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Stimulus Control of Pecking on a Response-Independent Feeding Schedule[1,2]

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ABSTRACT

Stimulus-controlled key-pecking occurred in seven out of eight pigeons under a response-independent feeding procedure regardless of whether a pre-food key light terminated before feeding (trace conditioning) or with food presentation or removal. With a single key-light, peck rates varied inversely with stimulus duration (delay conditioning) and although most pecks occurred within 1 sec of light onset there were more long latency and off-key pecks as the delay interval increased. With two pre-feeding key-lights birds always pecked the first light and also pecked the second light both when it was redundant and when feeding was non-differential in its presence or absence. Results were interpreted in terms of conditions under which conditioned respondents interfere with discriminated operants.

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RESUMEN

El picoteo bajo control del estímulo se presentó en siete de ocho pichones en un procedimiento independiente de la respuesta, ya fuera que una luz previa a la comida terminara antes de la alimentación (condicionamiento huella) o con presentación o remoción de la comida. Con una sola llave de luz, las tasas de picoteo variaron inversamente a la duración del estímulo (condicionamiento de demora), y aunque la mayoría de los picotazos ocurrieron dentro de un segundo a partir de la iniciación de la luz, hubo mayor número de picotazos de latencia larga y fuera de la llave a medida que aumentó el intervalo de demora. Con dos llaves de luz previas a la alimentación, las aves siempre picaron la primera luz y también picaron la segunda luz cuando era redundante y cuando el alimento no era diferencial a su presencia o ausencia. Los resultados se interpretaron en términos de las condiciones bajo las que las correspondientes condicionales interfieren con las operantes discriminadas.

Brown & Jenkins (1968) found that if the response key in a typical operant conditioning chamber was lighted for several seconds immediately prior to the free presentation of food, untrained pigeons, accustomed to eating from the feeder, soon began to peck the key when the light came on. In accordance with operant terminology the phenomenon was labelled autoshaping, and in accordance with operant procedures a peck turned off the key-light and made food immediately available. In Experiment 4 of the Brown & Jenkins' study, however, the key-light remained on for 8 sec prior to food presentation even if pecking did occur: the behavior of 12 birds was studied during two 80-reinforcement sessions in which key-pecks had no programmed effects. Five birds developed high rates of pecking on the lighted key; others either pecked at a low rate or less persistently, and in some cases key-pecking dropped out entirely. In one bird from this latter group a pecking response remained, but it drifted away from the key.

The procedure just described resembles classical Pavlovian conditioning, as does one used by Gamzu & Williams (1971). They randomly presented 8.6 sec. periods in which a response key was illuminated. During these stimulus periods free access to grain occurred randomly throughout the interval on an average of once every 33 sec. In 4 birds, key pecking developed and was maintained, which Gamzu & Williams (1971) interpreted as examples of classical conditioning. This interpretation is inconsistent with the traditional account of Pavlovian conditioning, which is than an unconditioned stimulus (US) elicits an unconditioned response (UR) that is eventually elicited by a conditioned stimulus (CS) paired with the US. By this account the location of key-pecking is not explained. However if a CS becomes a surrogate rather than a substitute for a US (Jenkins & Moore, 1973; Moore 1971) then pecking at the CS (the lighted key) could be explained in the Pavlovian paradigm.

In Brown & Jenkins' Experiment 4 the key light was always extinguished at the time the food tray was operated. Light offset could have been a discriminative stimulus (S^D) for approaching the feeder. Would pecking develop and be maintained if the key light remained on while food was presented? On finding a positive answer to this question we went on to examine the relationship between the duration of the stimulus preceding food presentation and key-pecking during this stimulus. That is, we examined the automaintenance of key-pecking with a Pavlovian delayed conditioning procedure.

Another recent reinterpretation of Pavlovian conditioning is that contingency more than contiguity relationships between conditioned and unconditioned stimuli are responsible for the phenomenon (Bloomfield, 1972; Rescorla, 1967). That is, a CS may elicit a CR not because stimulus contiguity forges a CS-US associative link, but because the CS predicts (informs about) the eventuality of the US. Such an account can be given of autoshaped pecks (Gamzu & Schwartz, 1973; Gamzu & Williams, 1971, 1973) if they are interpreted as classically conditioned responses. Gamzu and his colleagues studied autoshaped pecking with a single CS and manipulated its informational value by presenting the US both with and without the CS. They found that conditioned pecking was not maintained unless the US occurred more often in the presence than in the absence of the CS. We followed the method of Egger & Miller (1962) in using compound conditioned stimuli to vary information provided by CS about the US. On finding that pecking could be maintained by a redundant stimulus we went on to examine the automaintenance of key-pecking with a Pavlovian trace conditioning procedure.

