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TWO DIFFERENT KINDS OF KEY PECK IN THE PIGEON: SOME PROPERTIES OF RESPONSES MAINTAINED BY NEGATIVE AND POSITIVE RESPONSE-REINFORCER CONTINGENCIES[1]

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Pigeons emitted almost exclusively short-duration key pecks (shorter than 20 msec) when on negative automaintenance procedures, in which pecks prevented reinforcement. Peck durations under fixed-interval and fixed-ratio reinforcement schedules were generally two to five times longer than pecks under a negative automaintenance schedule. However, initial key pecks were of short duration, independent of procedure. The frequency of short-duration pecks was insensitive to differential reinforcement, while the frequency of long-duration pecks was sensitive to differential reinforcement. It is proposed that short-duration pecks arise from the pigeon's normal feeding pattern and are directly enhanced by food presentation, while long-duration pecks are controlled by the contingent effects of food presentation. The implications of the existence of two classes of pecks for the functional definition of operants and the separation of phylogenetic and ontogenetic sources of control of key pecking are discussed.

One of the major difficulties that confronts the experimental analysis of behavior is the identification of the behavioral unit. Much of Skinner's early work (*e.g.*, 1935; 1938) was addressed to this problem. Skinner saw the difficulty in attempting to define behavioral units independent of the environmental context, and he thus emphasized the functional relationships between behavior and environment (1935). A response class, or operant, was defined on the basis of those properties on which reinforcement was dependent. This functional definition of the operant carries with it the constraint that, while individual responses might differ topographically, they must be homogeneous with respect to their sensitivity to environmental consequences. Such a functional definition is successful if "the entity which it describes gives smooth curves for the dynamic laws of the reflex" (Skinner, 1938, p. 37).

The heuristic value of Skinner's approach is clear. In the last two decades, key pecking in pigeons has emerged as a prototypic operant, and hundreds of experiments have demonstrated that the rate of key pecking is extremely sensitive to, and easily modified by response-contingent reinforcement (*e.g.*, Ferster and Skinner, 1957; Honig, 1966). However, a number of recent studies (Brown and Jenkins, 1968; Rachlin, 1969; Williams and Williams, 1969) have suggested that the key peck is not always subject strictly to operant control and have raised the possibility that the functional approach to the definition of the key-peck operant may sometimes obscure the presence of multiple sources of control over behavior.

Brown and Jenkins (1968) exposed naive pigeons to a procedure in which feeder operations were regularly preceded by brief illuminations of the response key. Key pecks had no scheduled consequence. Nevertheless, the pigeons began pecking at the key (auto-shaping), and pecking was maintained, although food delivery was response independent (positive automaintenance). Though one might expect that the delivery of food serves to reinforce key pecking once it occurs in the Brown

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and Jenkins study, the Williams and Williams (1969) study makes it clear that such an explanation is at best incomplete. Williams and Williams explored a procedure in which food delivery was negatively contingent upon pecking the illuminated key (*i.e.,* on trials in which no peck occurred, key illuminations were followed by food; pecks at the illuminated key terminated the trial without food). Williams and Williams found that all pigeons developed and maintained substantial amounts of key pecking (negative automaintenance), despite the negative response-reinforcer contingency. In the Williams and Williams experiment, food delivery could not possibly have reinforced key pecking, because the key peck was the only response that could not be followed closely in time by food delivery. Finally, Rachlin (1969) investigated a procedure similar to Brown and Jenkins', except that shock termination was the reinforcer for key pecking. Though many pigeons did learn to respond on the key, the typical response was a wing flap, not a peck. While the functional definition of the operant permits the inclusion of responses with topographies as different as those of pecking and wing flapping, the fact that wing flapping occurred in the presence of shock, while pecking occurred in the presence of food, suggests that the nature of a reinforcing stimulus may have a direct influence on the form a response takes, aside from its contingent influence.

This point was elaborated by Williams and Williams (1969). They argued that an explanation of the negative automaintenance phenomenon may lie in the direct (rather than contingent) enhancing effect of food (or other reinforcing stimuli) on behavior. Pecking is a part of the pigeon's species-characteristic feeding pattern, and it is possible that the mere presence of food in a situation engenders pecking in a hungry pigeon (Staddon and Simmelhag, 1971). This direct enhancement of pecking by food was presumably operative in the Williams and Williams experiment, even though the contingency relationship between pecking and food was negative. Moreover, the fact that wing flapping rather than pecking predominated in the Rachlin study supports Williams and Williams assertion regarding the direct effects of food presentation and suggests that aversive stimuli, like shock, may directly enhance wing flapping.

An implication of the notion that food presentation directly enhances pecking is that such direct effects occur in all situations in which food serves as a reinforcing stimulus, *i.e.,* all situations in which the key peck is an operant, and food is the reinforcer. What makes the Williams and Williams (1969) and Rachlin (1969) studies unusual is that in those situations direct and contingent reinforcement effects did not summate. In the Williams and Williams experiment, direct effects enhanced pecking, and contingent effects reduced pecking; in the Rachlin study, direct and contingent effects initially influenced different behaviors (wing flapping and pecking). However, if direct and contingent enhancement of pecking typically occur concurrently, it is possible that the standard identification of the key-peck operant actually includes two distinct sub-classes of responses, one of which conforms to the notion of the operant (*i.e.,* is maintained by contingent reinforcement) while the other does not (*i.e.,* is a direct effect of food presentation).

The present series of experiments was designed to examine this possibility. It was assumed that if two different classes of key pecks existed, they would be directly reflected by differences in response topography. The particular dimension of the key peck studied was its duration. Wolin (1968) found that the duration of a key peck varied as a function of whether food or water was the reinforcer. If different reinforcers are reflected in different key-peck durations, then perhaps different sources of control by the same reinforcer (*i.e.,* by direct or contingent effects) are similarly reflected in different key-peck durations. Thus, the first two experiments reported below attempted to identify two populations of key pecks on the basis of differences in duration. It was expected that key pecks that occur on negative automaintenance (produced by direct effects of food presentation) would be different in duration from key pecks that produced food under operant reinforcement schedules.

Moreover, the existence of negative automaintenance suggests that the frequency of pecks in the class generated and maintained by the negative automaintenance procedure, unlike pecks that occur on standard operant procedures, is insensitive to response-contingent reinforcement. Hence, the third experiment below explored the possibility that negative automaintenance pecks (identified on the basis of duration) are insensitive to differential reinforcement (*i.e.*, do not increase in frequency when differentially reinforced), while operant pecks are sensitive to differential reinforcement.

EXPERIMENT I

This experiment explored the hypothesis that key pecks emitted on a negative automaintenance procedure were different in duration from positive automaintenance key pecks.

METHOD

Subjects

Four Silver King pigeons, deprived to 80% of their free-feeding weights, served; all were experimentally naive at the start of the experiment.

