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DIFFERENTIAL STIMULUS-REINFORCER EFFECTS ON THE DELAY OF REWARD GRADIENTS FOR DIFFERENT RESPONSES IN PIGEONS

by

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Table of Contents

List of Tables

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Introduction

Throughout the history of the study of learning many writers have distinguished between the learning processes involved in response-dependent (instrumental or operant conditioning) and response-independent (Pavlovian) procedures (e.g., Kimble, 1961; Rescorla & Solomon, 1967; Skinner, 1938). However, various findings have made it difficult to defend a two process distinction. The best that can be done at present is to define each learning process in terms of the procedure used to produce the behavioral change (Schwartz & Gamzu, 1977). Perhaps the phenomenon of autoshaping (Brown & Jenkins, 1968) most clearly exemplifies the difficulties involved in making a two process distinction. In an autoshaping procedure pigeons will approach and peck a keylight which is followed by food even though keypecking has no effect on food deliveries. Subsequent research by Williams and Williams (1969) using an omission procedure, provided evidence against the interpretation that this keypecking was maintained by superstitious reinforcement. These demonstrations that keypecking could be acquired and maintained with response-independent procedures (or in the Williams and Williams study in spite of a positive contingency for not keypecking), had a number of important implications. First, they provided evidence against the idea that keypecking was an arbitrary operant sensitive only to the instrumental processes of reward and punishment. Second, these findings reaffirmed that a two process distinction could not be made in terms of the type of behavior (autonomic versus skeletal) which each process could control.

An alternative approach to classifying behavior as being the result of Pavlovian or operant conditioning, is to investigate the extent to which that behavior is influenced by stimulus-reinforcer and/or response-reinforcer effects (Schwartz & Gamzu, 1977). Stimulus-reinforcer effects refer to behavior which can be ascribed to the correlation between a reinforcing stimulus and an antecedent discriminative stimulus. Response-reinforcer effects refer to behavior which can be ascribed to the correlation between a reinforcing stimulus and an antecedent response. The emphasis in this paper is on response-reinforcer and stimulus-reinforcer effects. Consequently it is important that these concepts are not confused with the effects of response-dependent and response-independent procedures. Although the concepts are clearly related (response-dependent procedures arrange a correlation between response and reinforcer while response-independent procedures arrange a correlation between a stimulus and a reinforcer), the emphasis in the present experiment is on the idea that behavior in response-dependent procedures may be the result of both response-reinforcer and stimulus-reinforcer effects. More specifically, the hypothesis is that stimulus-reinforcer effects differentially affect the delay of reward gradients for different responses in pigeons. Past research has demonstrated that stimulus-reinforcer effects may be an important determinant of performance in studies which employ pigeon's keypecking behavior as the dependent measure.

The Brown and Jenkins (1968) and Williams and Williams (1969) studies clearly demonstrate that keypecking may be influenced by stimulus-reinforcer effects. A number of other observations also support the notion that stimulus-reinforcer and response-reinforcer effects may interact to influence performance in response-dependent procedures. One such observation is positive behavioral contrast. One procedure for producing positive behavioral contrast is to change a multiple schedule with two equal variable interval (VI) components to a multiple schedule in which the reinforcement frequency in one component is reduced. This reduced reinforcement frequency in one component results in an increase in keypecking in the unchanged component (Reynolds, 1961). This increase in keypecking has been termed positive behavioral contrast. The most convincing explanation of positive behavioral contrast attributes the increased keypecking to stimulus-reinforcer effects. The rationale is that with the reduction in reinforcement frequency in one component, the unchanged component becomes a differential predictor of reward. The phenomenon of autoshaping is evidence that pigeons will peck a keylight which is a differential predictor of reward even in the absence of any response-reinforcer contingency. Therefore, when the reinforcement frequency in one component is reduced, keypecking to the unchanged component will increase because of those additional keypecks which can be ascribed to the stimulus-reinforcer contingency. This additivity theory of positive behavioral contrast has received a great deal of experimental support (see Schwartz & Gamzu, 1977, for a review).

Two other results indicate the influence of stimulus-reinforcer effects in response-dependent procedures. If keypecking is the required response pigeons typically do not perform well under either differential reinforcement of low rate schedules (DRL) or avoidance schedules. The former result can be ascribed to the stimulus-reinforcer based tendency for keypecking behaviors to be directed toward a stimulus which signals reward (e.g., Hemmes, 1975; Schwartz & Williams, 1971). The latter result can be ascribed to the stimulus-reinforcer based tendency for pigeons to avoid a signal for shock (e.g., Foree & LoLordo, 1974; Smith & Keller, 1970).

The preceding studies have demonstrated the importance of stimulus-reinforcer effects in a variety of response-dependent procedures. The present experiment is an attempt to demonstrate that stimulus-reinforcer effects may influence the delay of reward gradient. The rationale is that when a reward is delayed, the discriminative stimulus which precedes the response signals that reward is temporally distant. This stimulus-reinforcer relationship may influence performance in a delay of reward procedure. If the behavior which occurs because of the stimulus-reinforcer relationship is compatible with the required response, the stimulus-reinforcer effects in a delay of reward procedure will tend to improve performance. If the behavior which occurs because of the stimulus-reinforcer relationship is incompatible with the required response, the stimulus-reinforcer effects in a delay of reward procedure will tend to decrease performance. Therefore, stimulus-reinforcer effects may increase, decrease, or have no effect on the rewarded response when reward is delayed depending on the particular response requirement.

The Brown and Jenkins (1968) study indicates that stimulus-reinforcer effects tend to increase keypecking performance if reward is immediate. That is, keypecking which can be ascribed to stimulus-reinforcer effects is clearly compatible with a schedule in which keypecking is the required response. Other research indicates that increasing the interval between a keylight stimulus and reward decreases the tendency to approach and peck this keylight stimulus. Newlin and LoLordo (1976) reported that the acquisition of consistent autoshaped keypecking was retarded under a trace conditioning procedure as compared to a procedure in which food was presented while the conditioned stimulus was still projected on the key. Unfortunately, Newlin and LoLordo did not present complete data on the rate of autoshaped keypecking at steady-state. Consequently their results may not apply to steady-state behavior in delay of reward procedures. However, Ricci (1973) followed a 4 min inter-trial interval (ITI) with a sequence of four discriminable keylight stimuli each of which was 30 sec in duration. At steady-state Ricci found that the rate of autoshaped keypecking was less to stimuli which were further away from food than to stimuli which were temporally closer to the delivery of food. Staddon and Simmelhag (1971) demonstrated that temporal factors may also influence the probability of keypeck-like behaviors even in the absence of any keylight stimulus. They presented food at regular intervals, independent of the pigeon's behavior, and found that approach responses and pecking movements directed toward the magazine wall, increased in frequency as the time of food delivery approached. The Staddon and Simmelhag findings can be classified as a demonstration of stimulus-reinforcer effects influencing keypeck-like behaviors with the stimulus in their study being time. Finally, Wasserman, Franklin, and Hearst (1974) reported that pigeons withdrew from a keylight when the offset of that keylight never preceded the delivery of food by less than 33 sec. All of these findings provide evidence that the behavior which occurs because of stimulus-reinforcer relationships changes from being compatible with a required response of keypecking (Brown & Jenkins, 1968), toward being neutral, or even incompatible (Wasserman, Franklin, and Hearst, 1974), as the stimulus-reinforcer interval is increased. It should be apparent that this is exactly what is done in a delay of reward procedure in which the stimulus to which pecking is required is not present during the delay interval.

All of the preceding findings have demonstrated that behavior in response independent procedures changes as the stimulus-reinforcer interval is increased. However it remains to be shown that increasing the stimulus-reinforcer interval in a response-dependent delay of reward procedure will also affect behavior. As already noted increasing the stimulus-reinforcer interval by delaying reward should decrease keypecking performance because of the incompatibility of the behavior which can be ascribed to stimulus-reinforcer effects. (In the experiment to be reported below an increase in mean excess time will be used as an index of a decrease in level of performance. Mean excess time refers to the time taken to complete a response requirement above the minimum possible time needed to complete the requirement.) The effects of increasing the stimulus-reinforcer interval in a delay of reward procedure can be assessed by choosing response requirements such that the behavior which occurs because of stimulus-reinforcer effects changes from being incompatible with the required response toward being compatible as reward is delayed. Two such requirements are a withdrawal response requirement (WR) and a schedule which differentially reinforces other behavior (DRO). As the terms will be used here a WR schedule requires that the pigeon move away from a keylight which signals subsequent availability of food. A DRO schedule requires that the pigeon neither peck nor approach within 5 cm of a keylight which signals subsequent availability of food. When reward is immediate, and the ITI long enough, both of these responses should be difficult for pigeons (long mean excess times) because the stimulus-reinforcer based tendency to appraoch a keylight which is followed by food (Brown & Jenkins, 1968), is incompatible with the response requirements of withdrawing from (WR) or not approaching (DRO) the key. When reward is delayed the tendency to approach the keylight will be attenuated (or even completely eliminated) because of the increased stimulus-reinforcer interval. That is, as the delay interval is increased, behavior which occurs because of the stimulus-reinforcer relationship becomes more compatible with these two response requirements (Wasserman, Franklin, & Hearst, 1974).

The preceding analysis should not be interpreted to imply that delay of reward gradients are influenced only by stimulus-reinforcer effects. If stimulus-reinforcer effects were the sole determinants of the shape of the delay of reward gradients for different responses the preceding analysis would predict that when reward is delayed mean acess times should increase on a schedule in which keypecking is the required response, but that mean excess times should decrease on the DRO and WR schedules. However delay of reward gradients are presumably also influenced by the altered response-reinforcer relationship. In discrimination procedures for example, both choice responses are typically followed by the same delay of reward. Yet introducing a delay of reward into a discrimination procedure disrupts performance (e.g., Cox & D'Amato, 1977). Since response-reinforcer effects also influence performance in a delay of reward procedure, mean excess times on the DRO and WR schedules may increase, remain the same, or decrease when reward is delayed. Any of these results may occur depending on the relative influence of response-reinforcer and stimulus-reinforcer effects on the delay of reward gradients for these two responses. Mean excess times on schedules in which keypecking is the required response (fixed interval or FI schedules in this experiment) should always increase because both the response-reinforcer and stimulus-reinforcer effects steepen the delay of reward gradient for keypecking. If the stimulus-reinforcer effects influence performance on the DRO and WR schedules more than the response-reinforcer effects, mean excess times should decrease when reward is delayed. This result would provide conclusive support for the hypothesis that stimulus-reinforcer effects differentially affect the delay of reward gradients for different responses.

