



2018

# IS PECKING AVERSIVE TO A PIGEON OR IS IT ONLY THE DELAY TO REINFORCEMENT?

Danielle M. Andrews

*University of Kentucky*, [danielle.andrews26@gmail.com](mailto:danielle.andrews26@gmail.com)

Digital Object Identifier: <https://doi.org/10.13023/ETD.2018.195>

**[Click here to let us know how access to this document benefits you.](#)**

---

## Recommended Citation

Andrews, Danielle M., "IS PECKING AVERSIVE TO A PIGEON OR IS IT ONLY THE DELAY TO REINFORCEMENT?" (2018). *Theses and Dissertations--Psychology*. 137.  
[https://uknowledge.uky.edu/psychology\\_etds/137](https://uknowledge.uky.edu/psychology_etds/137)

This Master's Thesis is brought to you for free and open access by the Psychology at UKnowledge. It has been accepted for inclusion in Theses and Dissertations--Psychology by an authorized administrator of UKnowledge. For more information, please contact [UKnowledge@lsv.uky.edu](mailto:UKnowledge@lsv.uky.edu).

**STUDENT AGREEMENT:**

I represent that my thesis or dissertation and abstract are my original work. Proper attribution has been given to all outside sources. I understand that I am solely responsible for obtaining any needed copyright permissions. I have obtained needed written permission statement(s) from the owner(s) of each third-party copyrighted matter to be included in my work, allowing electronic distribution (if such use is not permitted by the fair use doctrine) which will be submitted to UKnowledge as Additional File.

I hereby grant to The University of Kentucky and its agents the irrevocable, non-exclusive, and royalty-free license to archive and make accessible my work in whole or in part in all forms of media, now or hereafter known. I agree that the document mentioned above may be made available immediately for worldwide access unless an embargo applies.

I retain all other ownership rights to the copyright of my work. I also retain the right to use in future works (such as articles or books) all or part of my work. I understand that I am free to register the copyright to my work.

**REVIEW, APPROVAL AND ACCEPTANCE**

The document mentioned above has been reviewed and accepted by the student's advisor, on behalf of the advisory committee, and by the Director of Graduate Studies (DGS), on behalf of the program; we verify that this is the final, approved version of the student's thesis including all changes required by the advisory committee. The undersigned agree to abide by the statements above.

Danielle M. Andrews, Student

Dr. Thomas R. Zentall, Major Professor

Dr. Mark Fillmore, Director of Graduate Studies

---

IS PECKING AVERSIVE TO A PIGEON OR IS IT ONLY THE DELAY TO  
REINFORCEMENT?

---

THESIS

---

A thesis submitted in partial fulfillment of  
the requirements for the degree of Master of Science  
in the College of Arts and Sciences at the University of Kentucky

By

Danielle Michelle Andrews

Lexington, Kentucky

Director: Dr. Thomas R. Zentall, Professor of Psychology

Lexington, Kentucky

2018

Copyright © Danielle M. Andrews 2018

## ABSTRACT OF THESIS

### IS PECKING AVERSIVE TO A PIGEON OR IS IT ONLY THE DELAY TO REINFORCEMENT?

The principle of least effort suggests that animals should minimize effort to reinforcement. Thus, not pecking should be preferred over pecking. However, pigeons often peck when it is allowed but not required (e.g., fixed time schedules) but pecking may be adventitiously reinforced. In the present experiment, to better compare a schedule of reinforcement that requires pecking with one that requires the absence of pecking, we compared a fixed-interval (FI) schedule in which reinforcement follows the first peck after the interval has elapsed and a differential-reinforcement-of-other behavior (DRO) schedule which requires pigeons abstain from pecking for a similar interval. The delay to reinforcement was matched on a trial-by-trial basis by extending the duration of the FI to match the DRO schedule that preceded it. Of 12 pigeons, 6 preferred the DRO schedule over the FI schedule and 6 did not show a schedule preference. Those that were indifferent between the schedules had acquired the contingences, as they responded appropriately to the two schedules but had a spatial preference stronger than their schedule preference. Individual differences in the preference of the pigeons may be related to their behavior during the DRO.

KEYWORDS: Schedule Preference, Differential-Reinforcement-of-Other Behavior, Pecking, Delay to Reinforcement, Pigeons

---

Danielle Michelle Andrews

---

April 24<sup>th</sup>, 2018

---

IS PECKING AVERSIVE TO A PIGEON OR IS IT ONLY THE DELAY TO  
REINFORCEMENT?

By

Danielle Michelle Andrews

Dr. Thomas R. Zentall

---

Director of Thesis

Dr. Mark Fillmore

---

Director of Graduate Studies

April 24<sup>th</sup>, 2018

---

Date

## TABLE OF CONTENTS

LIST OF TABLES.....	iv
LIST OF FIGURES.....	v
CHAPTER 1: INTRODUCTION.....	1
CHAPTER 2: METHODS.....	9
2.1 Subjects.....	9
2.2 Apparatus .....	9
2.3 Procedure.....	10
CHAPTER 3: ANALYSES.....	14
CHAPTER 4: RESULTS.....	15
4.1 Phase 1: Spatial Discrimination .....	15
4.2 Phase 2: Reversal .....	17
4.3 Phases 1 and 2 Combined.....	19
4.4 Phase 3: Visual Discrimination.....	22
4.5 All Phases.....	24
4.6 Individual Subject & Observational Data.....	32
CHAPTER 5: DISCUSSION.....	46
5.1 General Discussion.....	46
5.2 Limitations.....	50
5.3 Conclusion.....	50
REFERENCES.....	52
VITA.....	54

## LIST OF TABLES

Table 1: Summary of observed behavior during DRO terminal links and schedule preference during the last 10 sessions of Phase 3.....	33
-------------------------------------------------------------------------------------------------------------------------------------	----

## LIST OF FIGURES

Figure 1: Concurrent chain design for Group 1.....	12
Figure 2: Concurrent chain design for Group 2.....	13
Figure 3: The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 1.....	16
Figure 4: The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 2.....	18
Figure 5: The average proportion of choices of the DRO alternative during the last 10 sessions of Phases 1 and 2 and the combined average of both phases, with each subject represented by a dot.....	20
Figure 6: The average proportion of choices of the DRO alternative for each subject during the last 10 sessions of Phases 1 and 2 and the combined average of both phases.....	21
Figure 7: The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 3.....	23
Figure 8: The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 3 and the average of the last 10 sessions of Phases 1 and 2 with each subject represented by a dot.....	25
Figure 9: The average proportion of choices of the DRO alternative for each subject during the last 10 sessions of Phase 3 and the average of the last 10 sessions of Phases 1 and 2 combined.....	26
Figure 10: The average duration of DRO terminal links each subject experienced during the last 10 sessions of each phase.....	27
Figure 11: The Pearson correlation between the average number of DRO resets and the average duration of DRO terminal links, averaged across all 3 phases.....	28
Figure 12: The average number of DRO resets each subject made during the last 10 sessions of each phase.....	29
Figure 13: The Pearson correlation between the number of DRO resets per trial and the number of pecks to FI terminal links during the last 10 sessions of Phase 3.....	30



Figure 14: The average number of responses made to FI terminal links for each subject during the last 10 sessions of each phase.....	31
Figure 15: The number of DRO choices made by Subject #2797 each session of all 3 phases.....	35
Figure 16: The number of DRO choices made by Subject #4074 each session of all 3 phases.....	36
Figure 17: The number of DRO choices made by Subject #207 each session of all 3 phases.....	37
Figure 18: The number of DRO choices made by Subject #234 each session of all 3 phases.....	38
Figure 19: The number of DRO choices made by Subject #135 each session of all 3 phases.....	39
Figure 20: The number of DRO choices made by Subject #728 each session of all 3 phases.....	40
Figure 21: The number of DRO choices made by Subject #23644 each session of all 3 phases.....	41
Figure 22: The number of DRO choices made by Subject #23793 each session of all 3 phases.....	42
Figure 23: The number of DRO choices made by Subject #727 each session of all 3 phases.....	43
Figure 24: The number of DRO choices made by Subject #1869 each session of all 3 phases.....	44
Figure 25: The number of DRO choices made by Subject #19229 each session of all 3 phases.....	45
Figure 26: The number of DRO choices made by Subject #723 each session of all 3 phases.....	46

## 1. Introduction

The principle of least effort suggests that animals behave in a way that minimizes effort and time to reinforcement (Gengerelli, 1930; Tsai, 1932; Waters, 1937). Under this assumption, pigeons should prefer to refrain from pecking because pecking requires both time and effort. More pecking requires more time and it is well established that pigeons have a strong preference for immediate reinforcement over delayed reinforcement (Ainslie, 1975). However, pigeons often peck when it is allowed but not required (Hearst, 1987).

Furthermore, previous research has observed the persistence of pecking by pigeons despite schedules that require the absence of pecking in order to produce reinforcement (Williams & Williams, 1969). Hearst (1987) described this behavior as sign-tracking, behavior directed at signs of future reinforcement, and this behavior has been seen to persist even when it prevents reinforcement.