Method

Subjects

Six male white Carneaux and two male King pigeons were used. All were experimentally naive before autoshaping. The birds were maintained at 80% of their free-feeding weights throughout all phases of the experiments.

Apparatus

Two standard Lehigh Valley pigeon chambers were used, one with three keys and one with two keys. In the three-key chamber only the centre key was operative; a recorded peck on this key produced a loud feedback click. A standard in-line stimulus projector mounted behind the centre key provided a white key light on occasions specified by the feeding schedule. At other times the key remained dark. A similar arrangement existed in the two-key chamber, except the either key could be illuminated white or red. This chamber was in total darkness except during 3-sec. presentations of mixed grain and when a key light was on. With the three-key chamber the houselight, mounted above the centre key directed upward remained throughout a session. The feeder was illuminated and the key light remained on during 4-sec. mixed grain presentation in this chamber. The Carneaux pigeons (Birds 1200, 1987, 5429, 4313, 6303, 53) were trained in the three-key chamber; the King pigeons (Birds 103, 105) were trained in the two-key chamber. Programming was by digital and electromagnetic equipment and data were recorded on counters and cumulative recorders.

EXPERIMENT I

Procedure: Autoshaping

The Carneaux pigeons were first trained to eat from the feeder as soon as it was presented. Some birds began eating the first time they were placed in the experimental chamber, others did not do so until the second day. Each bird then received an autoshaping session in which food was presented at an average rate of once every 64 sec. The key was illuminated with white light for 4 sec. (12 sec. for Bird 53) prior to the delivery of food. The key remained lighted during the 4-sec. in which food was available.

Results

The results are presented in Table 1, which indicates on which stimulus presentation the first key-peck occurred, the total number of stimulus presentations received, and the total number of key-pecks emitted.

TABLE 1 *Stimulus presentation during which auto-shaping occurred and number of pecks made during the session.*

Bird	*Stim. Pres. with First Peck*	*Total Stim. Pres.*	*Total Pecks*
1200	14	20	29
1987	24	45	54(3*)
5429	–	90	–
4313	53	60	8
6303	7	70	460(69*)
53	12	40	61

* Numbers in parentheses indicates pecks on dark key.

Five of the six birds pecked the lighted key during the autoshaping session. Moreover, pecking was maintained during most of the subsequent stimulus presentations. Autoshaping occurred whether the stimulus came on

4 sec. or 12 sec. (Bird 53) prior to food presentation. Key-pecking was generally controlled by the key light; only Bird 6303 showed substantial pecking on the dark key (69 out of 460 pecks), and these pecks tended to occur in bursts immediately following food presentation.

Procedure: Delayed Conditioning

This part of the experiment looked at the pecking behavior of Birds 4313 and 6303 during the pre-food stimulus (white key light). Table 2 lists the duration of the pre-food stimulus, the order in which the different durations were presented, and the number of sessions at each value.

TABLE 2. *Duration of pre-food stimulus, number of sessions at each value, and per cent stimulus presentations on which key pecks occurred.*

Bird 4313			*Bird 6303*		
Stimulus duration (sec.)	*Number of Sessions*	*Per cent Stim. Pres. pecked*	*Stimulus duration (sed.)*	*Number of Sessions*	*Per cent Stim. Pres. pecked*
4	8	99	4	8	99
8	11	99	8	4	98
12	11	61	12	7	85
8	21	99	20	20	78
4	10	100	12	10	98
12	13	64	8	5	100
			4	5	100

Since food presentation always occurred at average intervals of 64 sec., as the duration of the pre-food stimulus was increased across conditions the inter-stimulus periods (dark key) became correspondingly shorter. Each session consisted of 60 stimulus presentations.

Three response measures were taken: the number of stimulus presentations (out of 60 per session) during which key pecking occurred; the number of pecks during each stimulus presentation; and the latency to the first peck following the onset of the stimulus.

Results

Segments of cumulative records characteristic of the pecking shown by these birds at the various durations of pre-food stimulus examined have been presented elsewhere (Innis & Keehn, 1972).