If mean excess times on the DRO and WR schedules increase when reward is delayed (if the response-reinforcer effects are stronger than the stimulus-reinforcer effects), the hypothesis would be weakly supported only if this increase was less than the increase in mean excess time on the FI schedule. The hypothesis would only be weakly supported by this second possible result because the scales for the different responses are probably not the same. Even if the same dependent measure is employed for all three responses (mean excess time in this experiment) there is an unknown relationship between mean excess time and the underlying scale which specifies strength of response tendencies. Furthermore, this relationship may be different for each response. The only assumption which can be made is that mean excess time is at least an ordinal measure of strength of response tendencies. Ordinal scales do not allow meaningful comparisons of gradient shapes because when such a scale is used it can be transformed an infinite number of ways. Furthermore it can be transformed in a different way for each response requirement to give any shape which maintains order, e.g., a monotonic function. For these reasons greater increases in mean excess times on the FI schedule than on the DRO or WR schedules when reward is delayed, could be ascribed to different underlying scales for the different responses and not necessarily to differential stimulus-reinforcer effects. In the absence of any convincing evidence as to the nature of the relationship of mean escess time to the underlying scale which specifies strength of response tendencies, a greater increase in mean excess time on the FI schedule than on the DRO or WR schedules when reward is delayed would provide suggestive evidence for differential stimulus-reinforcer effects. Similarly, greater increases in mean excess time on the DRO or WR schedules than on the FI schedule when reward is delayed (or no differences in the amount of increase in mean excess time on these schedules), would provide suggestive evidence against differential stimulus-reinforcer effects. Finally, decreases in mean excess time on the DRO or WR schedules (but not on the FI schedule) when reward was delayed could not be ascribed to differences in the underlying scales for the three responses because such a reversal in order could not be eliminated by any permissible transformation, one maintaining order. This last result would therefore provide conclusive evidence for the hypothesis that stimulus-reinforcer effects differentially affect the shape of the delay of reward gradients for different responses in pigeons.

Method

Subjects

Eight experimentally naive White Carneaux pigeons obtained from a local supplier served as subjects. They were unsystematically assigned to two groups of four birds. The birds were housed in individual cages in a continuously illuminated colony room. Water and grit were freely available. They were maintained at 75% of their free-feeding weights. Supplementary feedings of mixed grain (50% wheat and 50% milo) were given following test sessions as required.

Apparatus

Two plywood, sound attenuated, experimental chambers were painted flat grey. Each chamber was 32 cm high, 39 cm side to side and 35 cm front to back. A Gerbrands pigeon key was centered in one panel with the bottom of the key 22 cm above the false floor and 13 cm above the 5 cm x 5 cm aperture for the Lehigh Valley grain feeder. The feeding apparatus was modified to include a photoelectric cell in order to control actual eating time. A minimum force of approximately .1 N was required to operate the response key and produce an audible feedback click. An IEEE stimulus projector was used to present the various stimuli on the response key. The chamber was illuminated by a 6 watt bulb located above a round translucent window centered in the ceiling of the chamber. The houselight was on at all times except during grain presentation and at the completion of a session. A ventilating fan and white noise of approximately 80 dB (measured on the C-scale of a General Radio sound level meter Model #1551B) masked extraneous sounds. The speaker was mounted in the roof of the chamber behind the front panel. Each chamber was housed in a separate room and standard electromechanical programming equipment was housed in a third room. All data (total excess time, total number of keypecks to the various stimuli, etc.) were accumulated within a session on BRS/LVE counters.

The two chambers were virtually identical in all of the above respects. One chamber was modified to include a tilt floor which pivoted in a front to back direction. The floor was suspended from a steel bar (6 mm in diameter) which was anchored to the side of the chamber at one end, and to a 3 cm high (above the false floor) x 3 cm long x 1 cm wide block of wood at the other. The floor, bar, and block of wood were covered by grey tape. Covering the floor with tape (with the bar underneath the tape) provided a continuous surface with only a gradual slope on each side of the bar. This mitigated against the possibility of the bar impeding the movement of the pigeon. A microswitch was located underneath the floor and its circuit was completed whenever the pigeon was standing in the back half of the chamber. This made it possible to always ascertain whether the bird was in the front or back half of the chamber. A 1000 hz tone of approximately 85 dB was provided by a Hewlett Packard Model #200 AB audio oscillator.

The other chamber was modified to include a photobeam and photocell in the upper right and upper left hand corners respectively. The photobeam and photocell were arranged so that the circuit was broken if the pigeon's body blocked more than one-half of the area of a cross-section of a cylindrical column of light 18-19.3 cm above the false floor and 5-6.3 cm in front of the key. The photobeam was on at all times except during grain presentation and at the completion of a session.

Design

Each bird was tested on two different response requirements in each of two conditions. In one condition successful completion of the appropriate response requirement was followed by immediate reward. In the other, reward was delayed for 30 sec. The two requirements alternated within a session and the reward conditions were changed between phases. For the DRO group the two response requirements were a differential reinforcement of other behavior schedule (DRO) and a fixed interval 10 sec schedule for a keypeck response (FI 10"). The DRO schedule required that the bird neither peck the key nor break the photoelectric beam for a continuous 5 sec period. The 5 sec DRO timer operated continuously while the requirement was in effect as long as the bird neither pecked the key nor broke the photoelectric beam. If the pigeon engaged in either of the above behaviors the timer was reset and the keylight was darkened as long as the photobeam was broken. Peck and DRO requirements were each signalled by a different keylight stimulus.

For the WR group, the two response requirements were a withdrawal response schedule (WR) and the keypeck FI 10" schedule. The WR schedule required that the bird stand in the back half of the chamber for a continuous 5 sec period. Feedback was provided by a 1000 hz tone and attenuation of the white noise when the bird depressed the microswitch by standing in the back half of the chamber while the WR schedule was in effect. Each trial ended in food and each response requirement was signalled by a different keylight stimulus.

For two birds in each group the sequence of the two conditions of reward was immediate - 30 sec delay - immediate. For the other two birds in each group the sequence of conditions was 30 sec delay - immediate - 30 sec delay.

Procedure

Each bird was trained and tested in the same chamber throughout the experiment. One session of feeder training was given while the response key was covered by grey tape. This session was continued until the bird ate reliably from the food hopper within 3 sec of grain presentation.

Following feeder training all birds were hand shaped to peck the key. The key was trans-illuminated by a white traingle on a black background during all keypeck training and testing. All birds were shaped within two sessions. Further training of the keypecking response was given during the next three sessions. During the first of these sessions a 15 sec ITI (white keylight) was followed by presentation of the white triangle on the key. The first peck to the white triangle resulted in 3 sec of grain. (Entry of the bird's head into the food hopper interrupted a photoelectric beam and activated the food timer. This maintained a constant eating time of 3 sec across conditions.) The next session the schedule was increased to an FI 5" and the ITI was increased to 30 sec. For the last of these preliminary sessions the FI schedule was increased to its terminal value of 10 sec and the ITI was increased to its terminal value of 60 sec. These and all subsequent sessions ended after 60 grain presentations.

At this point training began on the DRO and WR schedules. With the exception of this training (and subsequent testing) on these different response requirements all procedures and stimuli were identical for the WR and DRO groups. Consequently procedural details will only be given for the DRO group. Training under the DRO schedule began by following the ITI with a keylight stimulus of three horizontal black bars on a white background. This stimulus signalled that a DRO schedule was in effect. A DRO 1" schedule was in effect for the first two training sessions. The DRO requirement was then increased by 1 sec every two sessions until the terminal value of 5 sec was reached. Two sessions were then given on the DRO 5" schedule. The DRO group was then divided into two subgroups. One subgroup was switched to a schedule in which the white triangle (signalling the FI 10") and the three horizontal bars (signalling the DRO 5") followed the ITI on alternate trials. Successful completion of the appropriate response requirement (either DRO 5" or FI 10" depending on the trial) resulted in 3 sec of grain. Testing continued under these conditions for a minimum of 15 sessions and until a stability criterion had been reached. To determine if criterion had been reached data were first grouped into blocks of three sessions. One part of the criterion required that the mean of the time which was taken to complete the DRO 5" (and FI 10") for each 3 day block varied by no more than 10% of the mean for the entire 9 day period. The second part of the criterion required that there not be any upward nor downward trend either over the last 3 blocks or over the 3 sessions within the last block. When criterion had been reached the bird was advanced to the next phase of the experiment. Otherwise the bird was tested for an additional 3 sessions and the 9 day period which was then checked consisted of these additional 3 sessions and the previous 6 sessions. When criterion had not been reached within 51 sessions the bird was advanced to the next phase after the 51st session.

After the stability criterion had been reached (or a bird had been tested for 51 sessions under one condition), the conditions were then gradually changed until a 30 sec delay of primary reward followed completion of the required response. This change was made by inserting sessions such that the delay was gradually increased from 0 to 30 sec across sessions. The sequence of delays used was 1, 3, 3, 5, 5, 7, 10, 13, 16, 19, 22, 25, 28, and 30 sec. The above sequence was not invariant in that in several cases 2-3 extra sessions of training under the shorter delay values were inserted when the experimenter judged that the delay time was being increased too rapidly. Bird E of the DRO group was tested under a 16 sec delay of reward after extremely long excess times were taken to complete the FI requirement at longer delays. On all trials the houselight remained on and the keylight was red during the delay interval. When criterion was reached under the 30 sec delay of reward condition, the birds were retested in the immediate reward condition. The experiment was completed when the stability criterion was again reached in the immediate reward condition.

The second DRO group was first tested with the 30 sec delay, switched to the immediate reward condition after the stability criterion had been reached, and then retested with the 30 sec delay. For both the initial change to a 30 sec delay of reward, and the reversal, the delay was gradually increased using the same procedure as before.

All birds were tested daily with the following exceptions. A bird was not tested if its presession weight was less than 70% or greater than 80% of its free-feeding weight. Birds were rarely underweight (less than 5 times for all birds combined). Certain birds were often overweight (A, C, D, and H) and were normally only tested six days a week. The second exception occurred when birds E, F, A, and B were not tested for a 3-5 week period between Phases I and II. The third exception to daily testing occurred when the experimenter took an occasional rest day. This occurred no more than 2-3 times per bird.

Results

All birds continued to keypeck on the FI schedule and complete the DRO and WR requirements when reward was delayed with one exception. Bird C often had very long excess times on the FI schedule in Phase I (delayed reward). This bird was gradually decreasing the time taken to complete the FI requirement when an equipment failure resulted in an almost complete absence of keypecking on the FI schedule. This breakdown in FI keypecking continued for two sessions. Bird C was therefore switched to conditions of immediate reward even though it had neither met the stability criterion nor been tested for 51 sessions in Phase I. The two sessions which occurred after the equipment failure were not used in the data analysis for this bird.