The question of whether pecking is aversive to pigeons, all other things being equal, remains an open question. Although one might have thought that this issue would have been settled long ago, the logic of it continues to make it a viable hypothesis. For example, recently Hinnenkamp, Shahan and Madden (2017) tested the hypothesis that nonreinforced pecking is responsible for avoidance of the optimal choice in the gambling paradigm. In the gambling paradigm, pigeons show a preference for a 20% chance of signaled reinforcement over a 50% chance of unsignaled reinforcement (Stagner & Zentall, 2010; see Zentall & Laude, 2013 for a review). Hinnenkamp et al. tested the hypothesis that when pigeons choose the 20% signaled reinforcement

alternative, pecking the signal for reinforcement was always reinforced and they rarely pecked the signal for the absence of reinforcement, whereas when they choose the 50% unsignaled reinforcement alternative, pecking was reinforced only 50% of the time. Thus, pecking the 50% unsignaled reinforcement alternative is often not reinforced and those unreinforced pecks to the signal for 50% reinforcement result in a preference for the suboptimal alternative. However, contrary to the hypothesis that preference for the 20% reinforcement alternative resulted from nonreinforced pecking, Hinnenkamp et al. found that the rate of nonreinforced pecking did not predict the preference for the suboptimal (20% reinforcement) alternative. Regardless of how much the pigeons pecked on nonreinforced trials (i.e., increasing the unit price per pellet), their preference for the suboptimal choice remained. There was no relationship between the degree of pecking on unsignaled nonreinforced trials and the preference for the suboptimal alternative. Although the rate of pecking did not appear to influence choice in this experiment, it is clear that understanding the influence of response rate on the value of reinforcement is still a relevant issue.

In order to measure preference between two schedules one needs to use a procedure that separates the choice for the schedule from the schedule itself. Concurrent chains provide a direct measure of choice between two alternatives by allowing entrance into the terminal link schedule to be determined by identical initial-link schedules (Ferster & Skinner, 1957; Sumpter, Foster & Temple, 2002). With this procedure, pecking in the initial link is used as a measure of the preference for the terminal link schedule.

Using a concurrent chains schedule to test the avoidance of pecking directly, Friedrich and Zentall (2004) provided pigeons a choice between a fixed-ratio (FR) of 1 peck versus 30 pecks, and found that they consistently chose the FR1. This finding implies that pigeons prefer to peck less; however, as noted earlier, more pecking requires more time (Ainslie, 1975). A schedule with a low pecking requirement typically produces a greater rate and percentage of reinforcers and a shorter delay to reinforcement compared to a schedule with a high pecking requirement (Pontes, Abreu-Rodrigues, & Souza, 2012). The question of interest is if one controls for delay to reinforcement, and as a result the rate of reinforcement, would pigeons show a preference for a schedule that did not require pecking over one that required pecking?

To try to address this question, Killeen (1968) encouraged pigeons to vary their response rate while attempting to control for delay of reinforcement. He recorded choice between the left alternative which encouraged pecking using a 30-s variable-interval (VI 30 s) schedule in which one response was required after a given amount of time which varied, and the right alternative which discouraged pecking (VI 30 s which only provided reinforcement if the pigeon refrained from pecking during the last 1.5 s of the interval). The manipulation was effective in producing different rates of pecking. On average 52.3 pecks per min were made on the left key and 0.95 pecks per min were made on the right key. Despite the difference in response rates, the pigeons were indifferent between the two alternatives. However, the no peck contingency during the last 1.5 s of the interval typically extended the delay of reinforcement in that alternative

compared to the standard VI 30 s schedule.

Fantino (1968) also investigated the influence of response requirements on choice. Comparable VI schedules were used in the initial link, followed by terminal links with varying response rate requirements. One terminal link required a high rate of responding (differential-reinforcement-of-high-rate, DRH, with no fewer than  $n$  responses in  $t$  s), while the other required only one response after a fixed duration (fixed-interval, FI). For other birds, one terminal link required a low rate of responding (differential-reinforcement-of-low-rate, DRL, with no more than  $n$  responses in  $t$  s) while the other was an FI schedule. The FI schedule was manipulated to provide the same proportion and rate of reinforcement as the DRH or DRL on the prior session. Fantino (1968) found that pigeons preferred the FI schedule, the schedule with the lower response requirement, over the DRH. He suggested that the response requirement, influenced choice beyond the rate of reinforcement alone. However, the DRH is unusual in that requires pecking at a high rate and that may be aversive to the pigeon in its own right. On the other hand, there were mixed results for the FI/DRL group. Two birds were indifferent and the third one preferred the FI schedule.

Moore and Fantino (1975) later attempted to control for the delay to reinforcement as well as rate of reinforcement by comparing a response-dependent schedule (variable-interval, VI) and a response-independent schedule (variable-time, VT, reinforcement was provided after the passage of a variable amount of time, independent of pecking) by using comparable inter-

reinforcement intervals between schedules. In the VT, the response rate is allowed to vary without control. Although the response rates were lower in the response-independent (VT) schedule compared to the response-dependent (VI) schedule, Moore and Fantino found that the pigeons were indifferent between the two schedules. However, given that the pigeons pecked at a moderate rate during the VT schedule, the difference in peck rates may not have been great enough to produce a differential preference.

Similarly, Neuringer (1969) found that there was no differential preference between an FI and FT schedule when inter-reinforcement intervals were held constant. But the FT was defined in terms of a blackout which may have biased the animals against that alternative. In this case the initial links were 90 s VI schedules with a 1.5-s delay if the bird switched keys while responding (a 1.5-s changeover delay, COD). A problem with the use of VI schedules in the initial link is the time to enter the terminal link will vary from trial to trial and local biases may result. One way to avoid the problem of local differences in the time to enter the terminal links is to require only a single response to the initial link.

As part of a larger study, Singer, Berry and Zentall (2007) compared pigeons' concurrent chains preference for pecking or not pecking (by using a differential-reinforcement-of-other-behavior schedule, DRO) over required pecking (fixed interval, FI), under conditions that controlled for the delay to reinforcement on a trial by trial basis by matching the duration of FI trials to the duration of the DRO trials. Of the seven pigeons tested, four were indifferent between the two schedules, one preferred the FI schedule, and two pigeons

preferred the DRO schedule. Thus, most pigeons did not prefer to avoid pecking and one actually showed a preference for pecking.

The purpose of the Singer et al. (2007) experiment was to create trials of equal duration, to determine if they had a preference for the stimulus that followed each of the schedules. The purpose of the present experiment was to more directly investigate the relative schedule preference between a DRO and FI schedule in which the schedule duration was controlled on a trial by trial basis. That is, when delay to reinforcement is controlled, do pigeons have a preference for pecking or refraining from pecking?

In the present experiment, I compared a pigeon's preference between a schedule associated with pecking (FI) and a schedule associated with the absence of pecking (DRO) for a comparable duration (Herrnstein & Morse, 1957; Reynolds, 1961). If the pigeon pecked during the DRO trial, the timer reset the interval and the pigeon had to refrain from pecking the full assigned duration to receive reinforcement. To equate for delay to reinforcement, I used a modified FI schedule, such that if pecking occurred during the DRO schedule, the subsequent FI schedule was extended to match the duration of the two schedules on a trial by trial basis. Preference for the DRO schedule would suggest that the pigeons preferred to refrain from pecking.

In Phase 1 of the experiment, I compared a pigeon's preference between reinforcement schedules using spatially-defined concurrent chains (access to the FI schedule on one side, access to the DRO on the other side, position was counterbalanced over subjects). Once a stable preference developed, the spatial

location of the two chains was reversed to determine if the pigeons would switch location to follow what appeared to be their preferred schedule (Phase 2). In Phase 3, I used a visual discrimination on the initial link to determine if the subjects would follow the initial link stimulus associated with their preferred schedule as it switched from side to side over trials.

If I find that the pigeons are indifferent and do not show a consistent schedule preference, I would assume that pecking is not sufficiently costly or aversive, relative to refraining from pecking, to result in a schedule preference. Indifference would suggest that time, or the delay to reinforcement, was the basis of choice by pigeons because when time is controlled, no clear differential preference has been found (Singer et al., 2007). Indifference would also be consistent with the delay reduction hypothesis (Fantino, 1969). The delay reduction hypothesis states that choice is dependent on the degree to which a conditioned reinforcer reduces the expected time to reinforcement, relative to its absence and should be independent of other variables such as required pecking.

A preference for the DRO schedule over the fixed-interval schedule would be consistent with the principle of least effort (Gengerelli, 1930; Tsai, 1932; Waters, 1937) as well as some previous research (Fantino, 1968).

If I find a preference for the FI schedule over the DRO schedule, it would suggest that pigeons prefer pecking rather than being required to refrain from pecking. In an FI schedule, a peck is required immediately before reinforcement and the association of that peck with reinforcement could actually result in a preference for pecking (as Singer et al., 2007, found for one pigeon).



Another interesting possibility is that the FI schedule will be preferred because although the schedules are equated for their duration, pecking has been found to result in the subjective speeding up of the passage of time (Zentall & Singer, 2008). That is, pigeons have been shown to underestimate the passage of time when they are satisfying a pecking requirement relative to when they are required to refrain from pecking. Specifically, Zentall and Singer trained pigeons to discriminate between a 2 s (short) and 10 s (long) stimulus. When the stimulus was white they were required to peck at it but when it was blue they had to refrain from pecking. They then used probe trials of intermediate duration to find the point of subjective equality (the bisection point), the stimulus duration to which they were equally likely respond 'short' or 'long.' A shift in the bisection point suggests a change in the subjective passage of time to an animal. Zentall and Singer (2008) found that when the pigeons were required to peck, the bisection point shifted to longer durations relative to when the pigeons were forced to refrain from pecking, suggesting that time passed subjectively slower when they were pecking than when they were not pecking. That is, presumably, it felt like not as much time had passed.

Finally, previous research suggests that individual differences may exist in preference among the schedules (Singer et al. 2007). If so, this might correspond to what behavioral ecologists refer to as behavioral syndromes, individual differences in preference among animals to ensure the variability needed for survival of the genes (Sih, Bell, Johnson & Ziemba, 2004).