When the stimulus was relatively short (4 or 8 sec.), the birds pecked the key at a fairly high rate during every stimulus presentation. At longer stimulus values, however, pecking was not maintained during all presentations (see Table 2), and response rate was much lower. Pecking was confined to the periods just before food presentation. The pecking on the dark key following food presentation, shown by Bird 6303 during its autoshaping session (see Table 1), extinguished after a couple of sessions.

Figure 1 is a plot of the average rate of key-pecking as a function of pre-food stimulus duration. The data are means across three days at the end of each condition. As Fig. 1 shows, rate of key-pecking declined systematically as the duration of the pre-food stimulus was increased. When the stimulus duration was then progressively decreased, response rate increased again. However, the rate was always considerably higher during the descending series. There was also a very low rate of key-pecking by Bird 4313 on the replication of the 12-sec stimulus condition (Fig. 1 open circle), which was preceded by several sessions with a 4-sec. stimulus.

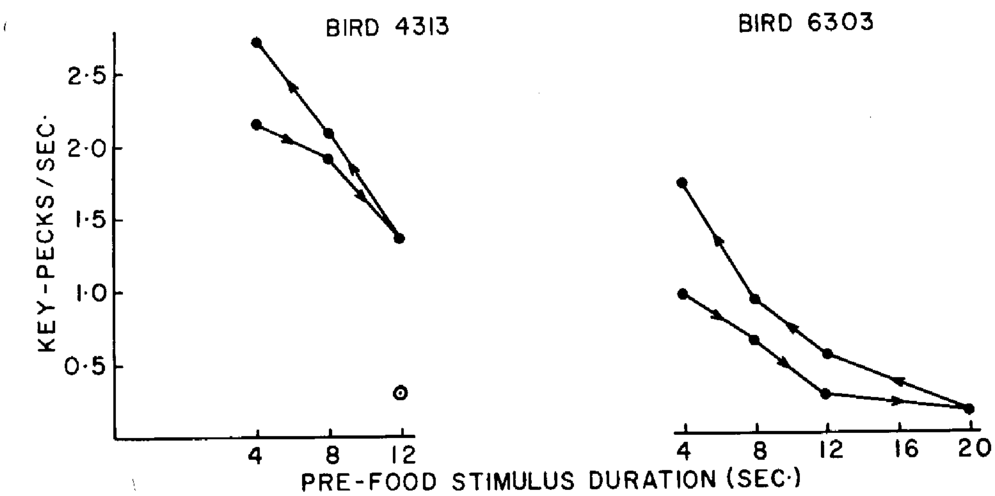

Figure 1. Rate of non-operant key pecking as a function of pre-food stimulus duration. The data are means, across all stimulus presentations in which key pecking occurred, over three days near the end of each stimulus condition. Arrow indicate the order of presentation. The data for the replication of the 12 sec., stimulus condition for Bird 4313 are represented by the open circle.

Bird 6303 generally pecked the key at a much lower rate than Bird 4313. This can be explained by the fact that the topography of the pecking behavior during the pre-food stimulus took two general forms: on-key and off-key pecking (Table 3). Pecking behavior was maintained throughout virtually all stimulus presentations regardless of the stimulus duration. However, the proportion of these pecks which operated the response key (key pecks) varied with stimulus duration, as Table 3 illustrates. Bird 6303 always made more off-key pecks, thus fewer on-key pecks, than Bird 4313. (Off-key pecks were counted by the experimenter who observed the bird on closed-circuit television for 20 consecutive stimulus presentations on each of three sessions at each stimulus duration).

TABLE 3. *Mean number of pecks per stimulus presentation by Bird 6303 over 20 intervals in each of its final 3 session of each condition.*

Stimulus time (sec.)	*Total pecks observed*	*On-key pecks*	*Off-key pecks*	*Proportion on-key*	*Total peck rate (per sec.)*
4	9.0	7.20	1.80	.80	2.25
8	16.8	7.25	9.54	.43	2.10
12	20.6	6.47	14.1	.31	1.72
20	20.3	2.0	18.3	.10	1.01

The latency data for the same three days as the response rate data presented in Fig. 1 are presented as histograms in Fig. 2. The height of each column indicates the number of stimulus presentations (out of 180) during which the time to the first response after stimulus onset (latency) fell within each of the latency bins. The number of stimulus presentations during which no pecking occurred are also indicated. As Fig. 2 shows, both birds pecked during all stimulus presentations of the shorter (4 sec. and 8 sec.) durations. When the pre-food stimulus was 12 sec., Bird 4313 pecked on only about two thirds of the presentations. This was the longest stimulus he received. Bird 6303 pecked the key during most 12-sec. stimulus presentations, and so was studied under a 20-sec. pre-food stimulus condition, at which point key-pecking was observed during only about three-quarters of the stimulus presentations. Considering stimulus presentations during which pecking *did* occur, the modal latency always fell in the first bin, i.e., most frequently the latency to the first key peck was just under 1 sec. As stimulus duration increased, the number of longer latencies increased until, for Bird 6303 with a 20 sec. stimulus, the distribution became quite flat.