Results are summarized in Tables I and II. (Acquisition data are contained in the appendix.) Table I summarizes the results for those birds who were tested twice under conditions of immediate reward and Table II summarizes the results for those birds who were tested twice under conditions of delayed reward. The mean excess times on the DRO (or WR) requirement over the last nine sessions of each condition are shown columns 1-3. The same measures for the FI requirement are shown in columns 8-10. (Only 17 sessions were used in computing the mean excess time on the FI schedule under conditions of delayed reward for Bird G because of a counter failure during one of the last nine sessions of Phase III for this bird.) The columns which contain the results for the immediate reward condition are indicated by an I and the columns for the delayed reward condition are indicated by a D. The subscripts indicate whether those data were obtained from the first or second group of sessions that bird was tested under that condition. The last nine sessions were used to determine if performance met the stability criterion and should therefore be representative of steady-state performance. Asterisks indicate those conditions in which the stability criterion was met within 51 sessions.

Columns 4 and 11 contain the mean excess times on the DRO (or WR) and FI peck requirements, respectively, averaged over the two conditions in which the bird was tested twice. The mean excess time on the DRO (or WR) schedule under conditions of immediate reward was subtracted from the same measure under conditions of delayed reward for each bird and the results are shown in column 5. Column 12 contains the same difference for the FI schedule. Positive values in columns 5 and 12 indicate that the bird took less mean excess time to complete the response requirement when reward was immediate than when it was delayed. This result was obtained for six out of eight birds on the DRO (or WR) schedule and suggests that as a group the response-reinforcer effects of delay were stronger than the stimulus-reinforcer effects of delay on these two schedules. All eight birds took less mean excess time to complete the FI requirement when reward was immediate than when it was delayed (column 12). Note that the result which would conclusively demonstrate differential stimulus-reinforcer effects (decreases in mean excess time on the DRO or WR schedules when reward was delayed) was not obtained. Consequently any tests of differential stimulus-reinforcer effects must compare mean excess times across the different responses. Unfortunately the DRO, FI, and WR scales are probably not the same. Nevertheless some indication of differential stimulus-reinforcer effects on these requirements may be obtained by analyzing the data in several different ways in which each analysis implies a different relationship of mean excess time to the underlying scale which specifies strength of response tendencies. This procedure will be followed here.

Insert Tables I and II about here

The first analysis compares the difference in mean excess time (delayed minus immediate) on the DRO (or WR) schedules to the same difference on the FI schedule. A significance test on difference scores would be appropriate if mean excess time is an interval scale measure of strength of response tendencies. The difference score on the DRO (or WR) schedule (column 5) was subtracted from the difference score for that bird on the FI schedule (column 12) and the results are shown in column 15. Seven out of eight values in this column are positive indicating that these birds showed a greater increase in mean excess time when reward was delayed on the FI schedule than when reward was delayed on the DRO (or WR) schedule. This result was statistically significatn ($p = .035$) according to a one-tailed binomial sign test (Siegel, 1956). A one-tailed test was employed because the hypothesis of differential stimulus-reinforcer effects predicts that the decrement in mean excess time when reward is delayed will be greater on the FI schedule than on the DRO (or WR) schedule. This prediction was supported.

A second way to analyze the data is to form a ratio of mean excess time (delayed over immediate) for each response. A larger ratio on one response than another indicates a greater proportional decremental effect of a delayed reward on mean excess time for that response. Greater proportional decremental effects on mean excess times suggest greater decrements in strength of response tendencies if the log of mean excess

Table Caption

Table 1: A Comparison of Mean Excess Times on the DRO (or WR) and FI Requirements over the Last Nine Sessions of Each Condition for those Birds who Were Tested Twice under Conditions of Immediate Reward

Table I

A Comparison of Mean Excess Times on the DRO and FI Requirements over the Last Nine Sessions of Each Condition for those Birds who Were Tested Twice under Conditions of Immediate Reward

		DRO OR WR							FI							Comparison FI to DRO	
		Mean Excess Time							Mean Excess Time								
Column		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Bird	Group	I_1	D	I_2	$\overline{I_1+I_2}$	Diff	Ratio	U	I_1	D	I_2	$\overline{I_1+I_2}$	Diff	Ratio	U	Diff Minus DRO Diff	Ratio over DRO Ratio
A	WR	3.0*	5.7	0.8*	1.9	3.8	3.0	3	0.4*	4.4	0.2*	0.3	4.1	14.7	0	0.3	4.9
B	WR	7.6*	6.4	7.7*	7.6	-1.2	0.8	113	0.6*	19.1	3.2*	1.9	15.9	10.1	0	17.1	12.6
E	DRO	12.6*	9.7	5.2	8.9	0.8	1.1	53	0.1*	5.6	0.5	0.3	5.3	18.7	0	4.5	17.0
F	DRO	1.8*	12.0*	8.8*	5.2	6.8	2.3	17	1.8*	10.4*	1.2*	1.5	8.9	6.9	0	2.1	3.0

Table Caption

Table II: A Comparison of Mean Excess Times on the DRO (or WR) and FI Requirements over the Last Nine Sessions of Each Condition for those Birds who Were Tested Twice under Conditions of Delayed Reward

Table II

A Comparison of Mean Excess Times on the DRO and FI Requirements over the Last Nine Sessions of Each Condition for those Birds who Were Tested Twice under Conditions of Delayed Reward

		DRO OR WR							FI								
		Mean Excess Time							Mean Excess Time							Comparison FI to DRO	
Column		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Bird	Group	D_1	I	D_2	$\overline{D_1+D_2}$	Diff	Ratio	U	D_1	I	D_2	$\overline{D_1+D_2}$	Diff	Ratio	U	FI Diff Minus DRO Diff	FI Ratio over DRO Ratio
C	WR	13.6	3.7	16.6	15.1	10.4	4.1	3	20.0	1.6	14.1	17.0	15.4	9.6	0	5.0	2.3
D	WR	9.6	5.1	13.9*	11.8	6.7	2.3	10	5.8	2.7	5.2*	5.5	2.8	2.1	26	-3.9	0.9
G	DRO	2.0	3.4*	2.9	2.4	-1.0	0.7	104	6.4	3.0*	6.1	6.3	3.3	2.1	21	4.3	3.0
H	DRO	12.0	3.8*	16.5	14.2	10.4	3.7	13	13.0	0.6*	9.6	11.2	10.6	18.7	0	0.2	5.0

time is assumed to be linearly related to strength of response tendencies. The ratios of mean excess time when reward was delayed to mean excess time when reward was immediate for the DRO (or WR) requirement are shown in column 6. The same ratios for the FI requirement are shown in column 13. The ratio on the FI schedule was then divided by the ratio on the DRO (or WR) schedule for that bird and the results are shown in column 16. Values greater than one in this column indicate that delaying reward had a greater proportional decremental effect on the FI schedule than on the DRO (or WR) schedule. This result was obtained from seven out of eight birds and was statistically significant according to a one-tailed binomial sign test ($\underline{p} = .035$). This result too suggests that stimulus-reinforcer effects tend to produce a steeper gradient for the peck response than for the DRO or WR responses.

The third comparison made is of the degree of overlap in mean excess times across the delayed and immediate reward conditions for each response requirement. This last analysis only assumes that mean excess time is an ordinal scale. Although ordinal scales can be transformed an infinite number of ways, all acceptable transformations of ordinal scales maintain order. In other words there is no way to transform an ordinal scale such that the degree of overlap, as measured by the Mann-Whitney U Statistic, could be changed. Note that when the test is used in this way it is being used strictly as a descriptive statistic not as an inferential statistic. The U values shown in column 7 were computed by determining the number of sessions (using only the last nine sessions of each condition) the mean excess time on the DRO (or WR) schedule under conditions of immediate reward, was less than the mean excess time under conditions of delayed reward. The same information for the FI requirement is shown in column 14. The larger the value of U the greater is the degree of overlap across the immediate and delayed reward conditions. (Note: This is different from most statistical tests where larger values are associated with larger differences between conditions.) The value of U was greater on the DRO (or WR) schedule in seven out of eight birds. This result too was statistically significant according to a one-tailed binomial sign test ($p = .035$). This result also supports the hypothesis of differential stimulus-reinforcer effects in that a greater degree of overlap on the DRO (or WR) schedule indicates that delay of reward has less of a decremental effect on these two schedules than on the FI schedule.

The lack of a comparable scale for the different responses also does not affect interpretation of the data obtained from birds B and G. These two birds took less mean excess time to complete the WR and DRO requirements respectively, when reward was delayed than when it was immediate. This result can be seen as a negative value in column 5 for these birds. This improvement in WR and DRO performance failed to reach statistical significance $U\ (9,18) = 49$ for bird B and $U\ (9,18) = 58$ for bird G, both p .05 according to a one-tailed Man-Whitney U test. (Note: The U values given here differ from the U values in Tables I and II for these birds because the U values given here were computed by determining the number of sessions the mean excess time under conditions of delayed reward was less than the mean excess time under conditions of immediate reward. The U values in Tables I and II were computed by determining the number of sessions the mean excess time under immediate reward was less than the mean excess time under conditions of delayed reward.) Even a failure to find a decremental effect when reward is delayed on these two schedules can be taken as support for differential stimulus-reinforcer effects when contrasted with the statistically significant decrement in mean excess time when reward was delayed on the FI schedule, U (9,18) = 0 for bird B, and U (9,17) = 21 for bird G, both p .001 according to a one-tailed Mann-Whitney U test. Of course it should be noted that some birds would be expected to show no statistically significant decrement when reward is delayed by chance alone.

Two related points probably need be discussed. The first point is the degree to which Phase I performance was recovered in Phase III. This did not appear to be a problem for most birds. The two most obvious exceptions are birds E and F. Bird E showed improvement in DRO performance (less mean excess time) across the three phases. Bird F failed to regain the efficient level of DRO performance seen in Phase I when retested under conditions of delayed reward in Phase III. Although the reasons for these findings are not clear at present, there is some indication that the topography of the behavior which occurred while the DRO schedule was in effect differed in Phases I and III. For example, informal observation of Bird E indicated that it head-bobbed toward the front wall during Phase I, a behavior which often interrupted the photoelectric beam, but head-bobbed toward the side wall during Phase III.