Brinker and Treadway (1975) also found individual differences in the

schedule preferences of Asian quail. One bird showed a preference for the VI schedule over the VT schedule but the remaining three subjects did not show a consistent preference. Response rates to the response-dependent VI schedule were significantly greater than those to the response-independent VT schedule yet one bird still preferred the VI over the VT schedule.

## **2. Methods**

### *2.1. Subjects*

The subjects were 12 non-naïve unsexed pigeons that had participated in unrelated learning experiments. All subjects were retired breeders from the Palmetto Pigeon Plant (Sumter, SC). During the experiment, the birds were kept at 85% of their free-feeding body weight to ensure motivation in the experiment. Grit and water were available to the birds at all times in their individual home cages (28 x 38 x 30.5 cm). The home cages were located in a climate-controlled room on a 12-hour light-dark cycle and cared for in accordance with University of Kentucky Animal Care Guidelines.

### *2.2. Apparatus*

The experiment took place in a standard LVE/BRS (Laurel, MD) test chamber measuring 36 cm high x 30 cm from the response panel to the back wall x 36 cm across the response panel. The pigeons responded to three response keys 18 cm above the floor, 2.5 cm in diameter, and 6 cm apart on the response panel. Behind each key was a 12-stimulus inline projector (Industrial Electronics Engineering, Van Nuys, CA) that projected one of five stimuli (white, red, green, blue and yellow for one group, white, vertical lines, green, blue and

yellow for the other group) onto the response keys. A center-mounted feeder located 10 cm above the floor which, when raised, was illuminated by a 28-V 0.04-A lamp allowed access to mixed grain for reinforcement. White noise was generated from outside the chamber and the apparatus was controlled by a computer in the adjacent room running Med-PC IV (Tatham & Zurn, 1989) with a 10-ms resolution.

### *2.3. Procedure*

Each session consisted of 60 trials, organized into triplets (3 trial blocks). Each triplet began with a forced differential-reinforcement-of-other-behavior (DRO) trial, then a forced modified fixed-interval (FI) trial of matched duration, and then a choice trial allowing a choice between the two schedules. As a result, each session included 20 forced DRO trials, 20 forced FI trials and 20 choice trials.

A critical aspect of the experiment was the equivalence of duration between alternatives because any difference in delay to reinforcement could account for a schedule preference if one was found. To equate schedule durations, each FI schedule was matched in duration to the previous DRO schedule. That is, if a bird pecked before the 10-s duration elapsed, the trial was extended until 10 s elapsed without a peck. As a result, depending on the time and number of DRO responses each pigeon made, the trials varied in duration.

A concurrent chain procedure was used. A white orienting stimulus was illuminated on the center key to signal the beginning of a trial. The orienting stimulus was used to ensure the birds were equidistant from either side key.

Following a single peck to the center key, it darkened and one side key was illuminated. This side key was the initial link for the forced DRO trial. Following one response to the side key, the key changed color to initiate the terminal link schedule. For the DRO schedule, any response to the illuminated response key reset the timer. Once 10 s elapsed without response, 2 s of access to mixed grain via the food hopper was provided. Following reinforcement, there was a 3-s lit inter-trial interval.

The next trial was a forced FI trial matched in duration to the previous DRO trial. The same chain as described above now occurred on the other side of the panel. Since the DRO duration was set at 10 s, the FI trial was at least 10 s long, depending on the duration of the DRO schedule. Reinforcement followed a single response after the FI had elapsed.

The third trial in each set was a choice trial in which both side keys were illuminated with discriminative stimuli allowing the birds to make a choice between the DRO schedule and the FI schedule. One response was required to change the color from the initial link to the terminal link of the selected key and darken the unselected key. Depending on the key selected, the contingencies were either FI 10 s or DRO 10 s. Following the choice trial, the bird received reinforcement. Pecks to darkened keys had no effect. Each experimental session provided 60 reinforcements.

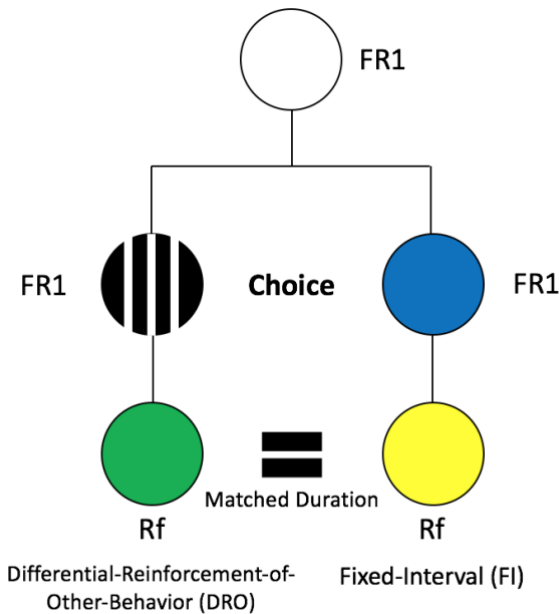
*Pre-training:*

Pigeons often have difficulty learning the DRO contingency. To facilitate learning the DRO contingency, the terminal link DRO duration started short and

was gradually extended. The subjects were trained using the procedure above but with a 1 s DRO schedule for 10 sessions, followed by a 2 s DRO for 5 sessions, then a 4 s DRO for 5 sessions, and the final 10 s DRO used in the remainder of the experiment.

*Phase 1: Spatial Discrimination:*

The location of the FI and DRO contingencies were spatially discriminable and signaled with distinctive stimuli. For one group, the FI schedule was signaled by a vertical line initial link followed by a green terminal link on the right side. The DRO schedule was a blue initial link followed by a yellow terminal link on the left side (see Figure 1). For the other group, the DRO schedule was signaled by a red initial link followed by green terminal link on the right side, while a blue initial link followed by a yellow terminal link on the left side signaled the FI schedule (see Figure 2).



*Figure 1.* Concurrent chain design for Group 1.

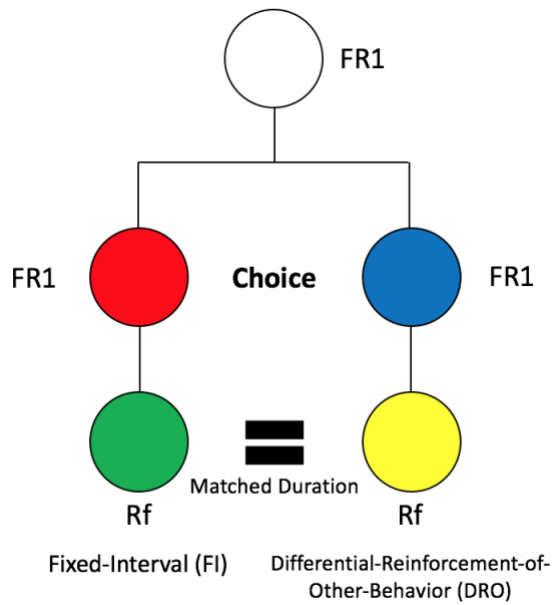


Figure 2. Concurrent chain design for Group 2.

*Phase 2: Reversal of the Spatial Discrimination:*

Once preferences had stabilized in Phase 1, the spatial location of the two schedules was reversed. The reversal was included to determine if the schedule preferences found might be due to spurious spatial preferences unrelated to the schedules.

*Phase 3: Visual Discrimination:*

Once preferences had stabilized in Phase 2, the visual stimuli randomly alternated on which side they appeared and the spatial cues were no longer relevant. All birds were tested until responding appeared stable upon examination of the preceding days' records.

In order to observe the behavior of the birds an additional session was conducted with a dim houselight to observe the behavior of the pigeons in the presence of the two schedules.

All but one bird experienced 22 sessions of the Phase 1 spatial discrimination, 15 sessions of the Phase 2 reversed spatial discrimination, and 28 sessions of the Phase 3 visual discrimination. Subject #723 experienced two fewer sessions of Phase 1 than the other subjects due to extreme stalling during test sessions.

### **3. Analyses**

The last ten sessions of each phase were used for statistical analyses to ensure stable performance and exclude variation due to initial learning. Session data were based on the mean of trial by trial data.

Preference was of primary interest and determined by the number of DRO choices out of 20 possible on choice trials. The proportion of DRO choices was used in calculations. Preference was defined as choosing one schedule 80% or more of the time. Indifference was categorized as 40% to 60% choice of the DRO schedule. Choice data were analyzed for changes over the three testing phases using a repeated-measures analysis of variance. The number of DRO choices was compared between counterbalance groups to identify any differences.

The duration of DRO terminal links, the number of times the DRO timer was reset (DRO resets), the number of pecks made to the FI terminal links (FI pecks), and the number of times the DRO alternative, as opposed to the FI alternative, was chosen on choice trials (DRO choice) was recorded and analyzed using Pearson correlations. Correlations were used due to large individual differences and the bimodal distribution of schedule preference.

Statistical significance was set at the  $p = .05$  level for all statistical tests.

#### **4. Results**

An independent-samples t-test was conducted to compare mean DRO preference between counterbalance groups for the average of all phases (Group 1  $M = 64.2%$ ,  $SEM = 18.5%$ ; Group 2  $M = 79.7%$ ,  $SEM = 20.6%$ ) and was found not to be statistically significant,  $t(10) = -1.37$ ,  $p = 0.20$ . As a result, the counterbalance groups were combined for all further analyses.