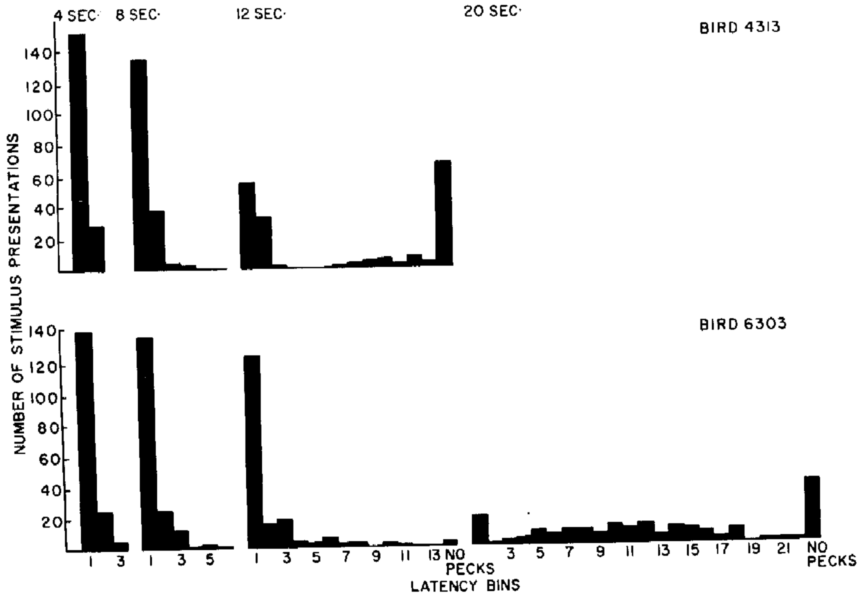

Figure 2. Histograms of latency (time to first key peck following stimulus onset) at each stimulus duration studied for both birds. The height of the bar indicates the number of stimulus presentation (out of 180) that had a latency falling within a particular bin. The latency bins across the abscissa are slightly less than one second wide. Each bin is three pulses wide and the latency timer made 3.3 pulses/second. During conditions when the stimulus was 12 or 20 sec., no key pecks were made on several occasions. These are included in the bins marked NO PECKS.

EXPERIMENT 2

Procedure: General

The King pigeons were autoshaped with a procedure in which key illumination for 4 sec. preceded grain presentation for 4 sec. at various intervals. They were then used for demonstration purposes, but were never reinforced for key-pecking or for any other specified response. They had been maintained in the animal colony at 80% weight levels for about three months before they were exposed to the five experimental procedures depicted in Fig. 3. Under each of these procedures, fifty 3-sec. response-independent signalled food presentations spaced 20 sec. apart were given in each experimental session. Normally each key was illuminated with a particular color (either red or white) except during baseline when either key could appear white at random.