The second problem which need be discussed is the degree to which the mean excess time over the last nine sessions is representative of steady-state performance in those birds who did not meet the stability criterion within 51 sessions. Examination of the session by session data suggests that the stability criterion was not met because of variability and not because of any long-term trend in performance. One indication that there was not any long-term trend is that in all but three cases there were a minimum of four reversals of the direction in change in mean excess time over the last nine sessions. Even in these exceptions (bird E in Phase II on the FI, bird H in Phase I on the DRO, and bird C in Phase I on the WR) there were a minimum of three sessions in which mean excess time went in each direction. That is, in these three exceptions the mean excess time may have increased for three consecutive sessions but if it also decreased for three consecutive sessions there is little evidence for any long-term trend. Finally, there was at least one reversal of direction over the last four sessions in all conditions for all birds.

Discussion

The results do not provide conclusive evidence for the hypothesis that stimulus-reinforcer effects differentially affect the delay of reward gradients for different responses in pigeons. Although differences in the relative steepness of the delay of reward gradients for different responses were obtained, little weight can be given to this result because the scales for the different responses are probably not the same. Because of this scaling problem the only result which would have provided conclusive evidence for differential stimulus-reinforcer effects would have been decreased mean excess times on the DRO and WR schedules when reward was delayed. The fact that six out of eight birds had greater mean excess times on the DRO (or WR) schedule when reward was delayed can probably be ascribed to the stronger response-reinforcer effects of a delayed reward counteracting the weaker stimulus-reinforcer effects which are hypothesized to be operating on these two schedules. Decreased mean excess times on these two schedules when reward was delayed may have been obtained by using some other combination of time values for the ITI, delay period, and DRO (or WR) requirement. It must be noted however, that three different methods of data analysis all yielded results which were consistent with the hypothesis of differential stimulus-reinforcer effects. Although all three are open to alternative explanations by making specific assumptions about the nature of the scales involved, there does not appear to be any convincing reason for making these assumptions. What is clear is that at the very least the results cannot be taken as evidence against differential stimulus-reinforcer effects. Since the results do provide suggestive evidence for differential stimulus-reinforcer effects, and since this hypothesis has widespread implications, further research is being conducted.

To give just one example, the hypothesis of differential stimulus-reinforcer effects has implications for the interpretation of the low rates of keypecking which are obtained in the early components of long FI chain schedules (Kelleher & Gollub, 1962). This finding has typically been taken as evidence that the stimuli which signal the early components acquire very weak secondary reinforcing properties, if any. That is, a low rate of keypecking in the first component (the component which is the furthest in time from food), has been interpreted as evidence that the second component is a very weak conditioned reinforcer. An analysis of this finding in view of stimulus-reinforcer effects suggests that the low rate of keypecking in the first component can be ascribed to the fact that the keylight which must be pecked in the first component signals that food is temporally distant. This stimulus would thus tend to be avoided (Wasserman, Franklin, & Hearst, 1974) and this stimulus-reinforcer avoidance effect would tend to counteract any tendency to peck the key resulting from the correlation between the response and (conditioned) reinforcer.

Stimulus-reinforcer effects may also influence the shape of the delay of reward gradients for responses in other species. It has been suggested (e.g., Deutsch, 1960) that maze running can be conceptualized as approach elicited by successive maze stimuli. If such a stimulus-reinforcer effect does in fact influence maze running, then delaying reward should decrease the signal value of maze stimuli and therefore steepen the delay of reward gradient for maze running.

In conclusion, the suggestive results which were obtained in the present experiment, although not conclusive, indicate the need for further research. Such research is currently being undertaken by the present author.

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Appendix A

Acquisition Data for Bird A

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks WR	0	0	0	2	0	1	0	0	0	4	2
Withdrawals	175	173	72	119	108	89	49	104	108	86	75
Time WR	483	512	318	449	366	336	195	302	321	265	227
Pecks FI	698	680	453	599	668	698	690	645	699	713	726
Time FI	338	309	413	301	300	300	300	300	300	300	300
Pecks ITI	30	0	2	0	0	0	0	0	0	0	0

Session	12	13	14	15	16	17	18	19	20	21	22
Pecks WR	3	2	2	2	1	0	0	0	0	0	0
Withdrawals	76	59	49	68	75	57	57	39	77	86	81
Time WR	246	206	190	231	233	199	203	167	251	272	266
Pecks FI	678	689	656	530	501	563	431	410	462	427	384
Time FI	300	300	300	310	304	304	307	339	302	302	305
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	23	24	25	26	27	1	2	3	4	5	6
Pecks WR	4	1	4	2	0	0	1	0	0	0	0
Withdrawals	72	73	83	53	54	65	55	61	70	52	60
Time WR	243	240	277	219	225	356	267	268	328	237	282
Pecks FI	331	418	349	388	363	143	122	134	115	93	88
Time FI	303	307	319	308	315	346	330	343	366	390	377
Pecks Delay						1876	1486	2657	2354	2117	2408
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix (cont.)

Session	7	8	9	10	11	12	13	14	15	16	17
Pecks WR	1	2	0	0	0	0	0	0	0	0	0
Withdrawals	78	58	76	52	61	75	86	107	82	85	38
Time WR	306	420	350	220	268	332	417	449	377	327	172
Pecks FI	78	81	63	51	44	48	65	45	56	104	63
Time FI	414	429	515	469	474	484	499	492	584	341	355
Pecks Delay	2201	2014	1595	1385	1296	158	849	198	277	1162	1317
Pecks ITI	0	0	28	10	0	2	0	0	0	0	0

Session	18	19	20	21	22	23	24	25	26	27	28
Pecks WR	0	0	0	0	0	0	0	1	0	0	0
Withdrawals	78	104	58	79	93	83	83	76	72	66	50
Time WR	340	433	312	308	464	411	399	416	374	367	282
Pecks FI	59	51	81	42	48	44	47	57	69	82	55
Time FI	393	444	396	478	455	415	437	405	383	366	386
Pecks Delay	1110	311	347	197	337	384	120	267	207	251	503
Pecks ITI	0	0	3	0	0	0	4	0	0	0	0

Session	29	30	31	32[a]	33	34	35	36	37	38	39
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	56	49	67	61	93	90	74	83	70	79	60
Time WR	316	289	358	361	470	489	415	416	425	374	315
Pecks FI	61	59	58	75	90	82	86	73	51	39	40
Time FI	370	413	469	384	380	481	443	479	560	502	398
Pecks Delay	370	106	146	211	388	284	201	395	194	24	122
Pecks ITI	0	0	0	0	26	4	0	0	0	0	0

Appendix A (cont.)

Session	40[b]	41	42	43	44	45	46	47	48	49	50
Pecks WR	0	0	0	0	0	23	0	0	0	0	0
Withdrawals	71	87	59	63	59	65	67	61	77	63	62
Time WR	336	412	375	315	382	323	284	310	401	325	304
Pecks FI	31	60	47	58	61	82	37	43	47	49	47
Time FI	412	450	424	408	378	413	421	451	423	477	476
Pecks Delay	173	89	148	170	402	167	139	86	153	152	98
Pecks ITI	0	0	1	0	0	0	0	0	0	0	0

Session	51	1	2	3	4	5	6	7	8	9	10
Pecks WR	0	0	0	10	2	0	0	0	1	0	1
Withdrawals	47	88	78	52	42	53	42	44	56	38	51
Time WR	255	468	360	327	217	242	188	186	219	174	199
Pecks FI	63	463	584	569	617	552	380	491	397	245	172
Time FI	425	365	315	301	302	303	306	304	315	332	337
Pecks Delay	243										
Pecks ITI	0	0	0	253	42	5	0	0	0	0	0

Session	11	12	13	14	15	16	17	18	19	20	21
Pecks WR	1	0	1	0	0	0	0	0	0	0	0
Withdrawals	53	45	52	51	39	37	36	41	38	36	37
Time WR	200	190	227	210	179	179	170	176	174	169	169
Pecks FI	380	259	326	357	371	638	580	490	543	420	500
Time FI	318	322	315	308	309	302	308	302	304	307	305
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix A (cont.)

Session	22	23	24
Pecks WR	0	0	0
Withdrawals	35	37	35
Time WR	169	172	169
Pecks FI	426	526	545
Time FI	320	302	301
Pecks ITI	0	0	0

[a] Only 26 WR and 27 FI trials

[b] Only 24 WR and 25 FI trials

Appendix B

Acquisition Data for Bird B

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks WR	53	33	32	32	38	32	36	35	27	16	20
Withdrawals	66	75	66	97	92	97	66	114	91	91	72
Time WR	326	374	402	403	402	406	272	451	368	392	398
Pecks FI	510	398	439	291	338	387	426	448	542	367	359
Time FI	348	326	319	364	338	324	311	325	303	328	319
Pecks ITI	39	0	1	2	19	6	22	4	6	1	0

Session	12	13	14	15	1	2	3	4	5	6	7
Pecks WR	20	31	24	18	4	0	0	0	0	0	0
Withdrawals	97	97	85	76	79	83	80	76	69	60	67
Time WR	413	367	397	360	433	508	466	409	462	359	366
Pecks FI	343	499	448	447	71	45	51	64	45	42	51
Time FI	333	313	326	312	476	446	931	432	616	686	654
Pecks Delay					3	1	1	6	9	4	13
Pecks ITI	6	6	3	0	0	0	0	0	0	0	2

Session	8	9	10	11	12	13	14	15	16	17	18
Pecks WR	0	0	2	0	0	0	1	0	0	0	0
Withdrawals	82	71	91	76	63	45	63	100	85	76	101
Time WR	362	325	443	387	347	256	316	394	442	354	416
Pecks FI	38	39	208	73	61	55	86	85	52	43	48
Time FI	789	542	343	499	483	620	571	402	407	515	679
Pecks Delay	7	2	32	31	41	32	25	21	44	16	44
Pecks ITI	2	0	2	6	0	0	0	25	77	5	6

Appendix B (cont.)