Apparatus

One wall of a standard pigeon chamber contained a three-key control panel with keys that could be illuminated by various colored lights. Only the center key was ever illuminated, and responses to the other two keys (assumed to be few, if any) were not recorded. The center key was about 8 in. (20 cm) above the floor of the chamber. A food magazine was 5 in. (12.5 cm) below the center key. A deflector was placed on the houselight, located 3 in. (7.5 cm) above the center key, so that the light was directed toward the ceiling of the chamber. Scheduling and recording were done with standard electro-mechanical equipment, which was housed in a separate room. Response durations were recorded in the following manner: a small jeweller's screw was mounted in the upper corner of the plastic section of a standard Lehigh Valley pigeon key, on the part of the key farthest from the microswitch. Another jeweller's screw was encased in Plexiglas, so that only the head was exposed, and mounted in the panel, so that when the key was not operated, the two screws were in contact. Each key peck broke the contact, and the duration of each break was timed to the nearest msec, stored, and printed by a PDP-8 computer. To eliminate artifactual durations that might have resulted from contact bounce, dust, vibration, *etc.*, no contact-break durations shorter than 8 msec were processed by the computer. The number of such short durations that may actually have been key pecks was almost certainly quite small, as evidenced by the fact that the number of responses per session, as recorded by the microswitch mounted on the key, and the number of durations per session, as recorded by the computer, rarely differed by as much as 1%.

Procedure

The four pigeons were trained to approach and eat from the food magazine. For the first 15 experimental sessions, the pigeons were divided into two pairs. Pigeons 4529 and 3974 were exposed to a negative automaintenance procedure. The key was illuminated for 6 sec with red light; if no peck occurred on the illuminated key after 6 sec, the light went out and the feeder was operated for 4 sec. A peck on the illuminated key prevented reinforcement at the end of the 6-sec trial. For the other two pigeons, key pecks had no consequence (positive automaintenance). Each 6-sec red-key illumination was followed by 4-sec access to grain. Each daily session consisted of 50 such trials, separated by a variable intertrial interval (10 to 90 sec) with a mean of 30 sec. The houselight was illuminated throughout the session, except during reinforcement, when a light in the feeder was illuminated.

After 15 such sessions, the first pair (4529 and 3974) was shifted to the positive automaintenance procedure, and henceforth, the four pigeons were treated identically. They continued on positive automaintenance for seven additional sessions. After this, an attempt was made to decrease response rate on the positive automaintenance procedure by systematically decreasing the probability that a trial would terminate in reinforcement, from 1.00 to 0.00, in steps. The purpose of this manipulation was to equate response rates on the negative and positive automaintenance procedures. Pigeons typically respond at substantially higher rates on positive automaintenance than on negative automaintenance (Schwartz and Williams, 1972), and it was possible that any difference in response duration that might have obtained between these two procedures could be attributed to differences in response rate. Thus, the probability that a positive automaintenance trial would terminate in reinforcement was decreased to 0.50 (seven sessions), then to 0.20 (seven sessions), then to 0.05 (seven sessions), and finally, to 0.00 (seven sessions). The procedure was then shifted to negative automaintenance for 23 sessions. Finally, the positive automaintenance procedure was reinstated for 20 sessions. In this phase of the experiment, the probability that a trial would terminate in reinforcement was determined by the proportion of the possible reinforcements in the last five sessions of the negative automaintenance procedure, *i.e.,* the proportion of the negative automaintenance trials in the last five sessions in which no peck occurred. Thus, the probability of reinforcement was 0.10 for Pigeon 4529; 0.30 for Pigeon 3974; and 0.60 for Pigeons 4784 and 4800.

Results and Discussion

The major finding of Experiment I is summarized in Figure 1, which presents the median key-peck duration for each pigeon over the last three sessions of each of the exposures to the negative automaintenance procedure, and averaged across the last three sessions of each of the positive automaintenance procedures. The solid lines connect the points for the pigeons that began the experiment on negative automaintenance, while the dashed lines connect the points for the pigeons that began on positive automaintenance. For the first two pigeons (4529 and 3974), median durations on negative automaintenance were quite short (10 to 12 msec), increased substantially on positive automaintenance, and decreased again on re-exposure to negative automaintenance. For the other two pigeons (4784 and 4800), median durations were between 40 and 50 msec on positive automaintenance, and decreased to about 20 msec on negative automaintenance. Thus, negative automaintenance key pecks were clearly different in duration from positive automaintenance key pecks.

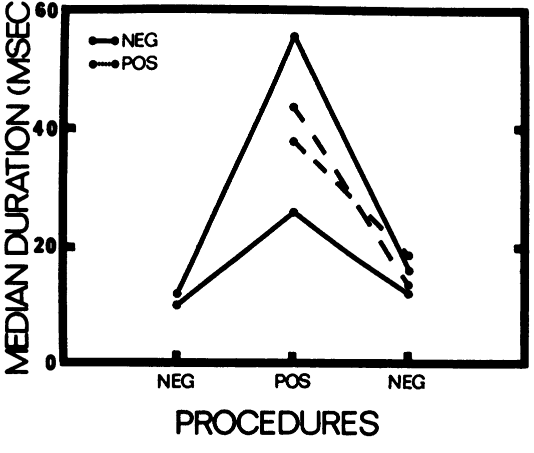

Fig. 1. Median key-peck duration of each pigeon from the last three sessions of exposure to negative automaintenance and positive automaintenance procedures. Solid lines connect the points for the pigeons that began on negative automaintenance, while dashed lines connect the points for the pigeons that began on positive automaintenance.

Session-to-session median durations for Pigeons 4529 and 3974 are shown in Figure 2. The vertical lines indicate procedure changes, and the numbers inside the panels indicate the probability that a trial would end in food delivery in the positive automaintenance procedure. For Pigeon 4529, the differences in durations obtained on the negative and positive procedures were quite clear; there was virtually no overlap in median duration between the two procedures. The differences were not as marked for Pigeon 3974. In the sessions of positive automaintenance, which immediately followed exposure to negative automaintenance (second and last panel), durations were essentially the same as on the negative procedure. It was only after considerable exposure to the positive procedure that differences between the negative and positive procedures appeared in duration, as well as in response rate. The pattern of responding by Pigeon 3974 in the early sessions represented in the second and last panels resembled more closely responding under negative automaintenance (1 to 3 responses per trial) than under positive automaintenance (10 to 15 responses per trial). However, by the termination of each of the procedures, median durations on positive automaintenance were 2 to 4 times longer than median durations on negative automaintenance.