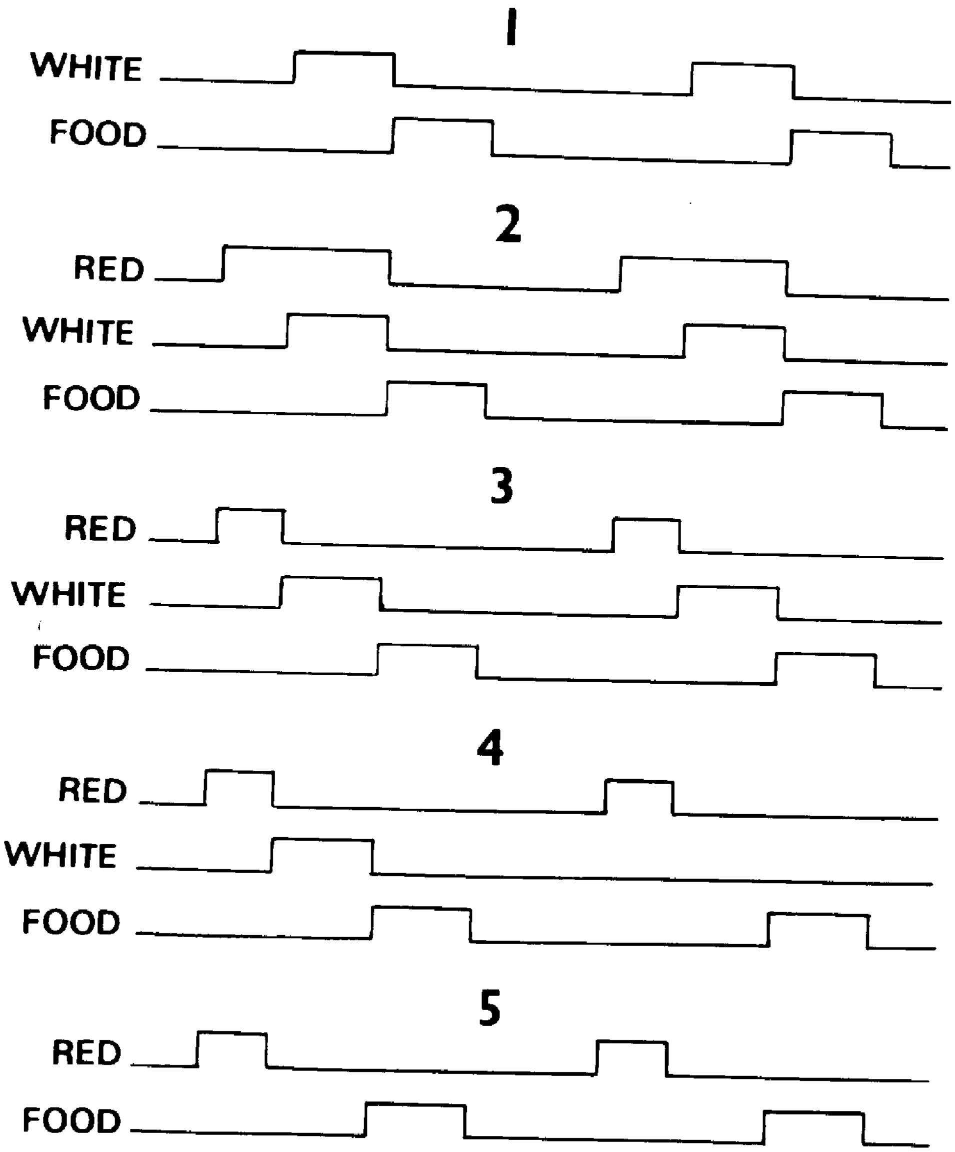

Figure 3. Relationships between red and white key-light onsets and offsets, and food presentation in the 5 stages of the experiment. Food presentations and white-light durations were always 3 sec. Red light durations were 2 sec. or 5 sec. (Procedure 2). Food presentations were 20 sec. apart.

Procedure 1: Baseline

This phase served to reinstate key-pecking in both birds. It lasted for four days in which food presentations were preceded by 3-sec. white illumination of either key selected at random. Key-light termination and food presentation occurred together and were response-independent.

Results

The results of this phase are shown in Block 1 of Fig. 4 and Fig. 5. Both birds emitted close to 2 pecks per sec. at the white key during the 3 sec. that it was illuminated (Fig. 4), and averaged between 0.5 and 1.5 pecks, in the first of each of the fifty 3-sec. illuminations of the key per session. The birds did not peck after every illumination of the key, but when they did peck it was with very short latency.