##### *4.1. Phase 1: Spatial Discrimination:*

In Phase 1, on average, the pigeons showed a preference for the DRO schedule. The average proportion of DRO choices was 73.63%,  $SEM = 11.04%$ . However, as shown in Figure 3, clear individual differences are apparent, as the proportion of DRO choices ranged from 1 to 100%. DRO preference was not significantly related to: the duration of DRO terminal links,  $r(12) = .04$ ,  $p = .91$ ; the number of resets made to DRO terminal links,  $r(12) = -.04$ ,  $p = .91$ ; or the number of pecks made to FI terminal links,  $r(12) = -.28$ ,  $p = .37$ .



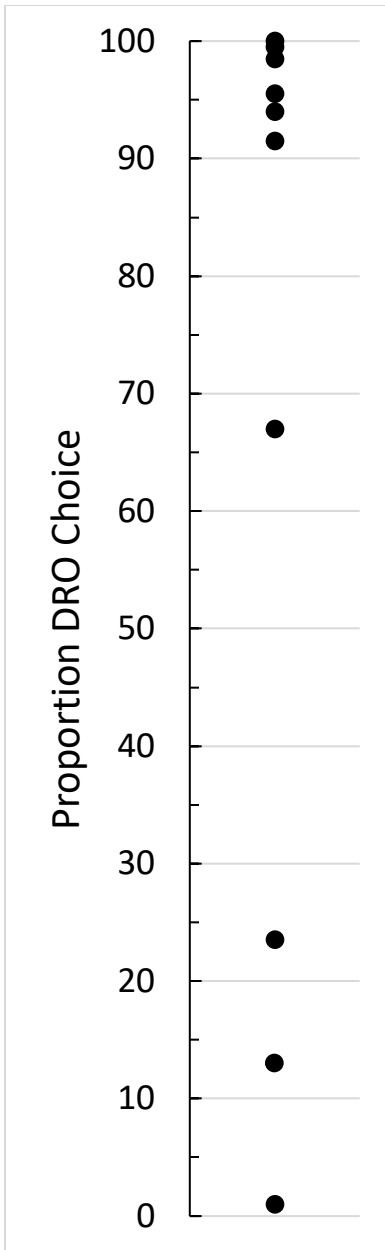


Figure 3. The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 1 ( $M = 73.63\%$ ,  $SEM = 11.04\%$ ) with each subject represented by a dot. Three birds chose the DRO alternative 100% of the time during the last 10 sessions, as a result only one dot is visible.

The average duration of DRO terminal links ranged from 10.14 to 12.29 s,  $M = 11.18$ ,  $SEM = 0.22$ . The average number of DRO resets was 0.69 per trial,  $SEM = .13$ . DRO duration and DRO resets were highly correlated,  $r(12) = .79$ ,  $p = .00$ . The average number of pecks to FI terminal links was 10.2 ( $SEM = 2.03$ ), although this ranged from 1.6 to 26.7 pecks per trial. DRO resets and the number of FI pecks were not significantly correlated,  $r(12) = .50$ ,  $p = .10$ . On average, birds pecked FI terminal links ( $M = 10.2$ ,  $SEM = 2.03$ ) more than DRO terminal links ( $M = 0.69$ ,  $SEM = .13$ ), and this difference was statistically significant,  $t(11) = -4.84$ ,  $p = .00$ , indicating that the schedules were quite effective in producing differential pecking.

#### *4.2. Phase 2: Reversal of the Spatial Discrimination:*

In Phase 2, once again, on average the pigeons showed a preference for the DRO schedule. Average proportion of DRO choices during the last 10 sessions of Phase 2 was 72.67%, ( $SEM = 11.31\%$ ), however this ranged from 0 to 100%. As in Phase 1, individual differences are apparent as shown in Figure 4. Pearson correlations revealed no statistically significant relationship between DRO choice and DRO duration ( $r(12) = -.23$ ,  $p = .48$ ), DRO choice and DRO resets ( $r(12) = -.07$ ,  $p = .84$ ), DRO choice and FI pecks ( $r(12) = .16$ ,  $p = .63$ ).

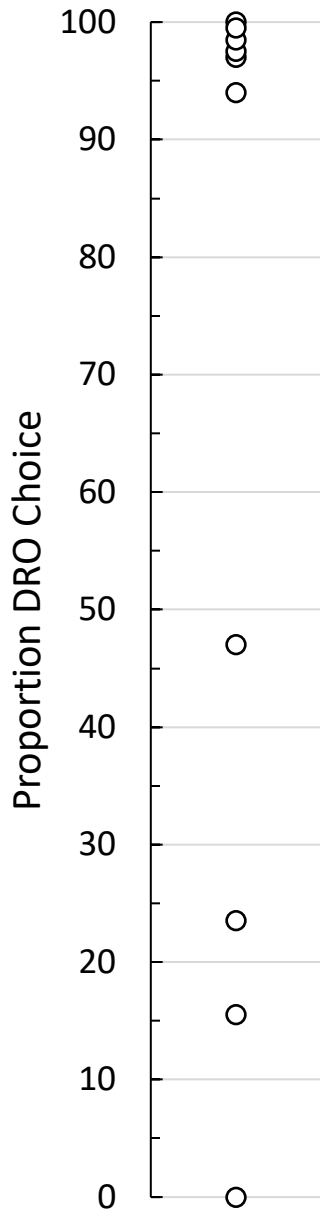


Figure 4. The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 2 ( $M = 72.67\%$ ,  $SEM = 11.31\%$ ) with each subject represented by a dot. Two birds chose the DRO 100% of the time and two birds chose the DRO 99.5% of the time, as a result only one dot of each is visible.

The average duration of DRO terminal links was 10.92 s,  $SEM = 0.26$ . The number of DRO resets ranged from .05 to 1.68 with an average of .59 resets per trial,  $SEM = .16$ . The duration of DRO terminal links and the number of DRO resets were highly correlated,  $r(12) = .97$ ,  $p = .00$ . The number of responses to FI terminal links ranged from 2.2 to 22.2 pecks per trial,  $M = 11.7$ ,  $SEM = 1.53$ . DRO resets and FI pecks were not significantly related,  $r(12) = .30$ ,  $p = .34$ . On average, birds were pecking FI terminal links ( $M = 11.7$ ,  $SEM = 1.53$ ) more than DRO terminal links ( $M = .59$ ,  $SEM = .16$ ), and this difference was statistically significant,  $t(11) = -7.47$ ,  $p = .00$ .

#### *4.3. Phases 1 and 2: Spatial Discriminations Combined:*

The average DRO choice proportion for each bird from Phases 1 and 2 combined provides a better indicator of preference than either Phase 1 or 2 alone because it controls for spatial biases. Average DRO choice proportions from Phase 1, Phase 2 and Phases 1 and 2 combined are shown in Figure 5 with each bird represented as a dot. Individual subject data are presented in Figure 6.

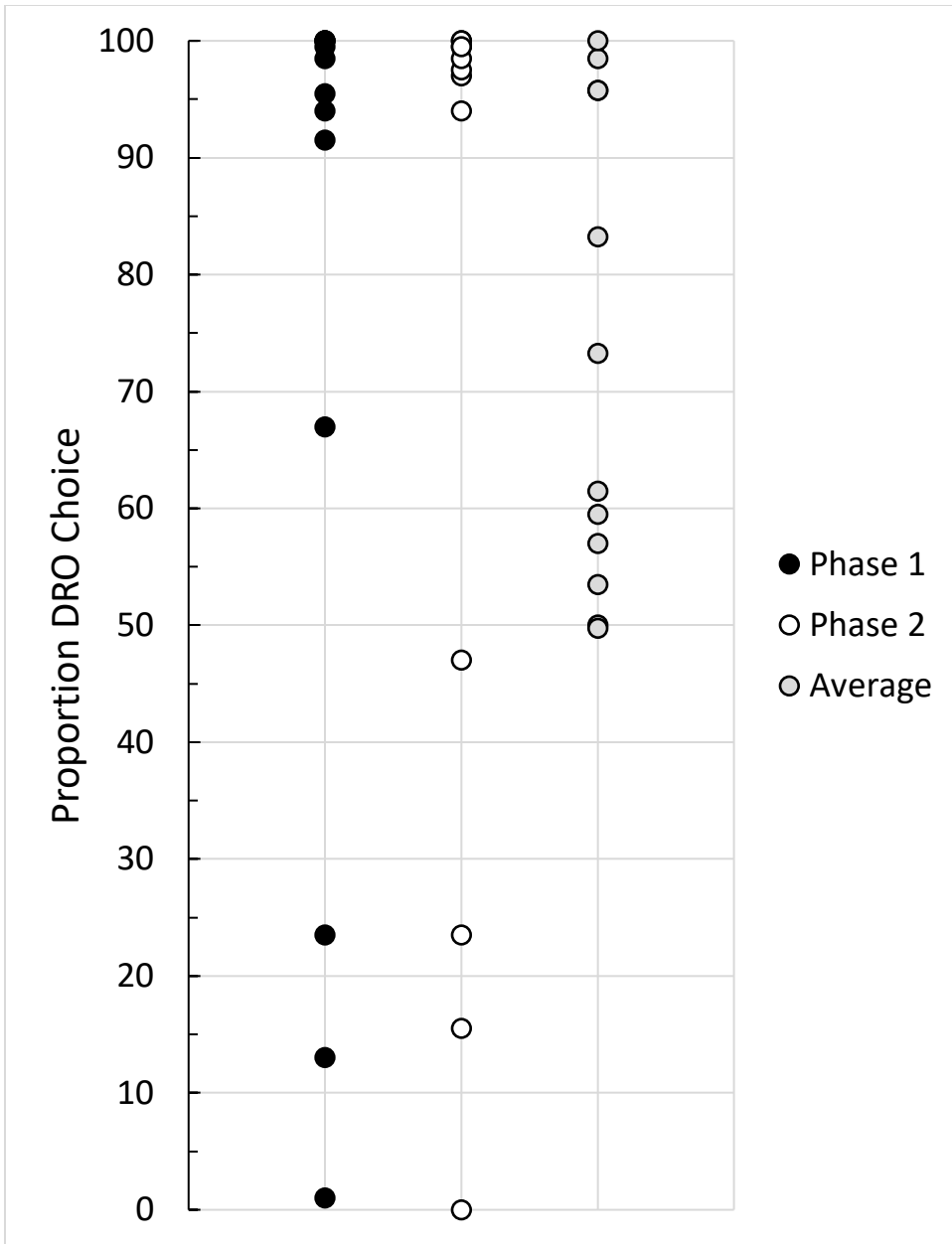


Figure 5. The average proportion of choices of the DRO alternative during the last 10 sessions of Phases 1 and 2 and the combined average of both phases, with each subject represented by a dot.