Figure 3 presents session-to-session median durations for the pigeons that began the experiment on positive automaintenance (4784 and 4800). It can be seen that median durations on the negative procedure were considerably shorter than those on the positive procedure. The exception to this generalization comes from the earliest experimental sessions (first panel), in which durations were quite short. It seems that initial peck dura-

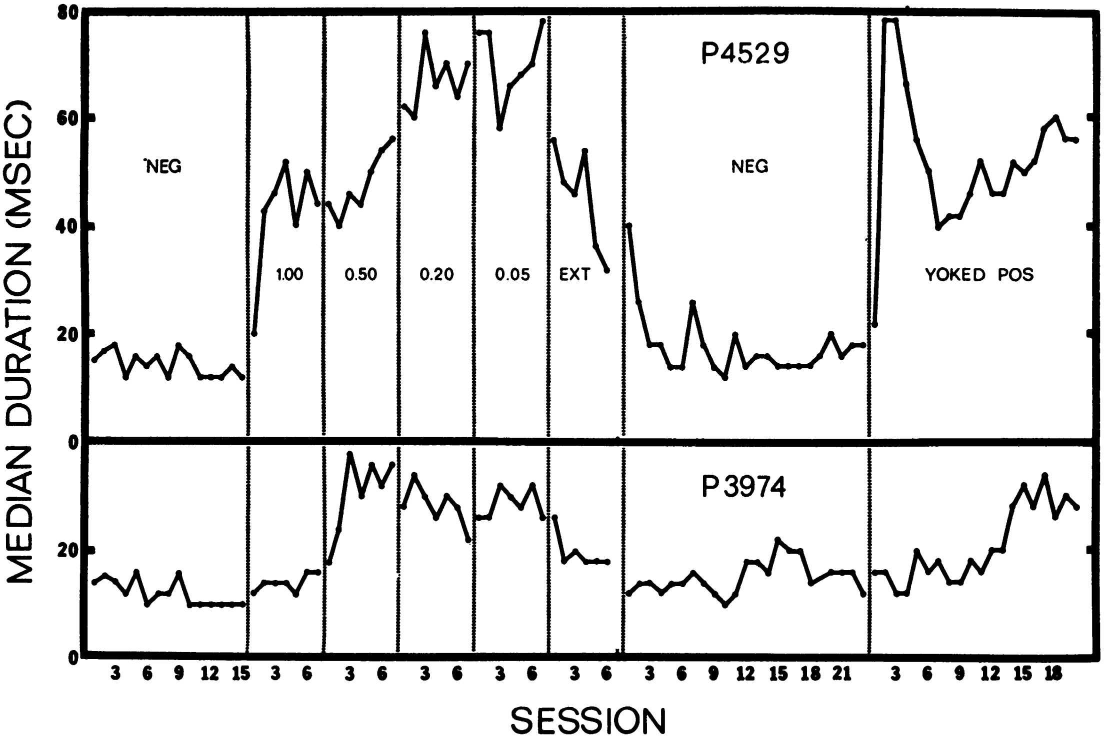

Fig. 2. Session-to-session median response durations for Pigeons 4529 and 3974. The vertical lines indicate procedure changes, and the numbers inside the panels indicate the probability that a positive automaintenance trial would end in reinforcement.

tions, no matter what the procedure, are short, and that experimental exposure is required in order for long-duration pecks to develop. Indeed, the durations of the first pecks of each of the pigeons in this experiment were quite similar: 12 msec for 3974 and 4800, 14 msec for 4529, and 18 msec for 4784. Moreover, the initial pecks of pigeons exposed to continuous reinforcement (Experiment II, below) were of approximately the same short duration.

The probability that a positive automaintenance trial would terminate in reinforcement was systematically decreased in an attempt to decrease response rate on positive automaintenance, and make it comparable to negative automaintenance response rates. This manipulation was not wholly successful. The pigeons had been making between 7 and 10 responses per trial on the positive automaintenance procedure, in which the probability that a trial would terminate with food was 1.00. At $p = 0.50$, and $p = 0.20$, response rates increased (to 12 to 16 responses per trial) for each pigeon, as did response duration (Figures 2 and 3). However, at $p = 0.05$, and extinction, response rates were comparable to those on negative automaintenance (frequent trials in which no response occurred, and 1 to 3 responses in other trials), while response durations remained considerably longer. Thus, it seems unlikely that the differences in duration between the positive and negative procedures could be attributed to differences in response rate.

Relative frequency distributions of duration, in 2-msec class intervals, from the last session of a number of the procedures employed in the present experiment are presented for Pigeon 4529 in Figure 4. In the upper-right corner of each panel, the procedure, the median duration, and the number of responses represented in the panel are indicated. The top panel shows that response durations on negative automaintenance were uniformly short. Instances of durations longer than 20 msec were quite common. On positive automaintenance (second panel), the short-duration pecks did not drop out entirely. In the session shown, 50 pecks shorter than 20 msec were emitted. Rather, what seemed like a whole new population of pecks, of longer duration, emerged. While the evidence for two discrete populations of pecks is not as clear for the other pigeons as for Pigeon 4529, in all cases, the tail of the distribution on the side of the short durations contains more pecks than the tail on the side of the long durations. This suggests that though the distribution of long-duration pecks may overlap the distribution of short-duration pecks, the population of short-duration pecks is nevertheless intact, and potentially separable from the population of long-duration pecks.

In extinction (third panel), while the distribution of durations tended to get shorter, it was nevertheless both longer and considerably more variable than the distribution of pecks on negative automaintenance. When the procedure was again negative automaintenance (fourth panel), the initial distribution of durations was essentially recovered. Finally, when the schedule was again positive automaintenance, the distribution of long duration pecks reappeared.

The present data may be summarized briefly:

(1) Negative automaintenance key pecks differ substantially in duration from positive automaintenance key pecks. The former are almost invariably shorter than 20 msec, while the latter are considerably longer.

(2) Initial key pecks, on either the negative or the positive procedure, are of short duration, *i.e.,* under 20 msec. With continued experimental exposure, the positive automaintenance pecks become longer, while negative automaintenance pecks remain short.

(3) The differences in response duration on the negative and positive procedures cannot be attributed simply to differences in response rate maintained by the two procedures.

(4) The distribution of durations obtained on the positive automaintenance procedure, while consisting primarily of long-duration pecks, also contained a substantial number of short-duration pecks.

Thus, the present experiment suggests that there are two populations of key pecks, of short and long duration. The fact that only