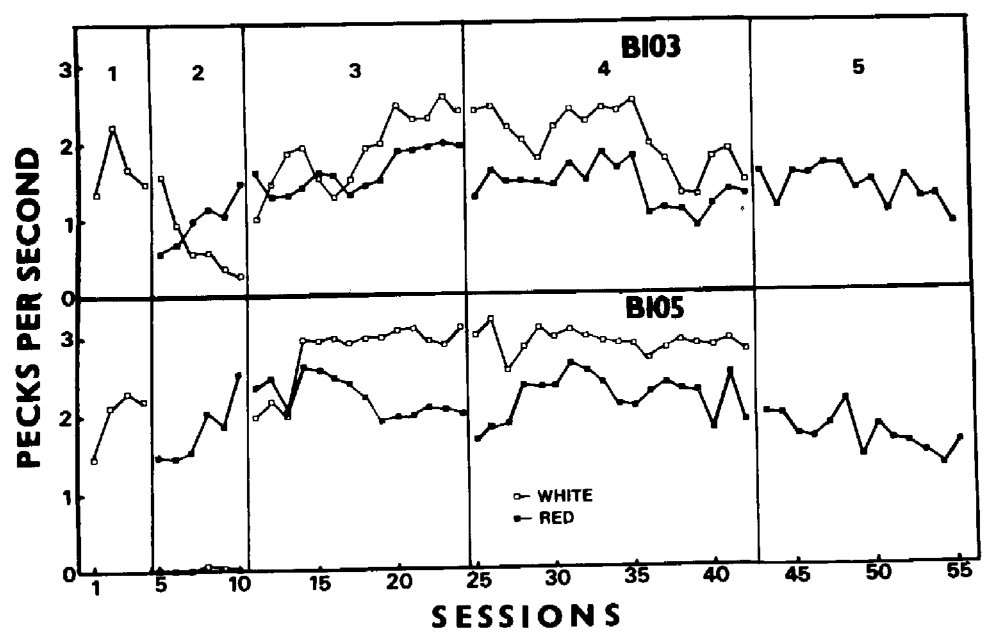

Figure 4. Rate of pecking by each birds on each key at each experimental stage shown in Figure 3.

Procedure 2: White Light Redundant

The baseline procedure was maintained except that now white illumination occurred only on one key, not on either at random. In addition the second key was illuminated red for 5 sec. before food presentations. Thus the sequence of events was 2 sec. red illumination of one key then 3 sec.

illumination of both keys, one red and one white, then 3 sec. food presentation with both keys dark. This phase lasted for 6 days.

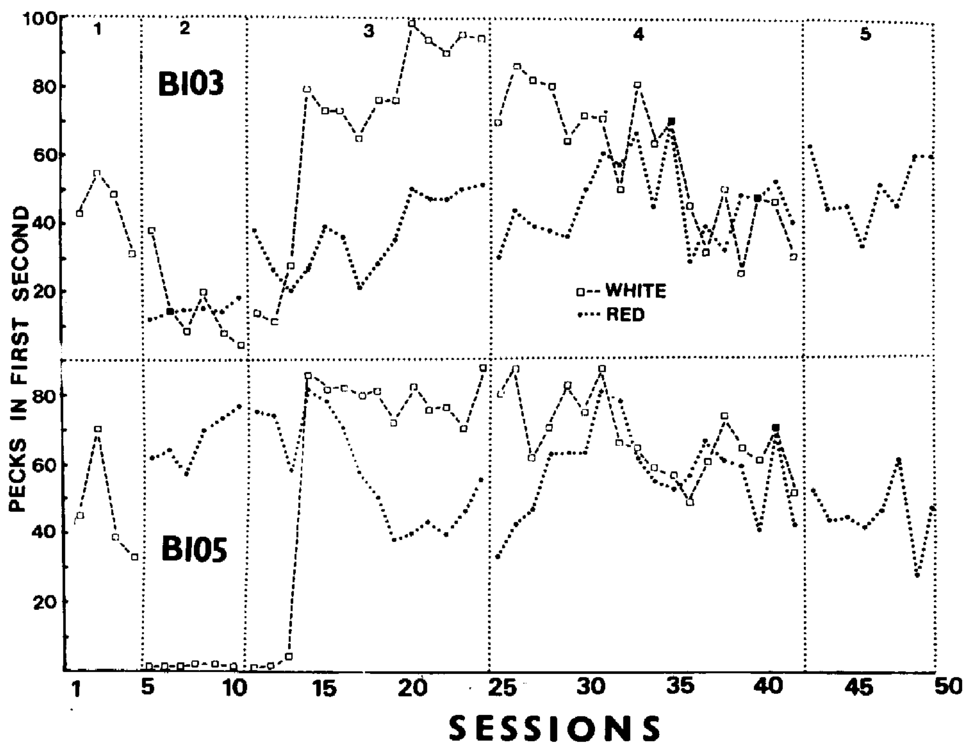

Figura 5. Total pecks made in the first 1 sec. presentation of each key over the 50 trials of each experimental session under the conditions shown in Figure 3. This datum was collected only up to Session 50.

Results

Results are shown in Block 2 of Figs. 4 and 5. Pecks at the red key quickly developed in both birds. At the same time white-key pecking decreased almost to zero, immediately in the case of Bird 105 and gradually over six sessions for Bird 103. Thus, even though feeding consistently followed white-key illumination, pecking at this key soon ceased. Gamzu & Williams (1971) showed that automaintained pecking does not occur if grain is presented non-differentially in the presence or absence of a lighted key. The present result indicates that even differential feeding (in the presence of the light but not in its absence) does not maintain key-pecking if key illumination is preceded by a second signal.