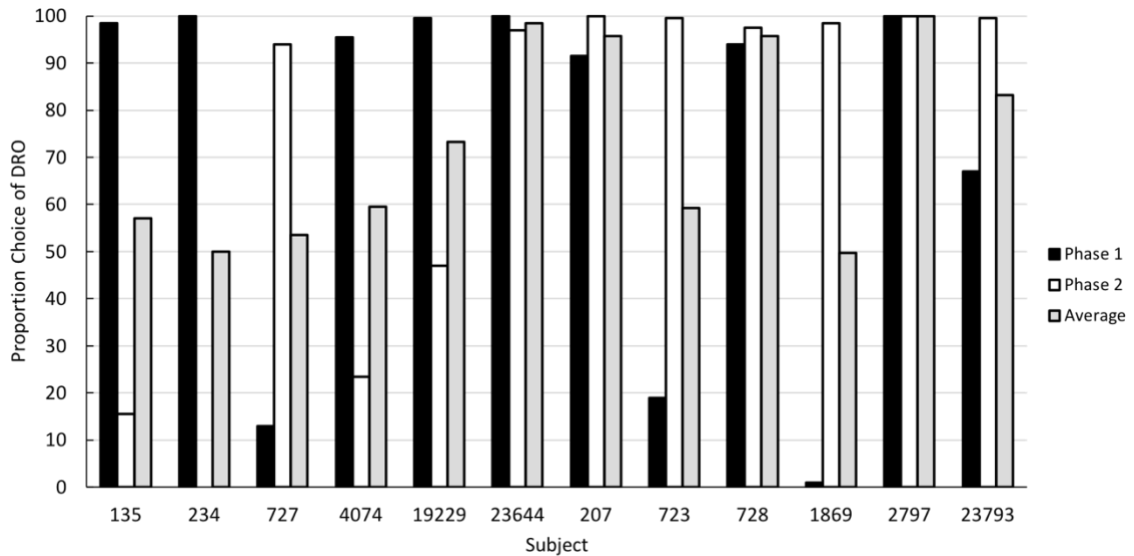


Figure 6. The average proportion of choices of the DRO alternative for each subject during the last 10 sessions of Phases 1 and 2 and the combined average of both phases.

A paired samples t-test showed no significant difference in the average DRO choice proportions between Phases 1 and 2; Phase 1  $M = 73.63\%$ ,  $SEM = 11.04\%$ ; Phase 2  $M = 72.67\%$ ,  $SEM = 11.31\%$ ;  $t(11) = .05$ ,  $p = .96$ . DRO choice in Phase 2 was inversely correlated with Phase 1 but not significant,  $r(12) = -.45$ ,  $p = .14$ . This inverse correlation was a result of the birds whose schedule preference reversed when the spatial location reversed.

The average duration of DRO terminal links was not significantly different between Phases 1 and 2,  $t(11) = 1.24$ ,  $p = .24$ . The number of DRO resets was not significantly different between the two phases,  $t(11) = .52$ ,  $p = .61$ . The number of responses to FI terminal links was also not different between phases,  $t(11) = -.87$ ,  $p = .41$ .

#### 4.4. Phase 3: Visual Discrimination:

As with the combined Phases 1 and 2, the results of Phase 3 indicated that there were clear individual differences. Figure 7 shows the proportion of DRO choices during the last 10 sessions of Phase 3, with each subject represented as a dot. The average DRO choice proportion during the last 10 sessions of Phase 3 ranged from 36.5% to 96.5%,  $M = 69.5\%$ ,  $SEM = 6.09\%$ . Pearson correlations between average choices of the DRO alternative and each: average DRO duration ( $r(12) = -.35$ ,  $p = .27$ ), DRO resets ( $r(12) = -.12$ ,  $p = .71$ ), and FI responses ( $r(12) = .47$ ,  $p = .13$ ), were not statistically significant.

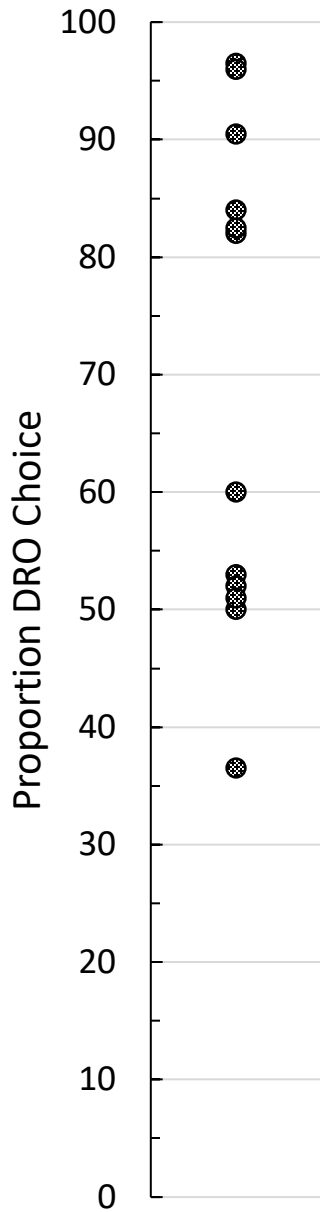


Figure 7. The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 3 ( $M = 69.50\%$ ,  $SEM = 6.09\%$ ) with each subject represented by a dot. Six birds showed a DRO preference ( $>80\%$  choice of DRO). Five birds were indifferent between schedules (40-60% choice of DRO). One bird was undetermined, below 40% but far above 20% criterion which would show FI schedule preference.



The average duration of DRO terminal links was 10.63 s,  $SEM = .18$ . The number of DRO resets ranged from .07 to 1.42 per trial,  $M = .42$ ,  $SEM = .13$ . There was a statistically significant correlation between DRO duration and the number of DRO resets,  $r(12) = .85$ ,  $p = .00$ . The number of responses to FI terminal links ranged from 4.3 to 24.6,  $M = 10.26$ ,  $SEM = 1.62$ . A Pearson correlation between the average number of DRO resets and the average number of pecks during FI trials during the last 10 sessions was statically significant,  $r(12) = .61$ ,  $p = .04$ . A paired samples t-test comparing the average number of DRO resets ( $M = .42$ ,  $SEM = .13$ ) and the average number of pecks to the FI ( $M = 10.32$ ,  $SEM = 1.60$ ) during the last 10 sessions of Phase 3 showed a significant difference between the two,  $t(11) = -6.37$ ,  $p = .00$ .

#### 4.5. All Phases:

A repeated-measures analysis of variance revealed no statistically significant differences in the average number of DRO choices between phases,  $F(2,22) = .05$ ,  $p = .83$ . Similarly, the proportion of DRO choices made across the last 10 sessions of Phase 1 and Phase 2 together were highly correlated with the average proportion of DRO choices in Phase 3,  $r(12) = .94$ ,  $p = .00$ . Figure 8 shows the comparison between these two choice proportions. The average DRO choice proportion for each subject during the last 10 sessions of Phase 3 alongside the average of Phases 1 and 2 is shown in Figure 9. Schedule preference and the duration of DRO terminal links were not significantly correlated in any phase, Phase 1  $r(12) = .04$ ,  $p = .91$ ; Phase 2  $r(12) = -.23$ ,  $p =$

.48; Phase 3  $r(12) = -.35$ ,  $p = .27$ . Therefore, longer trials did not seem to affect preference.