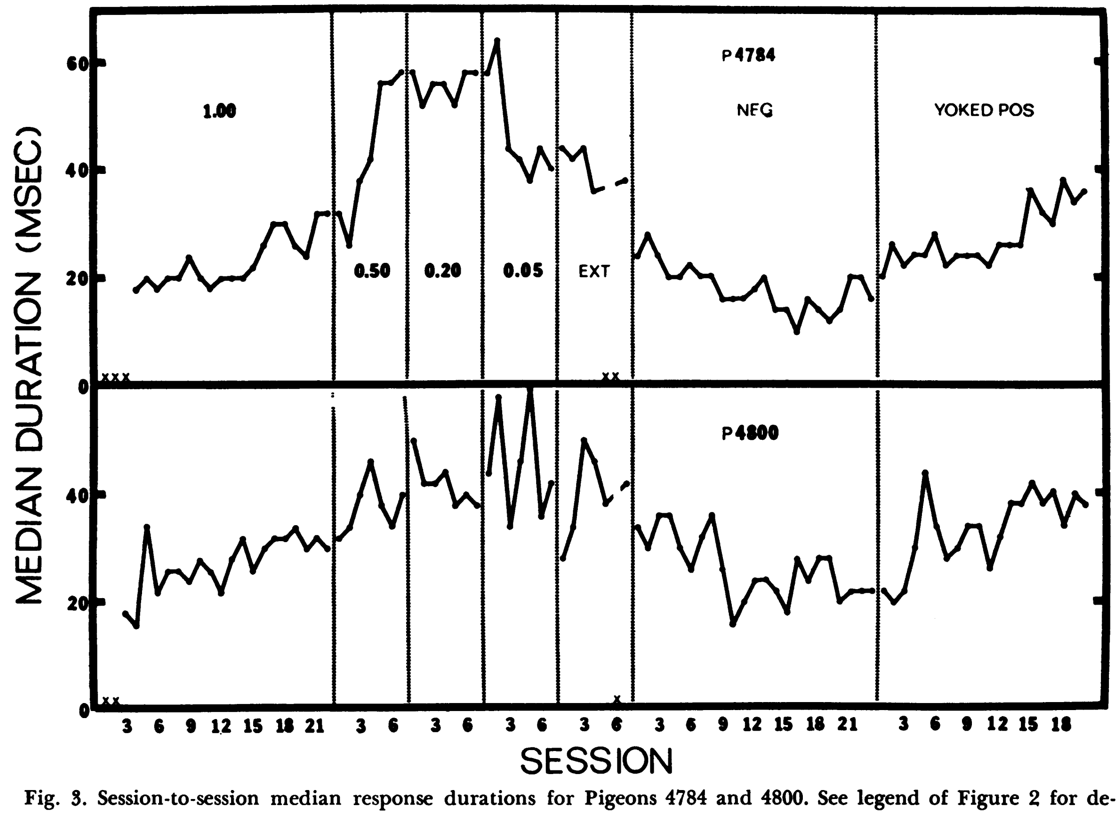

Fig. 3. Session-to-session median response durations for Pigeons 4784 and 4800. See legend of Figure 2 for details.

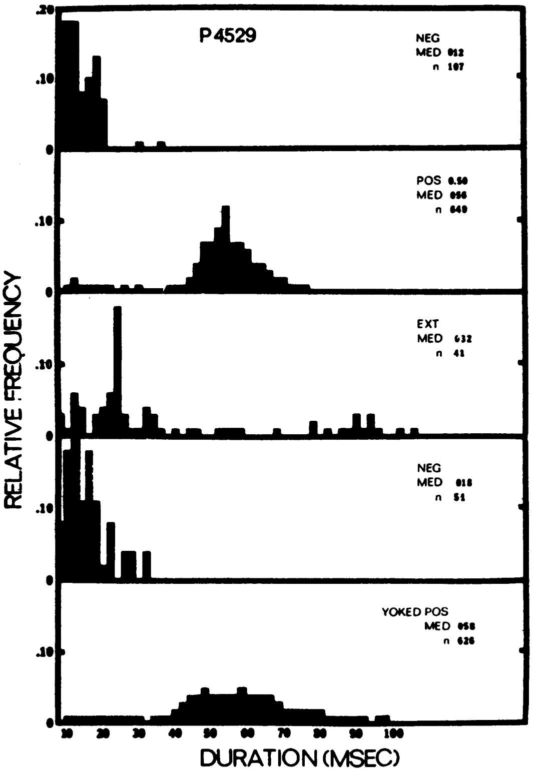

Fig. 4. Relative frequency distributions of duration, in 2-msec class intervals, for Pigeon 4529, from the last session of a number of different procedures employed in Experiment I. In the upper-right corner of each panel, the procedure, the median duration, and the number of responses represented in the panel are indicated.

short-duration pecks occur on the negative automaintenance procedure suggests that these pecks are produced as a direct effect of food presentation, and not by an operant contingency, since the negative key peck-reinforcer relationship can not, by definition, maintain a key-peck operant. On the other hand, the occurrence of both short- and long-duration pecks on the positive automaintenance procedure suggests that a variable other than the direct effect of food presentation is playing a role in maintaining key pecking in that situation. It is possible that an adventitious response-reinforcer contingency (Skinner, 1948) maintains the long-duration pecks on the positive automaintenance procedure since key pecks, once they occur on that procedure, are followed closely in time by food presentation. However, it is necessary to assess more directly the notion that long-duration key pecks are under operant control by studying procedures that contain explicit response-reinforcement contingencies. Hence, Experiment II examined the durations of key pecks maintained by conventional operant reinforcement schedules.

EXPERIMENT II

Though the first experiment demonstrated that key-peck durations on positive and negative automaintenance procedures were different, a question still remained as to the relationship between negative automaintenance key-peck durations, and the durations of pecks maintained by conventional operant reinforcement schedules. Thus, in order to examine the possibility that long-duration pecks are indeed under operant control, the durations of key pecks maintained by the conventional operant reinforcement schedules of continuous reinforcement (CRF), fixed-interval 30 sec (FI 30-sec) and fixed-ratio 25 (FR 25) were examined in Experiment II.

METHOD

Subjects

Four, naive Silver King pigeons (62, 88, 2858, and 1623) served.

Apparatus

The apparatus was the same as that described in Experiment I.

Procedure

The four pigeons were trained to approach and eat from the food magazine. They were then hand-shaped (Ferster and Skinner, 1957), over the course of two days, to peck the key, which was illuminated with red light. Following this, they were exposed to eight, 50-reinforcement sessions in which each key peck was reinforced (CRF). The key and houselight were continuously illuminated, except during reinforcement. The pigeons were then exposed to a positive automaintenance procedure, identical to that described in Experiment I, for seven sessions. Following this, the pigeons were divided into two pairs: Pigeons 62 and 2858 were exposed to an FI 30-sec schedule of reinforcement (a peck after 30 sec was reinforced; pecks before 30 sec elapsed had no scheduled consequence); Pigeons 88 and 1623 were exposed to an FR 25 schedule of reinforcement (every twenty-fifth peck was reinforced). After 18 sessions of 50 reinforcements, the reinforcement schedules in force for the two groups were reversed, for 21 sessions of 50 reinforcements.

RESULTS AND DISCUSSION

Figure 5 presents session-to-session median response durations for each of the pigeons on