Session	19	20	21	22	23	24	25	26	27	28	29
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	88	85	86	93	68	102	77	86	65	62	83
Time WR	379	400	368	424	303	432	392	482	401	349	473
Pecks FI	48	34	44	46	33	35	44	60	36	42	48
Time FI	596	990	1535	1063	1395	1112	676	441	1034	1146	957
Pecks Delay	17	35	49	18	8	21	21	27	12	33	21
Pecks ITI	9	4	1	2	2	0	0	2	0	0	0

Session	30	31	32	33	34	35	36	37	38	39	40
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	57	65	47	52	61	55	45	72	63	59	47
Time WR	1779	403	356	284	352	343	287	384	311	318	337
Pecks FI	84	44	41	59	44	33	52	46	177	77	83
Time FI	502	557	723	567	547	844	678	582	446	634	436
Pecks Delay	33	18	17	41	24	14	28	20	8	3	10
Pecks ITI	0	1	0	0	1	0	0	0	1	1	0

Session	41[a]	42	43	44	45	46	47	48	49	50	51
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	44	57	58	73	66	59	53	71	57	65	62
Time WR	301	295	351	370	403	348	297	422	300	276	312
Pecks FI	50	49	84	31	43	34	38	39	38	39	60
Time FI	728	690	826	1984	806	908	579	686	622	888	557
Pecks Delay	9	21	11	9	3	5	5	8	8	11	11
Pecks ITI	0	0	0	0	0	1	1	0	0	0	0

Appendix B (cont)

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	70	75	87	92	75	107	135	121	113	168	154
Time WR	349	368	391	408	384	440	534	436	718	682	702
Pecks FI	187	231	231		48	51	170	65	38	33	32
Time FI	354	341	345		422	459	369	427	422	556	799
Pecks ITI	0	0	0	1	0	0	1	0	0	11	11

Session	12	13	14	15	16	17	18	19	20	21	22
Pecks WR	0	0	0	1	0	0	0	0	0	8	0
Withdrawals	134	112	82	83	135	125	127	100	139	121	131
Time WR	597	524	459	413	575	549	474	412	487	397	516
Pecks FI	43	35	31	41	45	35	46	34	32	33	55
Time FI	442	662	647	722	451	699	412	912	1122	723	504
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	23	24	25	26	27	28	29	30	31	32	33
Pecks WR	0	0	2	0	0	0	0	0	0	0	0
Withdrawals	85	93	62	88	89	62	108	52	89	44	100
Time WR	355	431	377	445	415	336	440	316	429	271	393
Pecks FI	62	65	61	54	36	62	94	116	78	105	90
Time FI	380	367	369	388	432	500	367	327	403	369	411
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

[a] Only 29 WR trials

[b] Fixed Interval data not available due to counter failure.

Appendix C

Acquisition Data for Bird C

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	68	37	61	66	47	64	62	69	50	52	82
Time WR	580	235	631	364	1170	416	416	707	601	286	437
Pecks FI	127	45	49	77	36	43	33	34	44	41	34
Time FI	579	1324	1349	926	1211	751	1559	1936	1261	1507	906
Pecks Delay	603	304	70	33	41	75	93	115	146	101	48
Pecks ITI	1	0	1	0	0	0	0	0	0	0	0

Session	12	13	14	15	16	17	18	19	20	21	22
Pecks WR	0	0	0	14	0	0	0	0	0	0	0
Withdrawals	118	111	72	52	59	44	63	50	53	41	61
Time WR	552	495	357	309	281	222	410	258	248	238	391
Pecks FI	33	47	90	51	32	44	64	38	50	39	31
Time FI	780	562	1371	4122	5138	2105	1716	1011	608	2021	2704
Pecks Delay	77	65	37	83	17	72	54	16	34	50	21
Pecks ITI	0	0	6	1	0	0	0	0	0	0	0

Session	23	24	25	26[a]	27	28	29	30	31	32	33
Pecks WR	0	4	0	0	0	0	0	0	0	0	0
Withdrawals	80	68	113	64	62	61	81	73	46	66	68
Time WR	406	480	1084	353	336	390	539	534	259	349	316
Pecks FI	47	39	38	38	40	38	39	46	40	35	38
Time FI	928	1101	2548		2696	3799	2100	1609	2692	1998	719
Pecks Delay	35	296	368	202	204	160	91	140	76	64	130
Pecks ITI	0	0	0	0	0	0	0	0	0	1	0

Appendix C (cont.)

Session	34	35	36	37	38	39	40	41	42	43	1
Pecks WR	0	0	15	0	0	0	0	0	0	0	0
Withdrawals	36	74	68	52	71	79	80	56	55	89	104
Time WR	212	436	660	279	337	789	799	765	498	490	490
Pecks FI	32	48	50	38	43	33	37	34	70	40	394
Time FI	11688	881	670	1013	618	1724	593	1143	701	748	319
Pecks Delay	16	34	63	42	19	15	5	6	31	31	
Pecks ITI	0	0	0	0	0	0	0	0	0	0	1

Session	2	3	4	5	6	7	8	9	10	11	12
Pecks WR	0	0	0	0	0	0	1	0	0	0	0
Withdrawals	74	75	66	60	51	51	51	49	58	40	49
Time WR	664	331	276	301	479	265	234	218	243	188	232
Pecks FI	238	152	176	152	160	209	133	109	112	109	120
Time FI	354	365	362	377	355	342	439	382	397	406	430
Pecks ITI	0	0	0	0	0	1	0	0	0	1	0

Session	13	14	15	16	17	18	19	20	21	22	23
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	46	41	35	41	34	41	46	38	34	48	51
Time WR	223	180	189	200	202	201	219	196	175	211	233
Pecks FI	89	108	108	92	92	104	97	128	136	156	175
Time FI	457	443	406	418	406	405	433	329	397	357	367
Pecks ITI	0	0	0	0	0	7	0	1	0	20	18

Appendix C (cont.)

Session	24	25	26	27	28	29	30	31	32	33	34
Pecks WR	0	0	0	0	0	0	0	1	1	1	0
Withdrawals	43	32	42	35	60	55	43	40	53	46	47
Time WR	188	195	186	207	186	236	256	198	172	205	225
Pecks FI	205	187	185	253	229	285	296	281	321	328	272
Time FI	359	348	344	334	349	328	323	328	327	316	327
Pecks ITI	2	6	16	3	4	0	1	3	0	0	0

Session	35	36	37	38	39	40	41	42	43	44	45
Pecks WR	0	0	0	0	3	1	0	0	1	0	0
Withdrawals	47	52	60	73	72	61	65	62	56	64	49
Time WR	217	238	267	317	373	258	284	333	235	298	243
Pecks FI	248	210	224	236	186	240	149	133	149	133	176
Time FI	339	344	367	339	362	361	365	381	344	356	383
Pecks ITI	1	1	0	69	42	25	2	1	0	7	5

Session	46	47	48	49	50	51	1	2	3	4	5[b]
Pecks WR	0	0	1	0	2	2	1	4	2	0	1
Withdrawals	80	55	55	47	39	69	61	52	60	63	56
Time WR	386	275	261	203	196	245	360	322	411	382	275
Pecks FI	197	237	245	222	206	245	47	51	49	59	45
Time FI	356	344	332	329	353	346	918	822	713	661	366
Pecks Delay							101	93	125	282	251
Pecks ITI	0	12	4	10	20	76	3	34	52	23	43

Appendix C (cont.)

Session	6	7	8	9	10	11	12	13	14	15	16
Pecks WR	11	4	5	4	0	2	2	1	0	1	0
Withdrawals	68	55	56	42	75	69	114	70	63	110	86
Time WR	923	366	370	303	583	619	700	429	482	554	699
Pecks FI	97	71	216	55	55	39	52	39	45	42	40
Time FI	550	642	664	653	854	856	622	816	767	683	987
Pecks Delay	901	806	869	570	572	431	701	515	321	323	479
Pecks ITI	34	6	1	1	6	9	1	0	2	0	0

Session	17	18	19	20	21	22	23	24[c]	25	26	27
Pecks WR	0	0	1	0	0	0	0	0	0	0	0
Withdrawals	80	67	78	93	79	81	127	34	73	73	74
Time WR	641	449	685	586	544	576	827	295	681	503	585
Pecks FI	40	39	54	83	45	43	32	16	30	37	54
Time FI	886	939	771	558	620	619	1970	4450	4372	1109	466
Pecks Delay	387	260	341	329	246	258	77	13	39	346	322
Pecks ITI	0	13	28	6	0	0	0	0	0	0	0

Session	28	29	30	31	32	33	34	35	36	37	38
Pecks WR	0	0	0	0	0	11	9	5	0	5	1
Withdrawals	120	73	82	67	62	77	55	77	70	74	80
Time WR	780	534	622	526	599	617	508	559	528	617	635
Pecks FI	48	47	78	43	60	101	61	78	45	50	69
Time FI	618	639	594	488	497	422	722	569	597	529	533
Pecks Delay	397	330	712	723	843	448	784	761	616	282	547
Pecks ITI	0	10	0	0	0	35	3	2	0	6	0

Appendix C (cont.)

Session	39	40	41	42	43	44	45	46	47	48	49
Pecks WR	1	3	0	0	0	0	0	1	0	0	0
Withdrawals	90	100	80	87	80	107	77	78	89	89	89
Time WR	612	590	594	594	574	677	826	648	709	590	631
Pecks FI	55	47	55	62	51	50	44	42	34	36	41
Time FI	611	549	550	487	552	657	727	689	741	670	694
Pecks Delay	702	724	676	504	455	327	344	160	54	36	253
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	50	51
Pecks WR	0	0
Withdrawals	95	85
Time WR	681	502
Pecks FI	33	40
Time FI	792	982
Pecks Delay	155	151
Pecks ITI	0	0

[a] Bird removed in middle of 30th FI trial with total FI time equal to 2500 sec.

[b] Only 21 FI and 21 WR trials.

[c] Only 16 FI and 16 WR trials.

Appendix D

Acquisition Data for Bird B

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks WR	1	0	1	0	0	0	0	0	0	2	0
Withdrawals	285	274	106	161	119	115	152	86	102	119	128
Time WR	1599	1671	929	1182	985	551	992	526	561	2010	734
Pecks FI	53	42	70	83	49	37	39	60	60	43	88
Time FI	1683	611	520	641	512	633	825	473	1112	540	470
Pecks Delay	10	19	6	32	5	1	4	1	15	13	8
Pecks ITI	0	0	0	9	1	0	0	0	21	0	4

Session	12	13	14	15	16	17	18	19	20	21	22
Pecks WR	1	0	0	1	0	0	0	1	0	0	0
Withdrawals	136	112	84	88	80	92	149	85	126	106	120
Time WR	706	748	1065	666	585	606	1309	474	666	539	620
Pecks FI	88	65	51	62	65	103	51	40	137	55	58
Time FI	576	505	704	447	611	3200	581	532	423	609	549
Pecks Delay	7	3	6	3	11	1	9	1	25	3	4
Pecks ITI	0	0	0	0	5	0	1	1	20	0	0

Session	23	24	25	26	27	28	29	30	31	32	33
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	157	167	169	87	137	128	111	142	159	153	159
Time WR	725	738	738	526	641	675	707	706	1098	779	607
Pecks FI	87	91	54	43	61	53	67	75	89	81	76
Time FI	416	474	511	1595	536	488	463	412	445	452	437
Pecks Delay	6	2	2	29	3	1	5	3	1	4	2
Pecks ITI	0	0	1	0	1	5	4	1	1	0	0

Appendix D (cont.)