The sequence of events, red-key illumination, white-key illumination, food presentation, made the white light redundant as a signal for grain. But white-key pecking may not have ceased for this reason; the result could have been an artifact of interference by red-key pecking that continued after the white key was illuminated. This possibility was tested in the next phase.

Procedure 3: Non-Overlapping Red & White Keys

In this phase illumination of the red key preceded illumination of the white key by 2 sec. but did not overlap it. The sequence of events was: red key light on for 2 sec., white key light on for 3 sec., grain presented for 3 sec. This phase lasted for 14 daily sessions in which the standard procedure of fifty 3-sec. food presentations spaced 20 sec. apart was maintained.

Results

Results are shown in Block 3 of Figs. 4 and 5. For both birds white-key pecking recovered and reached a higher rate than pecks on the red-key. The rate also exceeded the baseline pecking rates before the red light was introduced. Also, more white-key pecking occurred than red-key pecking within 1 sec. of light onset. Typical behavior was that the birds pecked the red key shortly after it was illuminated and switched to the white key as soon as it came alight. The greater amount of white-key pecking than red-key pecking parallels Williams' (1965) results with serial conditioning of salivation in dogs, and confirms Ricci's (1973) finding that peck rate in pigeons increased as successive CSs became more proximal to the US. Ricci employed only one key, but key-switching was necessary in the present case.

The fact that white-key pecking resumed under the conditions of Procedure 3 supports the inference that the disappearance of white-key pecking under Procedure 2 was not because the white key light was redundant in that phase but was because red-key pecking interfered with white-key pecking. In the present phase the white key was redundant but was pecked nevertheless. Feeding was differential with respect to both keys, and both keys were pecked.

Procedure 4: Red Light Differential: White Light Non-Differential

Procedure 4 was the same as Procedure 3 except that on a random half of the food presentations in each session the white light was omitted. Thus the procedure was non-differential with respect to the white light inasmuch as response-independent food presentations occurred as often in its absence as in its presence. White light continued to predict food, for grain presentation always followed white-key illumination, but absence of white light did not predict no grain presentation. Red-key illumination always preceded food presentation, although with a 3-sec. delay. The procedure was differential with respect to the red light for feeding always occurred after red-key illumination and never occurred unless the red-key had been illuminated. The procedure continued for 18 days.

Results

Results are shown in Block 4 of Figs. 4 and 5. For all 18 days in the case of Bird 105, and for 11 days in the case of Bird 103, pecks to each key occurred at about the same rates as they had with Procedure 3. Over the last seven days with Procedure 4 pecking at each key by Bird 103 dropped by approximately 1 peck per sec. from the rate over the first eleven days with the procedure. Peck rate was higher to the white than to the red key for both birds even though a non-differential procedure was used with the white light and a differential procedure was used with the red ligt. Over the course of this phase of the experiment, for both birds there were declining numbers of responses made in the first 1 sec. of white light onset, as shown in Fig. 5, Block 4. The same figure shows a rapid rise in the rate of pecking the red-key during its first 1 sec. of illumination at the beginning of this phase, after which red and white keypeck rates in the first 1 sec. of key illumination became about equal.

Procedure 5: Trace Conditioning

Previous procedural changes were concerned with the role of the white stimulus in connection with feeding. The final procedure examined the white stimulus's relationship with the red stimulus. Specifically, is red-key pecking maintained as a CR in a trace conditioning relationship with the US, or is red-key pecking reinforced by white light onset? It is possible to view the change from Procedure 3 to Procedure 4 as one of down grading the white light as a predictor of the US or as one of halving the frequency of reinforcement of red-key pecking by the white light. In the present procedure the white light was omitted entirely. There were 13 daily session in which the grain US was presented 3 sec. after the termination of 2 sec. illumination of the red key. As before, sessions consisted of fifty 3-sec. grain presentations spaced 20 sec. apart.

Results

Block 5 of Fig. 4 and Fig 5 respectively show the rates of pecking at the red key by both birds (Sessions 43-55) and the number of pecks made in the first 1 sec. of red-key illumination (Sessions 43-50). Each bird pecked the red key on almost all of its fifty daily presentations under the trace conditioning procedure. There were 13 sessions with this procedure, representing a total of 650 trials in which the red key maintained pecking in the absence of possible reinforcement through white light onset. However, that number of CS-US trace pairings did not 'strengthen' red-key pecking, as measured by rate of pecking.