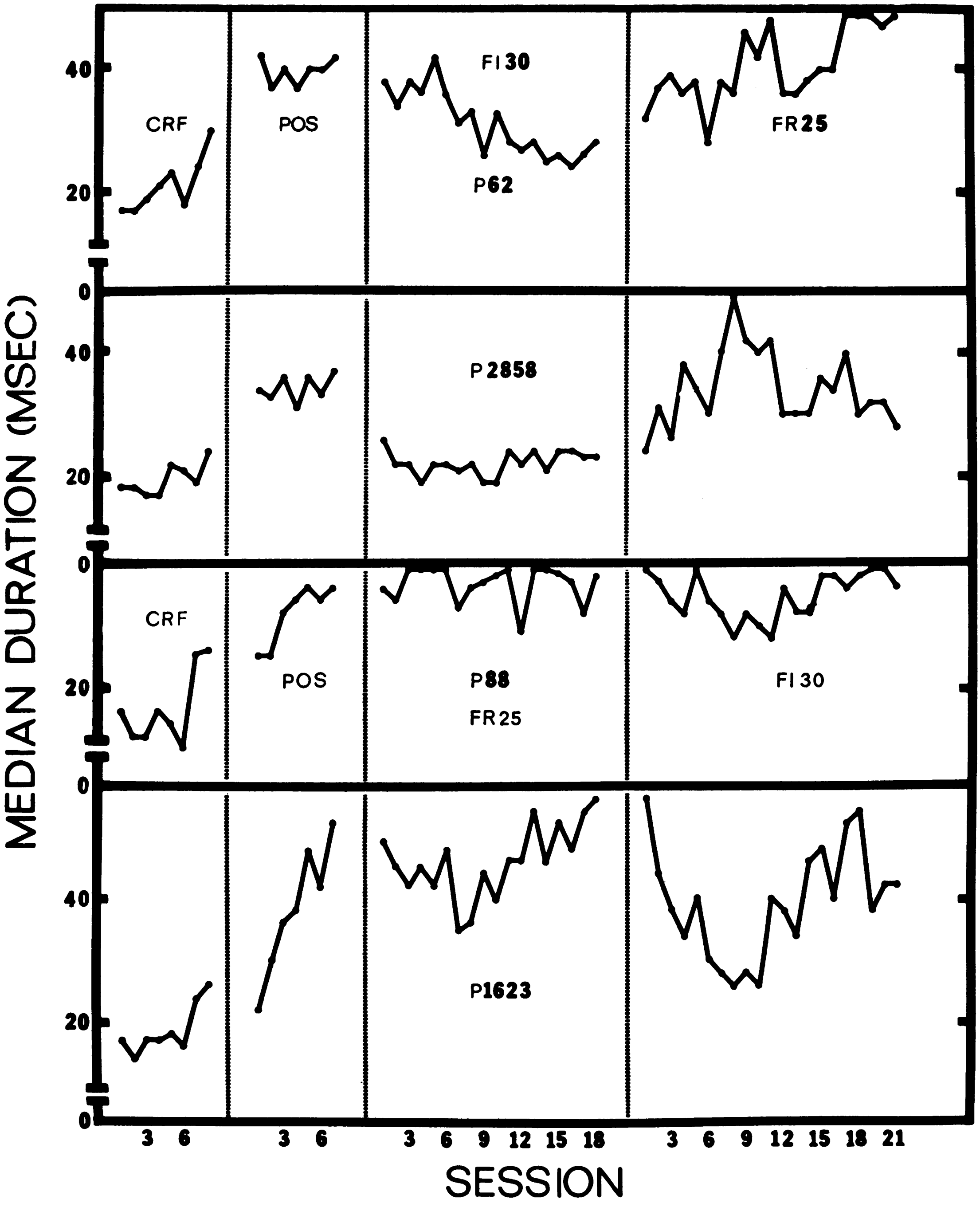

Fig. 5. Session-to-session median response durations for the four pigeons in Experiment II. See legend of Figure 2 for details.

CRF, positive automaintenance, FI 30-sec, and FR 25 procedures. The vertical lines in the figure indicate procedure changes. The data are plotted in the order in which the procedures were given. Thus, for Pigeons 62 and 2858, the FI data precede the FR data; for Pigeons 88 and 1623, the reverse is true. As in Experiment I, the initial responses of each pigeon on CRF were of short duration (10, 10, 11, and 15 msec for Pigeons 62, 2858, 88, and 1623, respectively). Indeed, the median durations of the pigeons on CRF tended to remain short, and though they did increase by about the sixth session, at terminal performance they were still shorter than median durations at the termination of the other three procedures, though longer than durations obtained on the negative automaintenance procedure (Experiment I).

Durations obtained on the positive automaintenance, FI, and FR procedures were similar to each other, though durations on the FI schedule tended to be shorter than durations on the FR. On all three procedures, durations were noticeably longer than on negative automaintenance.

Relative frequency distributions of duration, in 2-msec class intervals, on each of these procedures, are shown in Figure 6 for Pigeon 88. The data are taken from the first four sessions of the CRF procedure (cumulated), and from the last session of each of the other procedures. It is apparent that the duration distributions from the positive automaintenance, FI, and FR procedures were quite similar, though the FR distribution was somewhat less variable than the other two. The distribution from the CRF procedure was quite distinct, however. It resembled the distributions obtained on the negative automaintenance procedure, except that it was broader, *i.e.*, it contained substantially more long-duration pecks. It is possible that in these early sessions of CRF, one sees the emergence of the population of long-duration pecks out of the already present population of short-duration pecks. With increasing experimental exposure, the long-duration pecks increase in number, as evidenced by the increase in median duration depicted in Figure 5. However, it must be acknowledged that this account is speculative and that plausible alternatives exist. For example, it is possible that the critical determinant of long-duration pecks is intermittency of reinforcement. If so, then pigeons exposed to CRF after FI and FR exposure would still emit short-duration pecks, contrary to what the present account would suggest.

An essentially similar pattern of duration is shown in Figure 7, for Pigeon 1623. Again, the positive automaintenance, FI, and FR procedures yielded similar distributions, while the CRF procedure yielded a distribution that was broader than, but otherwise similar to

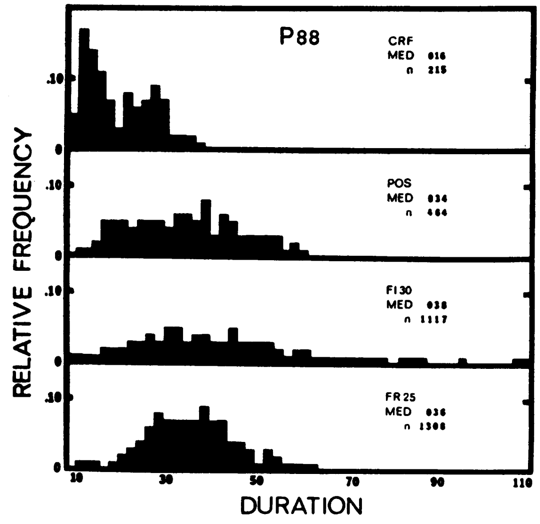

Fig. 6. Relative frequency distributions of duration for Pigeon 88, from the last session of each of the procedures employed in Experiment II. See legend of Figure 4 for details.

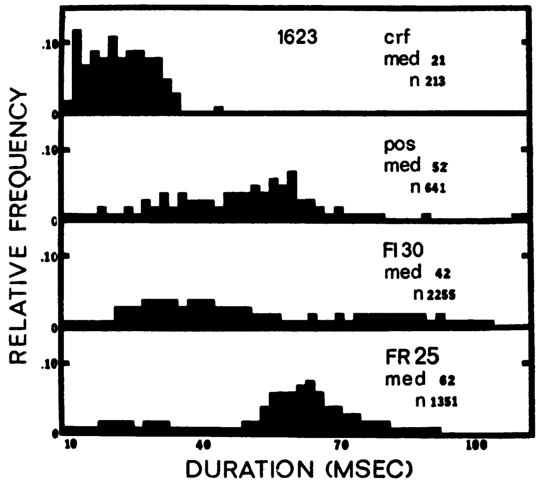

Fig. 7. Relative frequency distributions of duration for Pigeon 1623, from the last session of each of the procedures employed in Experiment II. See legend of Figure 4 for details.

negative automaintenance distributions. Also, the distribution of durations on FR was again less variable than on FI. It is possible that the contingency difference between FR and FI schedules favors more efficient, and hence less variable, peck topographies on the FR than on the FI.