Session	34	35	36	37	38	39	40	41	42	43	44
Pecks WR	0	0	0	0	0	0	0	0	0	0	0
Withdrawals	76	94	90	127	104	202	91	92	146	130	75
Time WR	431	470	410	516	500	612	477	436	735	573	340
Pecks FI	94	79	69	48	66	62	49	66	132	151	69
Time FI	458	446	457	477	477	452	451	439	438	404	428
Pecks Delay	4	2	1	0	1	1	1	6	15	9	3
Pecks ITI	0	0	0	0	0	0	1	0	0	2	0

Session	45	46	47	48	49	50	51	1[a]	2	3	4
Pecks WR	0	0	0	0	0	0	0	312	0	4	1
Withdrawals	84	102	106	82	89	58	124	312	228	198	79
Time WR	422	482	517	332	488	320	479	1801	479	536	281
Pecks FI	64	129	94	52	122	75	69	650	657	504	304
Time FI	418	789	431	565	342	411	472	274	310	362	405
Pecks Delay	5	0	10	13	11	20	24				
Pecks ITI	0	0	0	1	3	0	0	173	60	24	0

Session	5	6	7	8	9	10	11	12	13	14	15
Pecks WR	0	0	6	9	9	9	34	53	48	19	26
Withdrawals	67	56	54	68	60	52	99	65	51	55	75
Time WR	237	207	241	319	253	366	524	395	327	232	371
Pecks FI	153	252	249	270	288	451	378	349	274	92	62
Time FI	451	363	353	422	339	325	322	335	339	538	726
Pecks ITI	1	0	0	0	0	1	1	1	0	0	2

Appendix D (cont.)

Session	16	17	18	19	20	21	22	23	24	25	26
Pecks WR	45	10	33	35	26	5	7	30	11	23	34
Withdrawals	94	74	84	83	79	59	51	68	51	46	70
Time WR	426	303	333	393	384	221	227	322	212	300	333
Pecks FI	447	183	295	260	332	203	138	388	147	407	390
Time FI	311	335	319	341	328	365	457	328	459	346	330
Pecks ITI	1	0	0	0	0	0	0	1	4	1	0

Session	27	28	29	30	31	32	33	34	35	36	37
Pecks WR	19	6	11	7	27	53	14	15	19	30	18
Withdrawals	55	62	63	36	53	40	34	40	56	77	66
Time WR	251	280	287	200	249	325	203	225	393	481	340
Pecks FI	428	153	113	88	434	449	298	289	355	650	506
Time FI	330	506	529	409	318	327	373	347	334	306	323
Pecks ITI	5	0	2	0	5	35	0	1	0	0	0

Session	38	39	40	41	42	43	44	45	46	47	48
Pecks WR	2	2	28	13	9	0	9	8	5	16	6
Withdrawals	44	52	94	71	85	57	69	58	44	69	71
Time WR	225	230	412	449	439	288	373	277	220	330	376
Pecks FI	352	171	513	200	121	179	347	294	361	385	143
Time FI	326	368	313	336	420	358	324	336	398	331	412
Pecks ITI	0	0	0	0	0	0	3	3	3	0	2

Appendix D (cont.)

Session	49	50	51	1	2	3	4	5	6	7	8
Pecks WR	3	1	0	2	3	0	0	0	1	0	3
Withdrawals	66	50	59	51	62	64	52	68	45	49	59
Time WR	300	281	298	561	636	670	414	468	357	428	641
Pecks FI	139	102	230	116	59	47	41	38	73	42	39
Time FI	458	430	381	587	536	677	583	636	616	539	661
Pecks Delay				208	23	12	30	4	94	19	7
Pecks ITI	3	0	1	5	0	0	0	0	0	0	0

Session	9	10	11	12	13	14	15	16	17[b]	18	19
Pecks WR	3	0	0	0	0	0	0	3	1	0	4
Withdrawals	83	39	73	76	87	90	70	80	72	73	92
Time WR	1154	297	794	573	701	631	391	469	364	371	515
Pecks FI	126	101	72	115	49	35	36	58	50	60	50
Time FI	503	486	506	496	582	557	567	471	443	486	488
Pecks Delay	38	47	19	41	8	37	11	12	14	155	69
Pecks ITI	0	7	0	0	0	0	0	13	0	0	0

Session	20[c]	21	22[d]	23[e]	24	25	26	27
Pecks WR	4	0	4	7	8	1	4	3
Withdrawals	70	78	51	83	127	74	72	113
Time WR	490	619	314	521	716	519	612	606
Pecks FI	29	53	68	54	65	105	66	80
Time FI	324	477	513	466	448	414	467	380
Pecks Delay	35	274	417	217	182	356	210	101
Pecks ITI	0	13	17	0	0	4	1	6

[a]Only 26 FI and 27 WR trials. [b,d,e]Only 29 WR trials. [c]Only 22 FI and WR trials.

Appendix E

Acquisition Data for Bird E

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks DRO	1	18	14	0	0	1	0	0	0	0	0
Head Bobs	256	172	209	218	345	227	386	352	242	273	165
Time DRO	501	434	458	441	610	473	712	630	549	562	421
Pecks FI	590	579	738	374	824	927	1021	914	845	583	486
Time FI	311	371	318	322	306	300	302	304	302	330	318
Pecks ITI	0	2	0	0	0	0	1	0	0	0	0

Session	12	13	14	15	16[a]	17	18[b]	19[c]	20	21	22
Pecks DRO	36	0	2	1	0	0	0	0	15	0	0
Head Bobs	366	141	376	331	331	230	190	333	352	223	378
Time DRO	700	391	654	739	762	567	461	708	628	500	782
Pecks FI	563	374	417	432	305	405	208	108	488	321	314
Time FI	311	322	341	316	295	305	313	295	314	322	324
Pecks ITI	0	0	3	0	0	0	0	0	0	0	0

Session	23	24	25	26[d]	27	28	29	30	31	32	33
Pecks DRO	0	0	0	0	0	0	0	3	0	0	3
Head Bobs	285	216	140	206	176	227	257	195	163	221	89
Time DRO	613	536	433	462	398	540	566	472	422	467	294
Pecks FI	258	368	410	351	387	542	501	351	377	322	387
Time FI	336	318	313	310	309	306	310	321	325	320	322
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix E (cont.)

Session	34	35	36	37	38	39	40	41	42	43	44
Pecks DRO	0	0	1	0	0	0	1	1	1	0	1
Head Bobs	124	192	952	447	575	384	192	235	248	234	100
Time DRO	339	407	1859	977	413	1105	635	718	808	874	474
Pecks FI	346	352	472	490	527	471	541	447	469	419	350
Time FI	319	321	311	307	307	308	308	313	303	302	304
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	45	46	47	48	49	50	51	1	2e	3	4
Pecks DRO	0	1	0	0	0	0	6	0	0	0	0
Head Bobs	57	135	182	89	114	126	79	162	158	153	135
Time DRO	296	563	696	393	479	584	395	566	575	818	507
Pecks FI	361	495	510	435	423	449	514	67	43	42	49
Time FI	310	304	305	302	303	301	301	653	543	1230	829
Pecks Delay								27	21	33	32
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	5	6	7	8	9	10	11	12	13	14	15
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	89	98	250	343	320	116	215	151	105	109	102
Time DRO	365	413	562	612	642	520	814	664	469	469	396
Pecks FI	39	35	57	75	46	57	56	100	66	36	68
Time FI	488	910	971	713	722	694	1163	2133	652	757	824
Pecks Delay	51	27	33	28	11	17	11	72	29	16	31
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix E (cont.)

Session	16	17	18	19	20	21	22	23	24	25	26
Pecks DRO	1	0	0	0	0	0	0	0	0	0	0
Head Bobs	62	103	124	179	158	103	251	185	146	129	280
Time DRO	284	434	482	514	541	428	890	629	615	474	839
Pecks FI	68	45	34	56	38	45	133	101	60	83	71
Time FI	895	607	1088	1232	6300	1414	682	544	529	401	464
Pecks Delay	16	12	18	10	13	21	40	20	22	22	24
Pecks ITI	1	2	1	0	0	0	0	0	0	0	0

Session	27	28	29	30	31	32	33	34	35	36	37
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	149	198	210	96	173	106	140	162	72	112	68
Time DRO	582	576	732	422	720	577	575	1128	332	491	351
Pecks FI	111	120	242	167	115	109	105	64	73	93	72
Time FI	417	414	401	464	421	433	413	437	409	452	372
Pecks Delay	23	22	41	31	35	25	26	23	24	5	7
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	38	39	40	41	42	43	44	45	46	47	48
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	93	92	51	74	51	102	93	129	96	91	93
Time DRO	941	487	281	377	281	488	458	576	479	389	402
Pecks FI	84	64	100	58	106	116	77	100	80	75	69
Time FI	465	427	535	467	535	429	414	408	421	463	500
Pecks Delay	0	12	20	7	28	21	13	11	7	20	7
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix E (cont.)

Session	49	50	51	1	2	3	4	5	6	7	8[h]
Pecks DRO	0	0	0	25	0	1	0	2	3	1	0
Head Bobs	82	148	77	203	114	80	87	95	170	149	117
Time DRO	381	495	336	793	513	421	458	558	917	968	498
Pecks FI	58	52	71	705	456	427	500	431	418	80	
Time FI	508	520	471	318	309	312	307	313	312	379	
Pecks Delay	3	4	11								
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	9	10	11	12	13	14	15	16	17	18	19
Pecks DRO	0	0	0	0	0	0	0	1	0	2	1
Head Bobs	217	125	133	187	140	89	123	60	55	90	63
Time DRO	858	441	527	680	993	424	469	305	283	330	273
Pecks FI	337	383	385	141	262	359	297	297	281	269	261
Time FI	349	317	342	373	308	305	305	302	311	306	315
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	20	21	22	23	24	25	26	27	28	29	30
Pecks DRO	5	5	0	4	5	1	0	19	21	7	6
Head Bobs	105	107	115	76	61	58	67	76	79	62	75
Time DRO	293	340	363	249	226	219	207	242	211	224	259
Pecks FI	240	174	217	181	200	205	270	247	336	359	351
Time FI	324	343	321	334	322	315	312	317	305	308	305
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix E (cont.)

Session	31	32	33	34	35	36	37	38	39[i]	40	41
Pecks DRO	5	3	6	4	2	0	2	1	4	1	5
Head Bobs	103	79	67	114	103	91	140	141	122	86	157
Time DRO	317	280	255	342	356	321	440	425	388	318	511
Pecks FI	306	302	397	443	293	329	364	331	137	251	281
Time FI	301	302	309	301	308	304	303	305	236	310	312
Pecks ITI	0	0	0	0	0	0	0	0	0	0	3

Session	42	43	44	45	46	47	48	49	50	51
Pecks DRO	2	3	5	12	6	6	5	2	6	12
Head Bobs	129	117	61	86	92	56	109	71	68	69
Time DRO	414	392	235	279	323	236	373	291	257	265
Pecks FI	257	285	238	232	186	187	360	259	372	303
Time FI	312	314	321	319	316	321	307	322	314	306
Pecks ITI	0	0	0	0	0	0	0	0	0	0

[a,e] Only 29 FI trials.