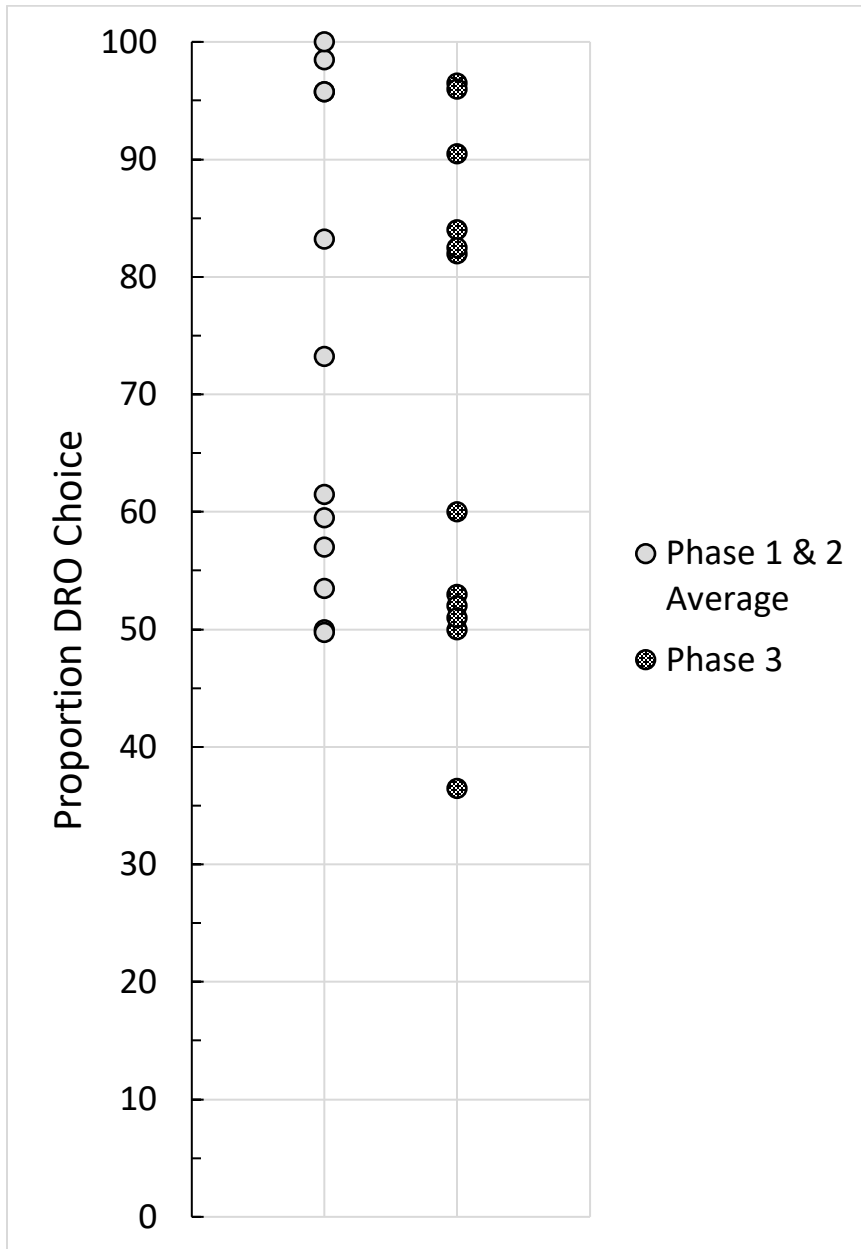
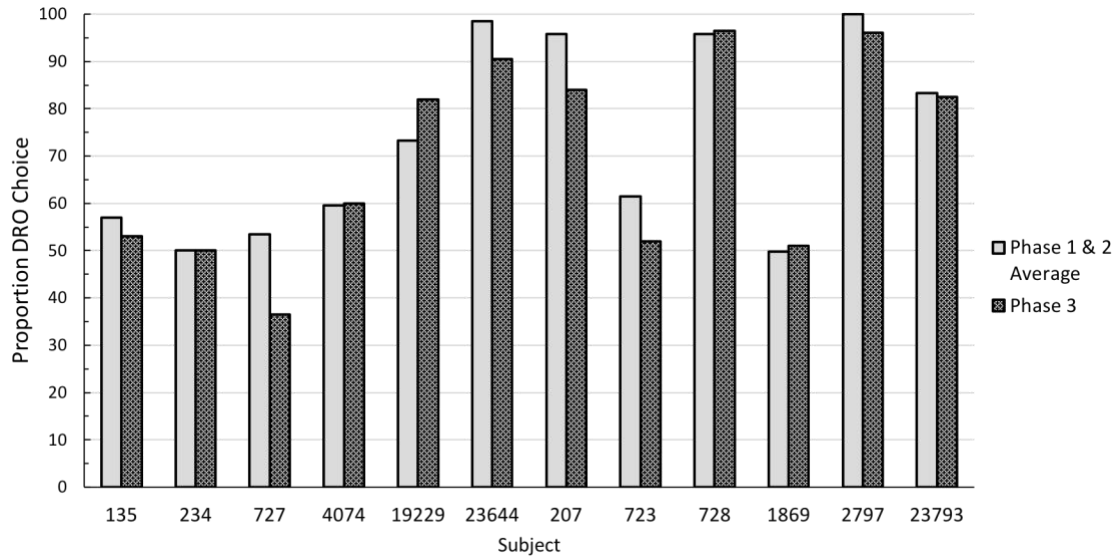


Figure 8. The average proportion of choices of the DRO alternative during the last 10 sessions of Phase 3 and the average of the last 10 sessions of Phases 1 and 2 with each subject represented by a dot.



*Figure 9.* The average proportion of choices of the DRO alternative for each subject during the last 10 sessions of Phase 3 and the average of the last 10 sessions of Phases 1 and 2 combined.

A repeated-measures analysis of variance was computed to compare the average duration of DRO terminal links during the last 10 sessions of each phase. There was a significant effect of phase on the average duration of the DRO trials; Phase 1  $M = 11.18$  s,  $SEM = .22$ ; Phase 2  $M = 10.92$  s,  $SEM = .26$ ; Phase 3  $M = 10.63$ ,  $SEM = .18$ ;  $F(2,22) = 4.00$ ,  $p = .03$ . Bonferroni post hoc tests showed that there was a significant difference between the average duration of DRO terminal links in Phase 1 compared to Phase 3,  $p = .01$ . On average, the DRO durations in Phase 3 ( $M = 10.63$  s,  $SEM = .18$ ) were 0.55 s shorter than those in Phase 1 ( $M = 11.18$  s,  $SEM = .22$ ),  $SEM = .17$ . The average duration of DRO terminal links for each subject during the last 10 sessions of each phase is shown in Figure 10.

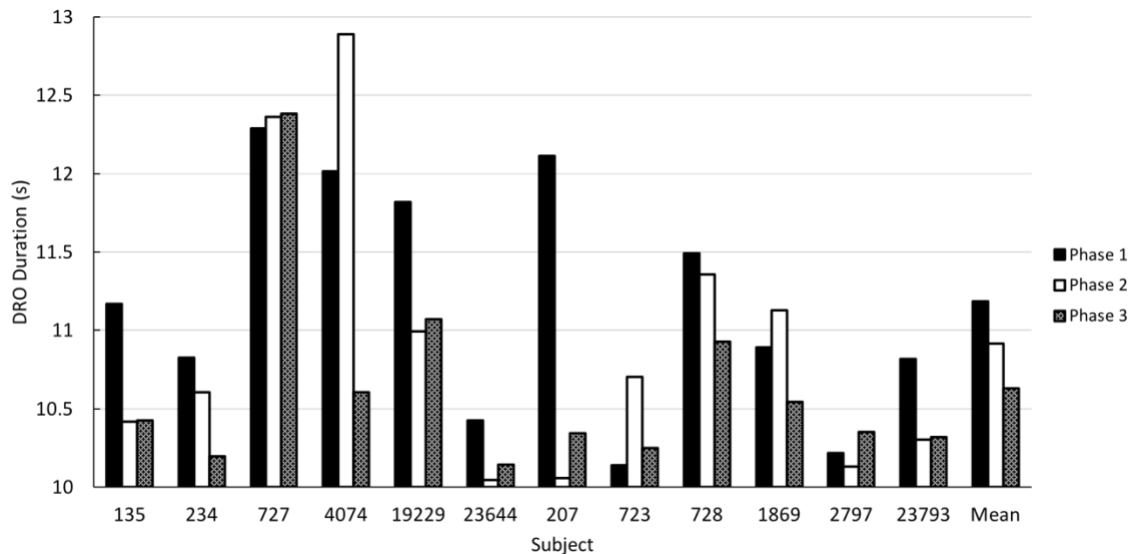
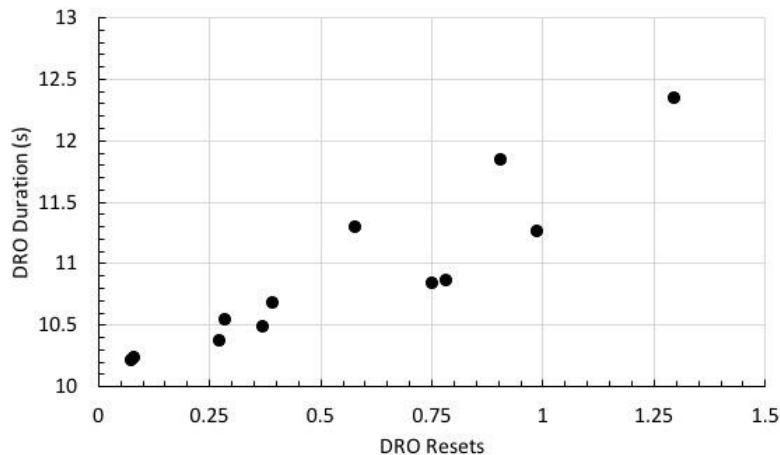


Figure 10. The average duration of DRO terminal links each subject experienced during the last 10 sessions of each phase, Phase 1  $M = 11.18$  s,  $SEM = .22$  s, Phase 2  $M = 10.92$  s,  $SEM = .26$  s, Phase 3  $M = 10.63$  s,  $SEM = .18$ .