There are two main conclusions to be drawn from Experiment II. First, the preponderance of long-duration pecks that characterizes positive automaintenance responding also characterizes responding in FI and FR reinforcement schedules. This implies that an adventitious response-reinforcer contingency is partly responsible for positive automaintenance responding. Second, the conclusion suggested in Experiment I that initial key pecks are of short duration, independent of procedure, and that long-duration pecks develop with exposure to a positive response-reinforcer contingency, is supported by the durations obtained on the CRF procedure in the present experiment.

EXPERIMENT III

The first two experiments established that there are at least two populations of key pecks: the short-duration pecks that occur on negative automaintenance, and the long duration pecks that occur on positive automaintenance and conventional reinforcement schedules. The present experiment attempted to analyze the apparent insensitivity of negative automaintenance key pecks to their consequences by directly testing the hypothesis that short-duration pecks are insensitive to differential reinforcement, while long-duration pecks are sensitive to differential reinforcement. To do this, pigeons were exposed to procedures in which only pecks within a specified range of durations were reinforced. The durations chosen were sometimes in the short-duration portion of the distribution, and were at other times in the long-duration portion.

METHOD

Subjects

The four subjects in Experiment II served. There was a two-week interval between the termination of Experiment II and the start of Experiment III.

Apparatus

The apparatus was identical to that described in Experiment I, except that the PDP-8 computer, previously employed only to record peck durations, was also employed to control the occurrence of reinforcement.

Procedure

The four pigeons were exposed to a variable-ratio (VR) 5 schedule, in which one of every five responses, on the average, was reinforced, for eight, 50-reinforcement sessions. A frequency distribution of durations across the last three sessions of VR 5 was computed for each pigeon. A differential-reinforcement-of-short-duration procedure was then instituted. Each response with duration in the first third (Pigeons 62 and 2858), first quartile (Pigeon 1623), or first quintile (Pigeon 88) of the distribution of durations on the VR-5 procedure was reinforced. No response with duration longer than this criterion (which was different for each pigeon) was reinforced. After 7 to 12, 50-reinforcement sessions on this procedure (the number of sessions varied from pigeon to pigeon), the duration criterion was modified on the basis of the distribution of durations for the last four sessions. The pigeons were then exposed to this procedure, in which responses in the first third of the new distribution of durations were reinforced for Pigeon 62 and 2858, and the first quarter of the distribution for Pigeons 88 and 1623, for 6 to 8 additional sessions. After this, the pigeons were returned to the VR-5 procedure for seven sessions, in order to regain relative frequency distributions of duration based on a non-differential reinforcement procedure. Finally, the duration distribution across the most recent three VR 5 sessions was computed for each pigeon, and the differential-reinforcement-of-duration procedure was again in force. This time, however, only responses in the fourth quintile of the duration distribution of each pigeon (in the long-duration peck region) were reinforced. After 14 sessions, the experiment was terminated.

RESULTS AND DISCUSSION

An effective way to evaluate the pigeons' sensitivity to the various procedures involving differential reinforcement of duration is to index responses per reinforcement. On VR 5, responses per reinforcement would be expected to hover around five, from session to session. On the differential reinforcement procedures, if the pigeon's behavior indicated no sensitivity whatsoever to the contingencies, *i.e.*, if the distributions of duration were uninfluenced, the procedure would effectively also be VR schedules, with the expected number of responses per reinforcement either 3, 4, or 5, depending on whether a third, a quarter, or a fifth of the duration distribution had been allotted to the reinforcement region. On the other hand, sensitivity to the contingency would be readily marked by a decrease from the baseline in the number of responses per reinforcement.

Figure 8 presents the relevant data. The session-to-session number of responses per reinforcement is indicated for each pigeon. Vertical lines indicate procedure changes, and each panel is labelled with the appropriate procedure. The horizontal lines indicate the number of responses per reinforcement expected if (a) there were no differential reinforcement contingency (VR), or (b) the differential reinforcement contingency had no effect on the distribution of duration. Data points below the horizontal lines are evidence that the pigeons were sensitive to the differential reinforcement contingency.

The second panel of the figure, for each pigeon, is from the differential reinforcement procedure. It is clear that none of the pigeons indicated sensitivity to differential reinforcement. Not a single point is below the horizontal line. Indeed, the effect of the differential reinforcement procedure was to increase substantially (rather than decrease) the number of responses per reinforcement. This rather surprising effect is similar to some data obtained in Experiment I, when the probability of reinforcement on positive automaintenance was decreased from 1.00 to 0.50 and 0.20. The effect of that manipulation (Figures 2 and 3) was to increase response rate and response duration. A similar increase in response duration in the present experiment would, of course, increase the number of responses per reinforcement.

This first exposure to a differential reinforcement procedure indicated that short-duration pecks were insensitive to differential reinforcement. A question remained, however, as to whether any pecks evidenced sensitivity to this type of procedure. This question is answered in the third panel of Figure 8, for each pigeon. In this procedure, the differential reinforcement criterion was modified to include all the previously reinforced durations, plus some additional, longer durations. As the third panel in the figure indicates, all four pigeons demonstrated sensitivity to this new contingency. Interestingly, the changes in the distributions of response duration that produced the decreases in responses per reinforcement occurred primarily in the newly positive regions of the distributions. The original criterion durations did not change much in frequency (see Figure 9).

After the VR 5 was in effect for seven sessions, in order to regain distributions of duration that were uninfluenced by differential reinforcement, the sensitivity of long-duration pecks to differential reinforcement was reexamined. This time, only pecks in the fourth quintile of the distribution were reinforced. As can be seen in the last panel of the figure, for each pigeon, sensitivity to this contingency was marked. At the end of the experiment, the pigeons were emitting between 1.8 and 2.5 responses per reinforcement. The width of the reinforced region was only 4 msec for one pigeon (2858) and 6 msec for the other three.