[b] Only 29 FI and 29 DRO trials.

[c] Only 28 FI trials.

[d] Only 29 DRO trials.

[f] Only 27 FI and 27 DRO trials.

[g] 31 FI and 32 DRO trials.

[h] Fixed Interval data not available due to counter failure.

[i] Only 23 FI and 24 DRO trials.

Appendix F

Acquisition Data for Bird F

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks DRO	2	6	2	3	3	1	2	0	3	0	7
Head Bobs	90	56	65	32	42	36	51	59	81	64	51
Time DRO	312	231	264	192	209	209	216	237	250	226	225
Pecks FI	152	90	45	45	32	41	30	33	66	99	134
Time FI	382	383	409	385	389	368	402	391	330	358	366
Pecks ITI	0	0	0	1	0	0	0	0	0	0	0
Session	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Pecks DRO	1	1	0	0	0	2	0	4	2	3	1
Head Bobs	84	66	52	36	53	55	49	51	82	31	55
Time DRO	302	249	230	207	191	214	199	202	233	203	216
Pecks FI	98	81	199	60	125	49	56	74	101	78	66
Time FI	350	354	349	378	347	448	360	353	354	393	403
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0
Session	**23**	**24**	**25[a]**	**26[b]**	**27**	**28**	**29**	**30**	**31**	**32**	**33**
Pecks DRO	0	11	0	0	0	14	19	5	1	1	0
Head Bobs	49	75	67	72	53	41	41	42	91	74	48
Time DRO	242	236	264	251	235	209	222	230	203	217	192
Pecks FI	34	60	50	65	172	148	162	101	79	184	91
Time FI	505	382	355	313	330	331	330	349	358	318	374
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix F (cont.)

Session	34	35	36	37	38	39	1	2	3	4	5
Pecks DRO	0	1	1	2	2	2	2	2	4	3	2
Head Bobs	53	49	38	36	40	34	99	78	74	217	130
Time DRO	201	209	203	203	203	198	372	267	327	613	720
Pecks FI	89	132	170	135	124	102	30	53	52	59	47
Time FI	429	366	321	340	346	335	547	589	668	550	615
Pecks Delay							494	269	506	652	638
Pecks ITI	0	0	0	0	0	0	3	0	0	0	0
Session	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Pecks DRO	6	1	9	3	3	0	0	4	0	6	0
Head Bobs	41	61	133	117	101	44	113	171	125	151	187
Time DRO	252	286	503	418	441	238	428	512	380	420	462
Pecks FI	45	36	32	44	30	33	35	56	39	49	36
Time FI	848	596	642	447	629	950	637	483	707	638	576
Pecks Delay	882	648	349	246	261	184	149	585	700	828	591
Pecks ITI	0	0	0	0	0	0	0	7	0	0	0
Session	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**
Pecks DRO	0	1	5	0	1	1	4	0	0	1	1
Head Bobs	184	172	259	235	257	184	670	369	324	232	293
Time DRO	449	489	709	573	667	471	1464	848	829	614	777
Pecks FI	54	115	113	122	65	68	102	45	46	48	62
Time FI	570	423	434	506	466	505	395	657	654	755	498
Pecks Delay	544	631	626	839	672	789	997	702	773	640	639
Pecks ITI	1	0	3	2	1	0	0	0	0	0	0

Appendix F (cont.)

Session	28	29	30	31	32	33	34	35	36	37	38
Pecks DRO	1	0	2	0	1	1	0	1	4	1	1
Head Bobs	291	251	190	243	451	299	240	188	316	285	224
Time DRO	752	722	557	712	988	740	619	498	804	715	566
Pecks FI	38	34	45	37	69	46	71	55	58	42	68
Time FI	516	539	518	654	528	615	405	680	451	643	525
Pecks Delay	510	484	514	710	602	500	248	533	667	590	965
Pecks ITI	0	0	0	0	0	0	1	4	1	0	0

Session	39	40	41	42	43	44	45	46	47	48	49
Pecks DRO	1	1	0	4	2	5	0	1	1	0	4
Head Bobs	303	202	206	175	184	206	142	141	226	162	179
Time DRO	745	522	591	497	539	558	461	460	579	460	494
Pecks FI	71	64	53	47	41	47	60	41	51	34	41
Time FI	469	427	481	629	692	496	602	526	555	659	695
Pecks Delay	175	699	746	666	898	876	877	1001	939	904	217
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	50	51	1	2	3	4	5	6	7	8	9
Pecks DRO	2	0	3	0	1	12	11	1	1	1	0
Head Bobs	203	172	185	116	201	123	86	124	60	77	70
Time DRO	564	507	535	440	591	376	325	413	346	377	355
Pecks FI	75	32	276	172	196	280	182	133	221	291	351
Time FI	602	672	346	320	333	371	340	341	323	316	303
Pecks Delay	966	927									
Pecks ITI	0	0	0	0	0	0	2	0	1	0	0

Appendix F (cont.)

Session	10	11	12	13	14	15	16	17	18	19[c]	20
Pecks DRO	2	0	8	3	1	1	0	3	0	0	0
Head Bobs	101	106	90	143	111	78	87	94	113	119	169
Time DRO	435	460	377	542	419	344	336	372	406	407	545
Pecks FI	453	431	219	141	113	231	97	60	161	441	356
Time FI	305	308	331	361	360	324	391	357	326	310	310
Pecks ITI	0	0	0	0	0	0	0	0	0	0	2

Session	21	22	23	24	25	26	27	28	29	30	31
Pecks DRO	2	4	0	0	1	0	0	0	0	2	3
Head Bobs	77	142	97	101	91	127	98	117	124	126	152
Time DRO	342	494	417	650	440	499	490	498	517	321	370
Pecks FI	231	188	328	312	198	121	174	83	180	170	435
Time FI	310	330	322	313	368	357	337	1484	455	332	306
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	32	33	34	35	36[d]	37	38	39	40	41	42
Pecks DRO	1	1	0	4	5	0	0	0	0	0	0
Head Bobs	101	63	125	158	393	325	383	300	260	250	179
Time DRO	315	243	341	422	863	860	968	737	724	538	424
Pecks FI	356	320	296	271	190	179	207	260	326	302	324
Time FI	310	306	310	319	395	316	322	324	313	322	312
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix F (cont.)

Session	43	44	45	46	47	48	49[e]	50	51
Pecks DRO	4	1	0	0	0	0	1	2	1
Head Bobs	271	199	252	152	92	146	90	231	109
Time DRO	572	477	542	343	296	352	238	381	364
Pecks FI	302	191	258	177	151	152	126	271	179
Time FI	310	327	327	358	352	361	223	324	330
Pecks ITI	0	0	1	0	0	8	0	0	0

[a]Only 28 FI and 29 DRO

[b]Only 27 FI and 27 DRO

[c]Only 29 FI

[d]Only 29 FI and 29 DRO

[e]Only 20 FI and 19 DRO

Appendix G

Acquisition Data for Bird G

Session	1	2	3	4[a]	5	6[b]	7	8[c]	9	10[d]	11
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	194	221	87	82	138	82	76	75	85	77	112
Time DRO	494	676	389	313	461	345	286	291	315	297	356
Pecks FI	89	38	80	43	36	38	53	46	65	43	32
Time FI	674	738	539	478	574	543	615	605	718	657	922
Pecks Delay	415	292	559	349	360	429	348	300	120	49	2
Pecks ITI	0	0	0	5	0	1	0	0	0	0	0

Session	12	13	14	15	16	17	18	19	20	21	22
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	99	187	81	83	139	95	48	86	61	61	63
Time DRO	366	540	346	335	420	430	240	303	297	255	270
Pecks FI	34	49	43	41	57	111	46	67	67	50	30
Time FI	562	436	731	683	473	391	513	429	475	500	879
Pecks Delay	25	5	7	8	10	37	11	8	11	5	1
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	23	24	25	26	27	28	29	30	31	32	33
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	78	42	61	47	62	45	43	56	56	64	55
Time DRO	266	210	263	264	305	221	218	246	253	254	234
Pecks FI	80	70	60	65	82	123	76	88	109	144	94
Time FI	384	424	423	500	451	436	392	454	443	370	393
Pecks Delay	1	3	2	3	1	3	4	3	3	14	6
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix G (cont.)

Session	34	35	36	37	38	39	40	41	42	43	44
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	41	40	54	56	27	27	22	27	35	28	38
Time DRO	225	239	271	348	204	188	178	191	199	188	200
Pecks FI	41	60	86	79	101	63	63	90	78	70	89
Time FI	899	539	425	418	401	464	528	424	407	424	452
Pecks Delay	2	0	17	13	21	4	6	9	5	0	3
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	45	46	47	48	49	50	51	1	2	3	4
Pecks DRO	0	0	0	0	0	0	0	9	0	1	0
Head Bobs	40	33	31	32	23	28	38	36	70	60	45
Time DRO	224	201	226	214	197	212	223	222	296	286	282
Pecks FI	61	56	30	42	75	40	53	353	579	312	277
Time FI	397	432	624	527	425	561	588	317	302	323	402
Pecks Delay	2	0	0	4	1	5	7				
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	5	6[e]	7	8	9	10	11	12	13	14	15
Pecks DRO	0	0	0	1	0	0	0	1	0	0	0
Head Bobs	46	53	67	63	47	61	52	51	43	39	48
Time DRO	309	234	256	244	269	266	257	255	233	254	249
Pecks FI	315	408	490	196	106	181	144	130	123	123	133
Time FI	349	303	317	344	362	350	413	418	396	399	403
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix G (cont.)

Session	16	17	18	19	20[f]	21	22	23	24	1	2
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	43	57	44	31	131	50	44	39	37	36	41
Time DRO	286	249	227	204	413	226	231	240	220	195	194
Pecks FI	149	107	154	209	168	159	66	269	122	126	51
Time FI	379	404	396	351	502	343	503	335	356	355	409
Pecks Delay										3	7
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	3	4	5	6	7	8	9	10	11	12	13
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	38	41	61	42	38	35	33	36	31	41	51
Time DRO	189	200	226	196	189	213	202	206	231	245	249
Pecks FI	70	74	50	106	38	42	51	45	32	36	48
Time FI	429	365	446	387	564	683	403	495	540	504	450
Pecks Delay	1	5	0	7	4	8	6	5	5	8	0
Pecks ITI	0	0	3	4	0	0	0	0	1	0	4

Session	14	15	16	17	18	19	20	21	22	23	24
Pecks DRO	0	0	0	1	0	0	0	0	0	30	0
Head Bobs	65	72	40	53	34	62	39	45	46	61	43
Time DRO	333	317	252	263	397	290	227	285	270	352	244
Pecks FI	43	44	33	77	57	52	47	46	33	45	103
Time FI	521	450	735	376	458	497	566	519	703	571	442
Pecks Delay	0	6	2	6	3	3	5	0	3	8	4
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix G (cont.)