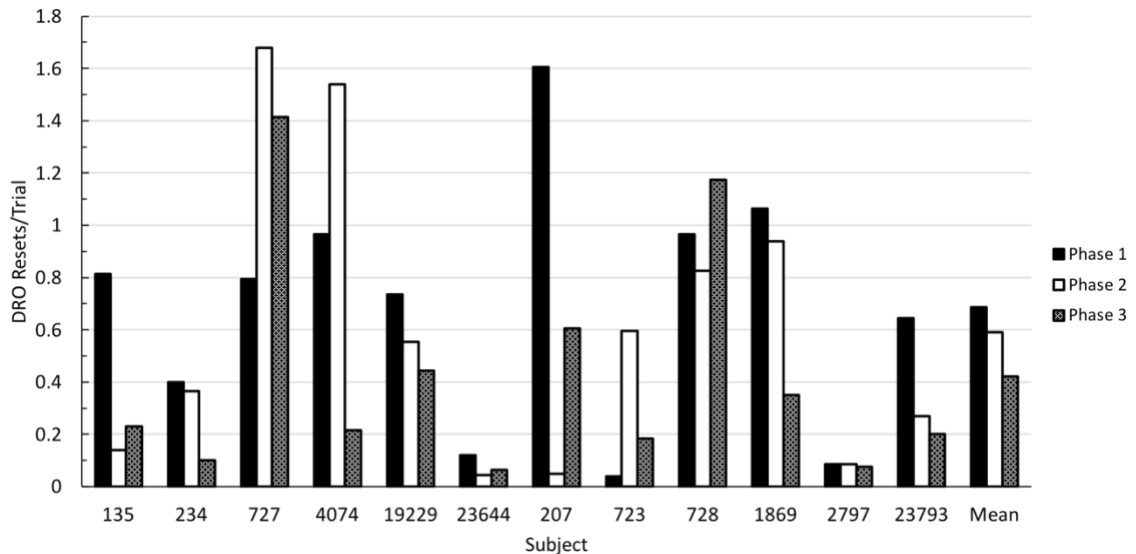
DRO duration and DRO resets were significantly correlated in all 3 phases, Phase 1  $r(12) = .79, p = .00$ ; Phases 2  $r(12) = .97, p = .00$ ; Phase 3  $r(12) = .85, p = .00$ . Average duration over the last 10 sessions of all 3 phases and the average number of DRO resets over the last 10 sessions of all 3 phases were also highly correlated,  $r(12) = .91, p = .00$  (See Figure 11).



*Figure 11.* The Pearson correlation between the average number of DRO resets and the average duration of DRO terminal links, averaged across all 3 phases,  $r(12) = .91, p = .00$ .

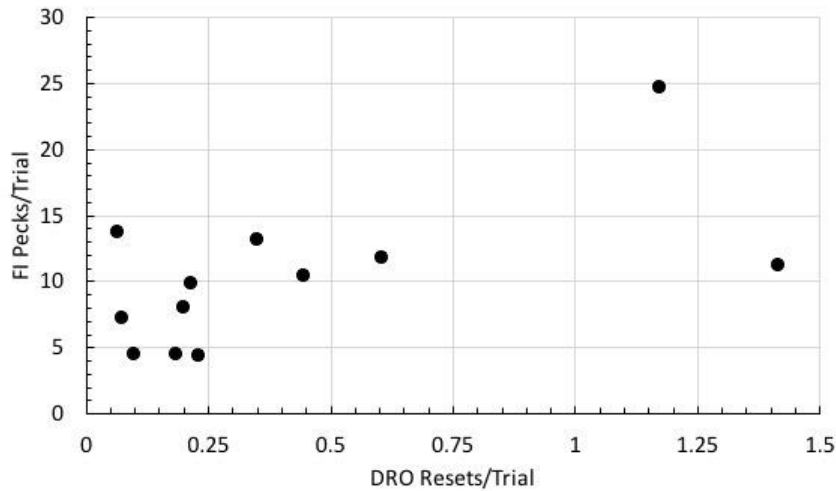
The number of DRO resets indicates the number of errors made during a DRO terminal link. The DRO schedule used in our procedure required the pigeon to refrain from pecking for 10 s, each time the pigeon pecked the DRO response key the timer reset and as a result the trial lengthened by the time prior to the reset. All of the birds were still resetting the timer during DRO terminal links during the last 10 sessions of the experiment. A repeated-measures analysis of variance was computed to compare the average number of resets to the DRO terminal links during the last 10 sessions of each phase, Phase 1  $M = .69, SEM =$

.13, Phase 2  $M = .59$ ,  $SEM = .16$ , Phase 3  $M = .42$ ,  $SEM = .13$ . There was not a significant effect of phase on the average number of DRO resets,  $F(2,22) = 1.53$ ,  $p = .24$ . The average number of resets to the DRO terminal links for each subject during the last 10 sessions of each phase is shown in Figure 12. The number of DRO resets were not significantly correlated with schedule preference in any phase, Phase 1  $r(12) = -.04$ ,  $p = .91$ ; Phase 2  $r(12) = -.07$ ,  $p = .84$ ; Phase 3  $r(12) = -.12$ ,  $p = .71$ . Therefore, longer trials did not seem to affect preference. Given the relatively short mean extension of the DRO duration due to DRO pecking, it appears that most of those pecks occurred immediately after the onset of the DRO schedule. Some of those pecks are likely carryover or double pecks from initial-link choice of the DRO schedule.



*Figure 12.* The average number of DRO resets each subject made during the last 10 sessions of each phase, Phase 1  $M = .69$ ,  $SEM = .13$ , Phase 2  $M = .59$ ,  $SEM = .16$ , Phase 3  $M = .42$ ,  $SEM = .13$ .

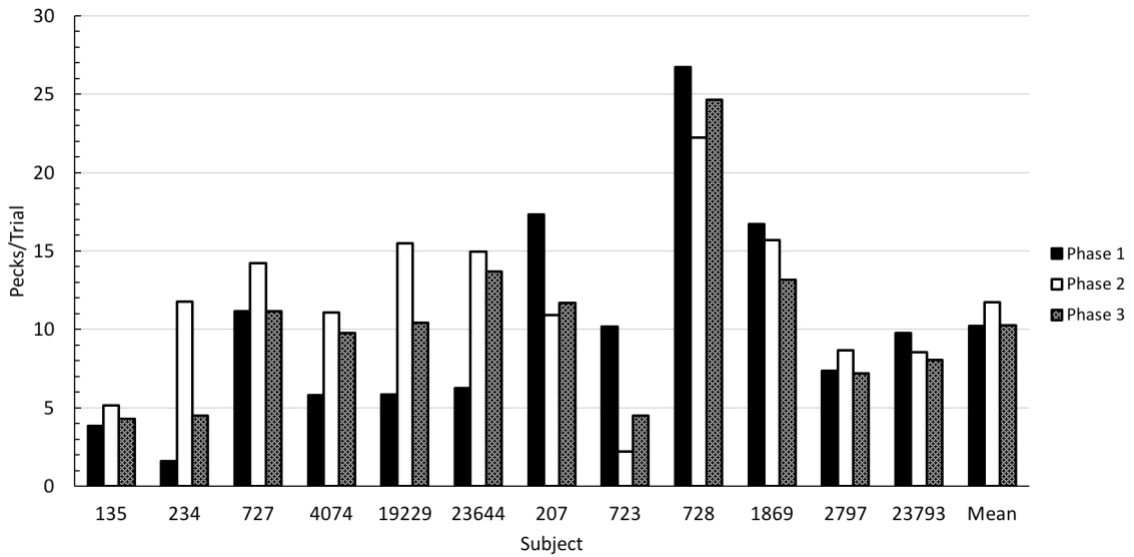
The average number of DRO resets and FI pecks were significantly correlated during Phase 3, but not during Phases 1 or 2, Phase 1  $r(12) = .50, p = .10$ ; Phase 2  $r(12) = .30, p = .34$ ; Phase 3  $r(12) = .61, p = .04$ . The correlation between DRO resets and FI pecks during the last 10 sessions of Phase 3 is shown in Figure 13.



*Figure 13.* The Pearson correlation between the number of DRO resets per trial and the number of pecks to FI terminal links during the last 10 sessions of Phase 3,  $r(12) = .61, p = .04$ .

A repeated-measures analysis of variance was computed to compare the average number of pecks to FI terminal links during the last 10 sessions of each phase. There was not a significant effect of phase on the average number of FI pecks,  $F(2,22) = .88, p = .38$ . The average number of pecks to FI terminal links during the last 10 sessions of each phase for each subject is shown in Figure 14. The number of responses to FI terminal links were not significantly correlated with schedule preference in any phase, Phase 1  $r(12) = -.28, p = .37$ ; Phase 2

$r(12) = .16, p = .63$ ; Phase 3  $r(12) = .47, p = .13$ . Therefore, more pecking did not seem to effect schedule preference.



*Figure 14.* The average number of responses made to FI terminal links for each subject during the last 10 sessions of each phase, Phase 1  $M = 10.21$ ,  $SEM = 2.03$ , Phase 2  $M = 11.74$ ,  $SEM = 1.53$ , Phase 3  $M = 10.26$ ,  $SEM = 1.62$ .

In all phases, the birds pecked during the FI schedule significantly more than during the DRO schedule, Phase 1  $t(11) = -4.84, p = .00$ ; Phase 2  $t(11) = -7.47, p = .00$ ; Phase 3  $t(11) = -6.37, p = .00$ . Better schedule discrimination was evaluated using the ratio of DRO resets to FI responses. Better schedule discrimination was not related to schedule preference, Phase 1  $r(12) = .37, p = .24$ ; Phase 2  $r(12) = .06, p = .86$ ; Phase 3  $r(12) = -.50, p = .10$ .



#### *4.6. Individual Subject Data and Behavioral Observations:*

We observed both, birds that waited during the DRO and refrained from pecking for the majority of the duration, and other birds that continued to peck in some way without resetting the DRO (pecked the key with insufficient force to activate the microswitch, pecked the metal around the key, pecked unlit keys or pecked the floor). It seemed reasonable that birds that continued to peck during DRO trials, would be more likely to be indifferent between the FI and DRO schedules, because the behavior in both schedules would be similar whereas birds that waited during the DRO would be more likely to show a schedule preference. A point-biserial correlation was used to identify any association between observed pecking and not pecking during DRO trials (dichotomous variable) and the proportion of DRO choice (continuous variable). However, we did not find a statistically significant association between pecking vs. not pecking during DRO trials and the proportion of DRO choice,  $r_{pb} = -.35$ ,  $n = 12$ ,  $p = .26$ . Contrary to our prediction, waiting during the DRO was actually negatively correlated with DRO choice although this association was not statistically significant,  $p = .26$ . Table 1 summarizes the behavior observed during DRO trials for each subject, as well as their schedule preference, percent of DRO choice and whether their behavior was consistent with their choice (not pecking during DRO and preferring DRO, pecking during DRO and being indifferent). Seven birds showed behavior inconsistent with their preference and 5 birds showed behavior consistent with their preference.