Figure 9 presents relative frequency distributions, from the last session of each procedure, for Pigeon 62. The open bars indicate the class intervals of duration that were reinforced differentially. There are two important points to be made about these data. First, compare the first and third panels of the figure. It was mentioned above that the sensitivity to differential reinforcement that occurred when the range of reinforced durations was increased (third panel) was due not to an increase in the frequency of originally positive, short-duration pecks, but to an increase in the newly positive, longer-duration pecks. The third panel of the figure bears this point out. The most striking difference between panels one and three in the distribution of durations within the reinforced region is the greater number of durations in the third panel which fall in the five longer-duration class intervals. Thus, in order for a pigeon to demonstrate sensitivity to the differential reinforcement contingency, the reinforcement region must include at least a portion from the population of long-duration pecks, and it is precisely this portion of the

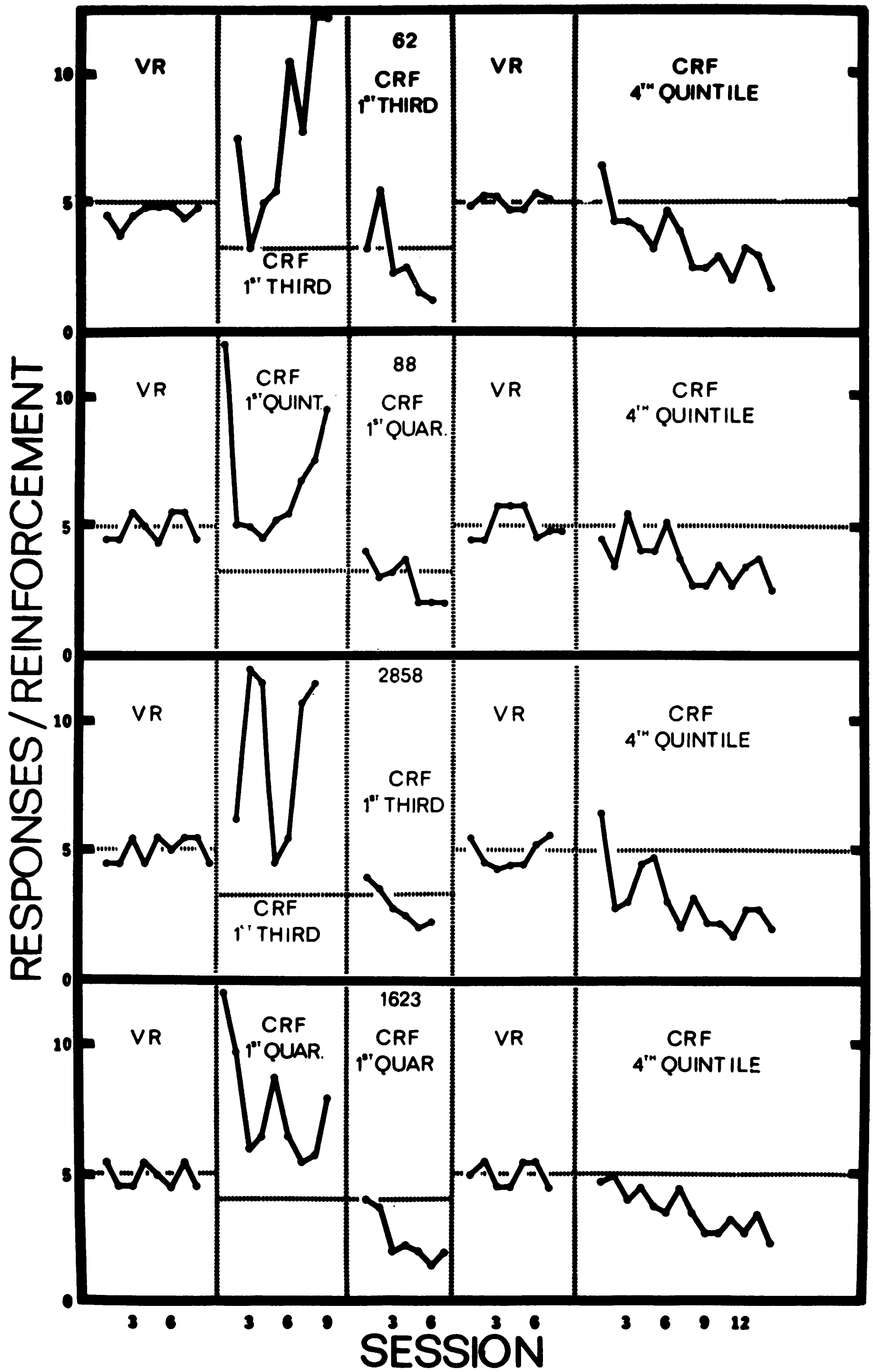

Fig. 8. Session-to-session mean number of responses per reinforcement for each pigeon, on each of the procedures employed in Experiment III. Vertical lines indicate procedure changes, and each panel is labelled with the appropriate procedure. The horizontal lines indicate the expected number of responses per reinforcement if (a) there was no differential reinforcement contingency, or (b) the differential reinforcement contingency had no effect. See text for further details.

distribution that is modified when the differential reinforcement contingency is effective. The second point comes from a comparison of the fourth and fifth panels of the figure. It can be seen that the frequency of short-duration pecks is essentially the same in both panels. Thus, the differential reinforcement contingency does not decrease short-duration pecks. The increased number of pecks in the reinforced region in the fifth panel is balanced by a decrease in other long-duration pecks. To summarize, the data in Figure 9 indicate that differential reinforcement of duration neither increases (third panel) nor decreases (fifth panel) short-duration key pecks. There is, however, a complexity in the distributions that permits no ready explanation, and hence, will merely be mentioned. There were more short-duration pecks in the first three procedures than in the latter two, despite similarities among the procedures themselves. The difference is especially marked in the first and fourth panels of Figure 9, despite the fact that the procedures employed were identical.

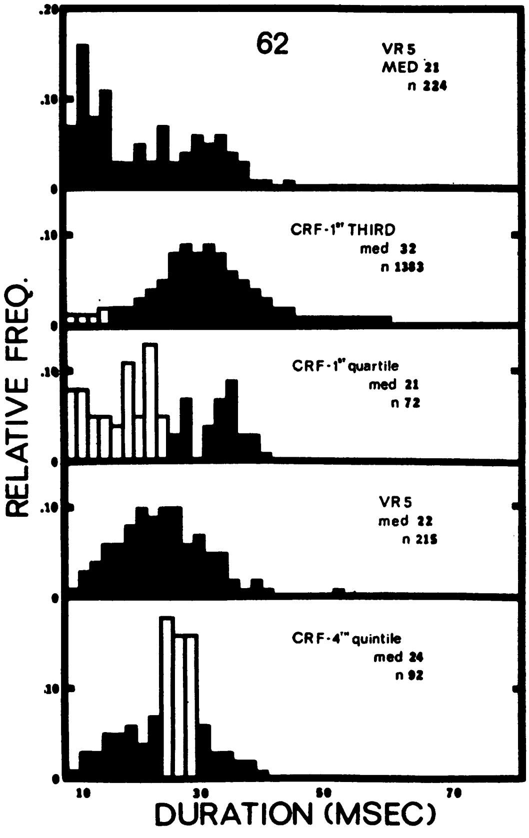

Fig. 9. Relative frequency distributions of duration for Pigeon 62, from the last session of each of the procedures employed in Experiment III. Open bars indicate class intervals of duration that were differentially reinforced. See legend of Figure 4 for further details.

Experiment III indicated that the frequency of short-duration pecks is insensitive to the consequences of these pecks, *i.e.*, unmodifiable by differential reinforcement, while the frequency of long-duration pecks is sensitive to their consequences. This result contributes to a reconciliation of the negative automaintenance phenomenon with standard operant phenomena. Since only short-duration pecks occur on negative automaintenance, and since short-duration pecks are insensitive to contingent reinforcement, it is no longer surprising that key pecking is not eliminated by a negative response-reinforcer contingency. The negative contingency does successfully interfere with the development of long-duration pecks, but at the same time, something in the negative automaintenance situation—presumably the direct effects of food presentation—sustain short-duration pecks.