Session	25	26	27	28	29	30	31	32	33	34	35
Pecks DRO	0	0	0	0	0	0	0	0	0	0	0
Head Bobs	54	48	64	33	37	40	43	50	41	51	92
Time DRO	310	242	297	211	233	232	224	233	240	285	482
Pecks FI	56	56	53	45	78	126	98	32	46	94	64
Time FI	456	451	446	480	381	335	341	423	901	407	481
Pecks Delay	5	4	0	1	5	21	10	3	1	5	10
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	36	37	38	39	40	41	42	43	44	45	46[g]
Pecks DRO	0	0	0	0	0	0	0	0	1	0	0
Head Bobs	67	55	87	120	159	63	160	73	35	51	37
Time DRO	344	285	373	424	479	278	696	312	252	293	223
Pecks FI	55	65	58	50	35	48	30	47	41	43	
Time FI	404	430	470	399	490	430	906	450	479	507	
Pecks Delay	11	5	4	3	8	10	37	2	6	8	3
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	47	48	49	50	51
Pecks DRO	0	0	0	0	0
Head Bobs	38	29	33	32	40
Time DRO	226	193	206	198	223
Pecks FI	65	49	61	54	60
Time FI	462	517	435	512	501
Pecks Delay	7	6	4	5	16
Pecks ITI	0	0	0	0	0

[a,b,e] 29 FI trials
[c] 29 DRO trials
[d] 28 FI trials
[f] 35 FI and DRO trials
[g] No FI data

Appendix H

Acquisition Data for Bird H

Session	1	2	3	4	5	6	7	8	9	10	11
Pecks DRO	25	0	0	0	0	1	0	2	0	0	1
Head Bobs	303	173	158	52	191	69	36	63	63	164	169
Time DRO	783	529	607	285	606	311	226	245	306	464	549
Pecks FI	69	104	114	30	101	84	49	43	57	58	33
Time FI	522	425	511	2821	580	580	1111	813	922	1690	2928
Pecks Delay	63	150	81	85	43	45	36	36	0	51	27
Pecks ITI	0	0	5	0	0	0	0	0	0	0	0

Session	12	13[a]	14	15	16	17	18	19	20	21	22
Pecks DRO	1	3	0	0	14	13	1	0	6	13	5
Head Bobs	277	63	36	30	52	48	45	31	68	74	64
Time DRO	704	233	185	221	265	243	238	214	268	281	270
Pecks FI	41	45	34	42	127	128	75	65	63	79	89
Time FI	1094	1387	1247	1154	593	388	685	669	730	539	600
Pecks Delay	14	50	27	33	82	81	56	38	74	39	45
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	23	24	25	26	27	28	29	30	31	32	33
Pecks DRO	15	29	1	3	4	2	13	32	25	8	11
Head Bobs	48	152	37	29	79	110	87	74	88	54	49
Time DRO	267	425	203	203	284	324	303	274	721	231	234
Pecks FI	90	80	50	45	89	83	98	133	157	107	157
Time FI	800	658	792	689	612	497	549	404	388	564	429
Pecks Delay	73	83	80	48	55	54	81	165	141	93	69
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Appendix H (cont.)

Session	34	35	36	37	38	39	40	41	42b	43	44
Pecks DRO	5	1	7	3	0	0	0	1	0	0	0
Head Bobs	61	36	74	146	31	135	81	143	143	130	59
Time DRO	248	221	276	479	417	378	350	475	496	475	282
Pecks FI	102	90	70	80	37	54	53	152	70	69	44
Time FI	961	613	665	673	654	967	615	396		479	1243
Pecks Delay	55	112	132	176	114	111	103	252	187	149	72
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	45	56	47	48	49	50	51	1	2	3	4
Pecks DRO	0	1	0	40	0	2	0	75	34	11	4
Head Bobs	63	120	121	280	160	156	158	188	72	59	30
Time DRO	300	421	458	1030	513	535	578	608	573	249	185
Pecks FI	44	35	30	41	62	71	40	469	380	171	68
Time FI	578	568	782	715	570	563	705	357	350	420	413
Pecks Delay	192	113	59	82	98	15	17				
Pecks ITI	0	0	0	0	0	0	0	210	7	3	0

Session	5	6	7	8	9	10	11	12c	13	14	15
Pecks DRO	6	13	30	45	36	93	34	32	31	71	82
Head Bobs	224	55	59	353	48	65	58	42	245	152	174
Time DRO	560	207	226	2794	196	226	443	139	566	279	317
Pecks FI	212	374	504	542	400	583	275	427	670	678	580
Time FI	330	319	308	313	304	300	344	203	300	304	303
Pecks ITI	0	0	1	0	17	1	0	0	1	3	0

Appendix H (cont.)

Session	16	17	18	19	20	21	22	23	24	25	26
Pecks DRO	41	55	53	92	50	62	64	52	49	85	91
Head Bobs	138	167	164	147	138	128	173	84	108	139	127
Time DRO	266	316	327	299	280	241	326	214	286	232	237
Pecks FI	619	588	611	536	204	506	440	430	341	500	558
Time FI	306	306	302	306	342	308	310	312	324	307	301
Pecks ITI	0	0	0	0	0	4	2	0	0	0	0

Session	27	1	2	3	4	5	6	7	8	9	10
Pecks DRO	60	0	8	15	26	4	0	5	0	1	2
Head Bobs	105	237	211	412	282	259	305	358	173	159	127
Time DRO	251	572	558	860	616	678	694	915	539	546	444
Pecks FI	407	62	74	127	122	120	47	72	254	79	105
Time FI	363	586	616	419	416	446	834	498	376	1021	817
Pecks Delay		28	30	325	413	95	31	0	31	71	327
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	11	12[d]	13	14	15	16	17	18	19	20	21
Pecks DRO	2	0	0	0	3	3	0	4	1	0	0
Head Bobs	193	226	187	163	339	185	169	303	131	100	222
Time DRO	817	594	587	567	1052	625	547	807	481	385	646
Pecks FI	109	107	45	128	84	103	52	124	56	56	66
Time FI	663	585	735	487	701	494	690	520	764	688	568
Pecks Delay	210	65	3	64	15	72	45	43	1	2	1
Pecks ITi	0	0	0	0	0	0	0	0	0	0	0

Appendix H (cont.)

Session	22	23	24[e]	25	26	27	28	29	30	31	32
Pecks DRO	0	0	0	0	0	0	0	2	4	0	0
Head Bobs	221	168	138	159	162	153	104	181	343	283	150
Time DRO	911	616	460	698	652	571	551	895	1144	1444	835
Pecks FI	71	273	207	41	45	51	44	47	105	100	34
Time FI	466	393	310	647	568	649	652	600	664	636	1006
Pecks Delay	7	1	0	2	17	3	8	2	2	4	3
Pecks ITI	0	0	0	0	0	0	0	0	0	0	0

Session	33	34	35	36	37	38	39	40	41	42	43
Pecks DRO	0	0	2	0	5	1	1	4	2	3	1
Head Bobs	367	86	149	165	95	116	87	111	153	304	300
Time DRO	1989	348	855	822	353	475	408	415	876	869	907
Pecks FI	169	33	44	48	95	45	112	66	47	77	62
Time FI	1077	1021	1067	976	514	1364	1033	701	4759	614	517
Pecks Delay	1	18	73	43	39	38	120	132	34	46	57
Pecks ITI	0	0	0	0	0	2	0	0	0	0	0

Session	44	45	46	47	48	49	50	51
Pecks DRO	3	0	1	0	2	1	0	0
Head Bobs	233	234	195	197	367	240	114	272
Time DRO	627	633	531	581	915	589	358	754
Pecks FI	50	45	122	66	119	62	118	70
Time FI	605	700	488	557	658	571	640	551
Pecks Delay	41	37	53	38	35	44	38	34
Pecks ITI	0	0	0	0	0	0	0	0

[a] 28 FI, 29 DRO trials
[b] No FI data
[c] 20 FI, 19 DRO trials
[d] 29 FI trials
[e] 23 FI, 23 DRO trials

DIFFERENTIAL STIMULUS-REINFORCER EFFECTS ON THE DELAY OF REWARD GRADIENTS FOR DIFFERENT RESPONSES IN PIGEONS

by

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Stimulus-reinforcer effects refer to behavior which can be ascribed to the correlation between an antecedent discriminative stimulus and a subsequent reinforcer. Pigeons tend to approach and peck a keylight which signals immediate delivery of food but tend to withdraw from a keylight which signals that food is far away in time. These stimulus-reinforcer effects should tend to steepen the delay of reward gradient for a keypeck response. However, stimulus-reinforcer effects should flatten the delay of reward gradients for the responses of not approaching or withdrawing from a keylight which signals food. Each of eight pigeons was tested on two response requirements in each of two conditions. In one condition successful completion of the appropriate requirement was followed by immediate reward. In the other, reward was delayed for 30 sec. For the DRO group (n=4) the two requirements were a differential reinforcement of other behavior schedule (DRO) and a fixed interval schedule for a keypeck response (FI 10"). For the WR group (n=4) the two requirements were a withdrawal response (WR) and the same FI 10" schedule. The DRO schedule required that the pigeon neither peck nor approach within 5 cm of a keylight which was followed by food for a continuous 5 sec period. The WR schedule required that the pigeon stand in the back half of the chamber for a continuous 5 sec period. The response requirements were presented on alternate trials following a 60 sec inter-trial interval and each was signalled by a different keylight stimulus. The dependent measure was mean excess time (time taken to complete the requirement above the minimum possible time). On each of three measures, seven out of eight birds provided evidence for the hypothesis that stimulus-reinforcer effects steepen the keypeck gradient more than the DRO or WR gradients. These measures

were (a) greater increases in mean excess time when reward was delayed on the FI schedule than on the DRO (or WR) schedule, (b) larger ratios of mean excess time (delayed over immediate) on the FI schedule, and (c) less overlap of mean excess times across the delayed and immediate reward conditions on the FI schedule. It was suggested that stimulus-reinforcer effects are likely to affect the delay of reward gradients for responses in other species as well.