preference for the cross stimulus; one subject responded equally to the two. In these birds, in 18 of 50 choice trials (36%) where the first response was made to the red stimulus the pigeons switched keys, while they switched keys in only 13 of 119 instances (11%) in which the first response was directed to the cross.

The frequency of initial choice responses to the cross showed a dramatic increase when feeder presentations were changed to 2- and 14-sec for the red and cross stimuli, respectively. Virtually all initial responses, and the vast majority of total responses, were directed to the cross stimulus under this condition, although preference was not exclusive. The frequency of switching was also indicative of the preference for the cross stimulus. Once responding was initiated to the red stimulus, in 5 of 13 cases (38%) the birds switched keys; they switched keys in only 5 of 171 instances (3%) when the first response was made to the cross stimulus.

All subjects reexposed to the original baseline conditions (4-sec feeder presentations following red and cross stimuli) showed a substantial reduction in the number of initial responses and total responses allocated to the cross stimulus. The percentage of trials in which birds switched from the red stimulus to the cross, and vice versa, was equal (13%).

Under the extinction condition, the number of sessions before responding ceased was highly variable and inconsistent across subjects.

No measure of behavior (latency, rate, trials with a response, response duration, or temporal distribution of responding) during extinction was lawfully related to the duration of feeder presentations during training, thus these data are not presented.

CHAPTER VIII

Discussion

The results of the present experiment are consistent with previous findings showing that duration of feeder presentation exerts only weak and variable control over the rate of autoshaped responding and the number of trials with at least one response (Balsam et al., 1978; Balsam and Payne, 1979; Gibbon and Balsam, 1981). Response latency, a measure that has been shown to systematically vary as a function of duration of food presentation (Balsam et al., 1978; Balsam and Payne, 1979), was sensitive only when extreme values (2- and 14-sec and 4- and 4-sec) were compared. Mean latencies at intermediate values (4-sec and 8-sec, and 2-sec and 10-sec) failed to covary with duration of feeder delivery.

These findings appear to be in accordance with an adapted version of the Scalar Expectancy Model, which Gibbon (1977) and Gibbon and Balsam (1981) have found to account for the effects of several variables on autoshaped responding. This model predicts that duration of feeder presentation, or other "motivational differences", should have little or no effect on autoshaped responding. While the findings of the present study support this contention with respect to response rate, latency to respond, and trials with a response, duration of feeder presentation clearly affected choice: As the duration of feeder deliveries following presentation of the cross (50% pairing) increased,

the percentage of initial choice responses and total choice responses allocated to this stimulus also increased, although the relation was not linear. These changes in preference were found to be reversible when feeder durations were returned to their initial values.

It is of some interest that preference for the red stimulus, always paired with food, which was evident in Experiment I reversed when the total duration of food presented following cross illuminations, paired with food 50% of the time, was greater than the total duration of food delivery following red illuminations. In addition, as the total duration of food presentation following cross illuminations increased, the number of instances in which the birds began responding to the red stimulus and switched to the cross stimulus also increased. However, the birds did not consistently "match" relative choice responding to the relation duration of food presentation following each stimulus. When the red stimulus was paired with greater or equal total access to food, this stimulus was preferred more often than simple matching would predict, although matching was evident in a few instances. However, when the red stimulus was associated with 2-sec access to food and the cross stimulus with 14-sec access, the cross stimulus controlled more choice responding than matching would predict. This finding indicated that, although probability and duration of feeder presentations were confounded in the present study, the effects of the latter variable were not overshadowed by those of the former.

The present data generally support Nevin's (1974, 1979) contention

that response rate and patterning do not necessarily reflect the strength of a response, as indicated by other measures. Nevin has suggested that the resistance of responding to changes in conditions, such as the imposition of extinction, is the best measure of its strength. While some data from operant paradigms support this contention (e.g., Shettleworth and Nevin, 1965), in the present study the persistance of pecking the red and cross stimuli during respondent extinction was not related to the duration of feeder presentations during training.

CHAPTER IX

General Discussion

In order to evaluate the effects of a change in experimental conditions, one must use a sensitive dependent variable. In the present studies, choice was found to be sensitive to frequency (Experiment I) and duration (Experiment II) of food delivery under an autoshaping procedure. Other commonly used measures of responding (i.e., rate, latency, percentage of trials with a response) were less sensitive to these parameters, although not totally unaffected. A plethora of data indicate that, under both continuous and discrete-trial operant procedures, choice is an extremely sensitive measure (e.g., deVilliers, 1977). Under such schedules, the relative number of responses emitted to one alternative often is directly proportional to the relative frequency or duration of food presentations under that alternative (deVilliers, 1977). At its simpliest, this "matching" relation takes the following form, first described by Herrnstein (1961):

$$\frac{R_1}{R_1 + R_2} = \frac{r_1}{r_1 + r_2}$$

where R_1 and R_2 are the number of responses emitted under each alternative and r_1 and r_2 are the total number (or time) of food deliveries under these alternatives. No such "matching" relation was consistently observed across conditions in the present studies. However, matching has been obtained only when responses actually produce the reinforcer, and then only if a changeover delay is arranged such that switching

from one alternative to the other is never immediately followed by food. Autoshaping does not involve a response-reinforcer dependency, nor allow a changeover delay to be arranged during choice trials (this would involve a negative response-food dependency and confound the interpretation of findings). Thus, the failure to find consistent matching or responding and frequency or duration of food presentation is not surprising.

To date, the use of choice as a dependent variable in what are paradigmatically respondent conditioning procedures has been infrequent, probably because choice implies directed responding, which is rarely observed in respondent conditioning. The present study, like an earlier report by Fisher and Catania (1977), indicates that choice is a tenable measure of autoshaped responding. While the general utility of this measure remains to be determined, the present results underscore the inherent relation between independent and dependent variables, and corroborate a growing body of literature indicating that programmed stimulus-stimulus relations, as well as response-reinforcer contingencies, can exercise potent control over a topographically complex directed response, the key-peck. This control may be particularly clear in the allocation of behavior when pigeons are provided with obvious and incompatible response options.

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