The major results from these three experiments may be summarized briefly:

(1) There are two kinds of key peck, which may be differentiated on the basis of duration.

(2) Negative automaintenance key pecks are all short-duration pecks.

(3) Key pecks maintained by conventional reinforcement schedules are of both long- and short-duration, though primarily the former.

(4) Initial key pecks maintained by all appetitive procedures examined are short-duration pecks.

(5) Short-duration pecks are insensitive to differential reinforcement, while long-duration pecks are sensitive to differential reinforcement.

GENERAL DISCUSSION

The present series of experiments has demonstrated that the response class typically defined as the pigeon's key peck consists of two topographically distinct subclasses of responses. Key pecks of short duration are maintained by the direct effects of food presentation, while key pecks of long duration are maintained by contingent effects of food presentation. The implication of this finding for strategies of response definition, as well as the possible relationships between short- and long-duration key pecks is discussed below.

On the Definition of the Operant

Skinner's notion that operants may be defined functionally, *i.e.,* on the basis of those properties of responses on which reinforcement is dependent, has recently been criticized, on logical grounds, by Shick (1971). Shick pointed out the interdependence of the definitions of operants and reinforcers, and suggests that they can be defined only relatively, in pairs (*e.g.,* key pecks for food, bar presses for water, *etc.*). Moreover, Shick noted that since the definition of the operant depends on the nature of the reinforcement contingency, there can be no operants in procedures in which reinforcement is response-independent (*e.g.,* positive automaintenance). The way to make definitions less context dependent, according to Shick, is to require that a class of responses be labelled an operant only if it satisfies the criterion of orderliness (Skinner, 1938) in combination with any reinforcer. However, this proposition would result in the exclusion of most response classes that have been traditionally studied as operants. It has been shown for example, that salivation in dogs is an operant if water is the reinforcer (Miller and Carmona, 1967), but a respondent if food is the reinforcer (Sheffield, 1965). Also, the key peck is not clearly a satisfactory operant with shock termination as a reinforcer (*e.g.,* Azrin 1959; Hoffman and Fleshler, 1959; Rachlin, 1969), though it obviously is with food as a reinforcer (*e.g.,* Ferster and Skinner, 1957).

A further problem for the definition of an operant is raised by the present data. The notion that the key-peck operant subsumes two different classes of pecks, only one of which is sensitive to contingent reinforcement, both belies the notion that members of an operant class are homogeneous with respect to their sensitivity to environmental consequences, and obscures an assessment of the relative contributions of the different effects of reinforcing stimuli in controlling behavior. Whether similar topographical constraints exist on the definition of other operants (*e.g.,* bar pressing or alley running), or whether the key peck poses unique definitional problems, is a subject for further study.

Thus, the functional definition of the key-peck operant is at once too narrow (in the sense that, as Shick points out, it is over-dependent on context) and too broad (in the sense that it includes non-operant pecks). However, the recognition of these definitional problems may ultimately result in a more detailed, and more generally applicable assessment of the variables that control operants. It may be possible now to define the key-peck operant, independent of context, on the basis of topography. Such a definition would facilitate trans-situational comparisons, and help to disentangle the phylogenetic and ontogenetic origins of behavior (Skinner, 1966). For example, the idea that pecks that occur on negative automaintenance differ in duration, and locus of control, from pecks that occur on operant reinforcement schedules, makes reconciliation of the negative automaintenance phenomenon with conventional operant phenomena less difficult. Similarly, the imperfect control over key pecking by reinforcement contingencies observed in other procedures (Schwartz and Williams, 1971), such as the DRL (differential reinforcement of low rate), may be reassessed in light of the two different kinds of key peck, and two sources of control posed in the present discussion. Schwartz and Williams (1971) suggested that much non-reinforced DRL key pecking is the result of direct enhancement of pecking by food presentation, as in negative automaintenance. They suggest that food presentation has both direct and contingent effects on pecking in all operant procedures, but that in most procedures, both effects serve to enhance pecking. On the DRL, however, (as in negative automaintenance) the response-reinforcer contingency is meant to constrain pecking so that direct and contingent effects are in opposition. This implies that many DRL key pecks are of short duration, and that, as Hemmes (1970) has shown, if the required operant is not a part of the pigeon's consumatory repertoire, DRL performance is more efficient, *i.e.,* includes fewer non-reinforced responses. Finally, it may be profitable to examine other properties of responses that comprise an operant class for systematic differences in sensitivity to experimental variables. Blough (1963) did such an analysis of interresponse times, and found that short (less than 0.35 sec) and long interresponse times were sensitive to different variables.

On the Relation between Short- and Long-Duration Pecks

Initial key pecks by all pigeons studied in the present experiments were of short duration, independent of procedure. Durations remained short with continued exposure to negative automaintenance, but lengthened with exposure to operant reinforcement schedules. On the basis of the notion that short-duration pecks are intimately tied to the pigeon's normal feeding pattern, it seems plausible that pigeons come into the experimental situation with that response topography already established, and develop the long-duration pecks with experimental exposure. It is possible that short-duration pecks comprise what Skinner (1938, 1966) has called a "minimal unit", a phylogenetically based behavior pattern on which operants are built (see Gamzu, 1971). If short-duration pecks are "minimal units", then long-duration pecks (at least in appetitive situations) presumably develop out of short-duration pecks, and depend for their early occurrence on both reinforcement and the prior occurrence of short-duration pecks. What this implies is that the effectiveness of contingent reinforcement may well depend on a class of responses, short-duration pecks, over which reinforcement contingencies have no control. Support for this notion comes indirectly from attempts to train pigeons to key peck to avoid or escape shock. Such attempts have either failed (Azrin, 1959; Hoffman and Fleshler, 1959), or required prolonged and painstaking shaping (Rachlin and Hineline, 1967). One can account for these difficulties by noting that in such procedures, the source of the short-duration pecks—food presentation—is absent, so that there is no "minimal unit" out of which operant key pecks may develop. The kinds of operants that are more easily trained in such situations (*e.g.*, head lifts or wing flaps) may provide clues as to which "minimal units" are present.

However, this argument about the dependence of operant pecks on the prior occurrence of short-duration pecks must be qualified. First, all pigeons in the present experiments were initially trained to peck the key with either auto-shaping or conventional hand-shaping procedures. It is possible that with some shaping procedures (*e.g.*, one in which a particular topography that yields only long-duration pecks is differentially reinforced), short-duration pecks might never occur in substantial numbers. Second, despite the difficulties, many pigeons do learn to key peck to escape or avoid shock (Rachlin, 1969; Rachlin and Hineline, 1967). It is possible that the experimenter inadvertently shaped long-duration peck topographies in those experiments, or that the absence of "minimal units" makes shaping difficult, but not impossible.

Finally, it is possible that the relationship between short- and long-duration pecks changes with continued exposure to reinforcement contingencies, so that long-duration pecks, though initially dependent on short-duration pecks, become less and less dependent as a function of prolonged contingent reinforcement. At present, all of these possibilities require experimental investigation.

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