A clear decline in the rate of pecking by Bird 105 is evident in Block 5 of Fig. 4, but frequency of pecks in the first 1 sec. remained at the terminal level of Procedure 4 (except for Bird 105 in Session 49) over the 8 sessions on which this datum was recorded.

GENERAL DISCUSSION

Stimulus controlled key-pecking was established and maintained in seven out of eight pigeons trained with autoshaping procedures that resembled classical respondent delay and trace conditioning. Autoshaping acquired its name in the context of operant conditioning and in the first experiments of Brown & Jenkins (1968) operant technology prevailed in that autoshaped pecks were reinforced. Operant technology was discarded in the fourth experiment by Brown & Jeakins (1968) and in the study by Gamzu & Williams (1971) wherein food delivery was response-independent after the manner of classical, Pavlovian, technology. Pavlov first explained the result of his procedure as the 'chaining' of an unnatural stimulus to a natural stimulus-response event, and 'stimulus substitution' became an acceptable description of classical conditioning, especially of conditioned salivation, the proto-typical conditioned response. However, Pavlov studied salivation only for convenience (Pavlov, 1927, pp 17-18). He knew that conditioned behavior was complex and often described a CS as a US surrogate (*cf.* Moore, 1971). Jenkins & Moore (1973) demonstrated that 'autopecking' resembles classical conditioned in this respect by showing that key-pecking is topographically appropriate to water or food as the US. At this level the present experiments demonstrate Pavlovian delay and trace conditioning of key-pecking by pigeons.

However the fact that autoshaped responses resemble classically conditioned responses does not explain them, it only allocates them to a class.

Also, key-pecking by the pigeon may be a special case, for the autoshaped key-pressing by squirrel monkeys reported by Gamzu & Schwam (1974) cannot be interpreted as mistaken key-eating.

The clue to autoshaping as it relates to classical and operant conditioning may be that the pigeon has been phylogenetically selected on the basis of pecking. (Man and monkey might likewise have been selected on the basis of reaching and placing in the mouth.) That is, the pigeon pecks at *objects,* not at food, and eating is a discriminated operant because pecks at food are reinforced and pecks at non-food are not. By this account food-pecking by the pigeon is an accident of nature (in the sense that the natural reflex, in Pavlov's sense, is not peck-at-food but peck-at-objects, so that the basic behavioral unit for survival is the discriminated operant not the natural reflex), and the classically conditioned response of pecking is an aberration of nature (because the pigeon pecks at the object instaed of at food.) There is evidence (Gilbert, 1973 and personal communication) that pecking at a CS reduces the possibility of obtaining food. Pecking at the object continues even when it prevents obtaining the food (Williams & Williams, 1969), although there is a difference between pecks that do and do not interfere with feeding (Schwartz & Williams, 1972).

Further data are needed on the conditions under which pigeons peck at objects when they could be pecking at food, or the conditions under which discriminated operants fail to develop. Gamzu & Schwartz (1973) found that autopecking was only maintained if the US occurred more in the presence than in the absence of the CS; that is, their pigeons pecked a lighted key so long as the key light was informative about forthcoming food. In the present study prediction was important. In Procedure 3 of Experiment 2 the white light was redundant (as it was always preceded by the red light) but it still always predicted food.

In Procedure 4 of Experiment 2 the white light was non-informative as food occurred as often in its absence as in its presence, but its presence always predicted food. In both cases pecking at the white key was maintained.

Jenkins (1975) described an experiment in which autopecking occurred to a key-light that predicted food and not to a key-light that appeared at random with respect to food. The apparatus was a long box with the keys at each end with the food dispenser in the middle. The spatial separation between key and feeder meant that key-pecks interfered with food-pecks, but key-pecking at the predictive key developed nevertheless. The arrangement that Jenkins employed necessitated an interval of time between key-pecking and the bird's arrival at the feeder. This arrangement resembles the trace conditioning procedure of Experiment 2, which also maintained autopecking. What has been described as the predictability of food following a stimulus may be reducible to parametric accounts of probabilities of pecking as a function of CS-US intervals (delay or trace) and as a function of CS-US pairings (schedules) in context, where context extends the notion of schedule to include reinforcements given in the absence of responses as well as occasions on which responses secure reinforcement (Jenkins 1970; Keehn & Coulson, 1970).

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