Table 1.

*Summary of observed behavior during DRO terminal links and schedule preference during the last 10 sessions of Phase 3.*

Bird	Observed Behavior	% DRO Choice	Preference <sup>a</sup>	Behavior Consistent with Choice <sup>c</sup>
135	Mostly waited during DRO, head-bobbing toward response key or pecked key with insufficient force to reset DRO.	53	Indifferent	No
234	Waited during DRO, paced between response keys and moved to middle of panel anticipating reinforcement.	50	Indifferent	No
727	Waited during both initial and terminal links of DRO trials, slow to advance to terminal link. Pecked response key or edge around response key, interval passed when looking to hopper long enough.	36.5	Indeterminate <sup>b</sup>	Yes
4074	Pecked during DRO, interval completed when pacing between keys. Maintained position on left side, pecked unlit left key when right key lit.	60	Indifferent	Yes
19229	Pecked during DRO, then pecked with insufficient force until not recognized. Began waiting during DRO as session goes on.	82	DRO	No
23644	Waited during DRO, head bobbing toward key but no contact. Occasionally pecked unlit center key. Checked hopper often.	90.5	DRO	Yes
207	Waited during DRO, occasionally pecked response key with insufficient force to reset DRO.	84	DRO	Yes
723	Waited during DRO, moved to middle of panel near hopper anticipating reinforcement.	52	Indifferent	No
728	Pecked during DRO, only waited a few seconds at a time. Pecked metal around response key, pecked key with insufficient force or head-bobbing toward key. Also paced between keys.	96.5	DRO	No
1869	Waited during DRO, explored operant box. Often remained on initial links and orienting stimuli because did not peck with sufficient force.	51	Indifferent	No
2797	Waited during DRO, occasionally pecked unlit keys. Remained positioned near hopper in middle of panel.	96	DRO	Yes
23793	Pecked the floor and newspaper lining during DRO.	82.5	DRO	No

*Note.* Observational data collected during 1 session immediately following completion of Phase 3. Houselight was illuminated and may have disrupted normal behavior.

<sup>a</sup>DRO preference defined as 80% choice of DRO alternative or greater. Indifference defined as 40-60% choice of DRO alternative. FI preference defined as 20% choice of DRO alternative or less.

<sup>b</sup>Preference of #727 considered indeterminate because percentage of DRO choice fell between criterion levels.

<sup>c</sup>Consistent behavior was considered waiting during the DRO if showing a DRO preference or pecking during the DRO if showing indifference between schedules.

The number of DRO selections made during the 20 choice trials of each session for each bird is displayed in Figures 15 through 26. If birds had a spatial preference that was stronger than their schedule preference then the schedule preference would reverse in Phase 2 following the reversal of the spatial location of the two schedules. Most birds showed some level of disruption in their choices immediately following the reversal. However, as Phase 2 progressed, birds that preferred the DRO showed an increase in DRO choices (e.g., see Figure 15). In Phase 3 the initial link visual discrimination removed the possible spatial preference as the source of an apparent schedule preference. In this phase, the absence of a schedule preference would be seen as a 50% choice of the DRO schedule.

Subject #2797 displayed a clear preference for the DRO schedule. As can be seen in Figure 15, for the last 10 sessions of both Phases 1 and 2 the proportion DRO choice was 100%. The visual discrimination of Phase 3 produced more variability in choices, but a strong 96% preference for the DRO schedule remained. This bird was successful at discriminating between schedules, shown by an average of 7.2 responses to FI terminal links and only .08 resets during DRO terminal links. During the DRO schedule, this bird maintained a position near the center of the panel, with its head oriented to the hopper.

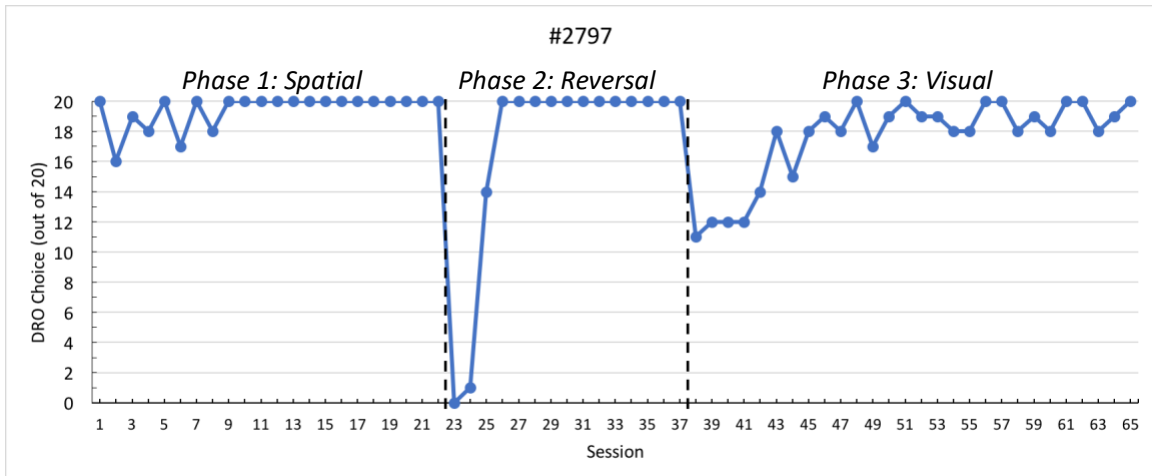


Figure 15. The number of DRO choices made by Subject #2797 each session of all 3 Phases.

Subject #4074 favored the left side and did not show a consistent schedule preference. The number of DRO choices made during each session are shown in Figure 16. During Phase 1, this pigeon chose the left key most of the time and continued to peck the left key after the reversal. On the last 10 sessions of Phase 3, it chose the DRO schedule 60% of the time on average. Thus, it showed a weak preference for the DRO schedule. This pigeon was observed waiting on the left side of the response panel throughout the session and pecking the unlit left key even on trials on which the right key alone was illuminated. During the DRO schedule, this pigeon would move back and forth between the keys. #4074 responded well to the schedule contingencies, as it responded more to FI terminal links than DRO terminal links, FI Pecks  $M = 9.8$ , DRO Resets  $M = 0.22$ . When pecking was not reinforced it would begin pecking the key with insufficient force to operate the microswitch or more slowly, orienting to the

hopper after every few responses. On several FI trials this pigeon failed to peck sufficiently hard for several seconds after the FI schedule had elapsed. The extended FI trials may account for the small preference that this pigeon had for the DRO schedule.

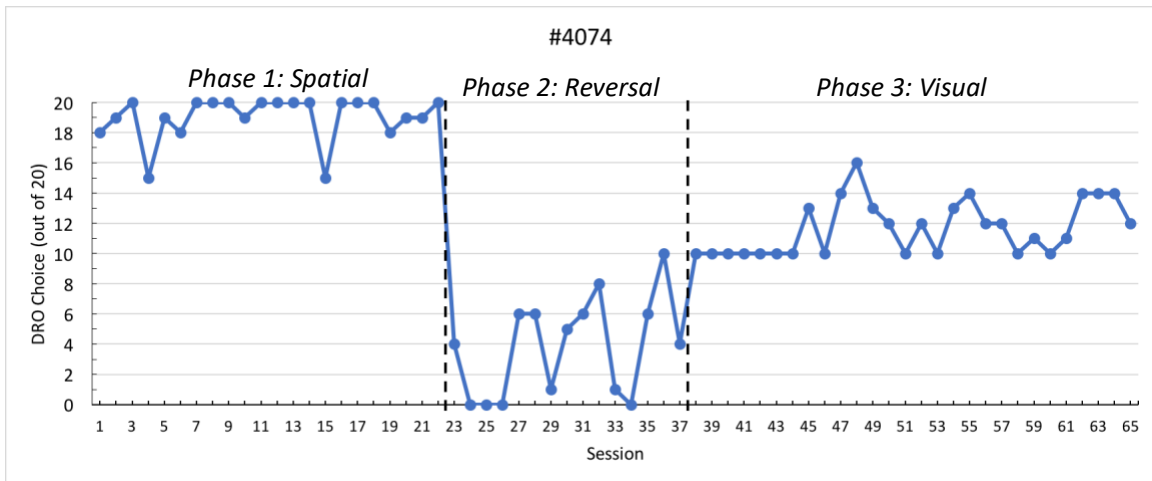


Figure 16. The number of DRO choices made by Subject #4074 each session of all 3 Phases.

Subject #207 showed a preference for the DRO schedule through all 3 phases; Phase 1  $M = 91.5\%$ , Phase 2  $M = 100\%$ , Phase 3  $M = 84\%$ , over the last 10 sessions of each phase. The number of DRO choices made during individual sessions are shown in Figure 17. When observed, this bird waited during DRO terminal links and did not peck, DRO Resets  $M = 0.61$ . Perhaps the houselight was disruptive enough for the pigeon to respond less during observation. While waiting, it would move its head closer to the hopper or move between the lit key and the hopper. During FI trials, he would peck through the entire interval until reinforcement, FI Pecks  $M = 11.7$ .

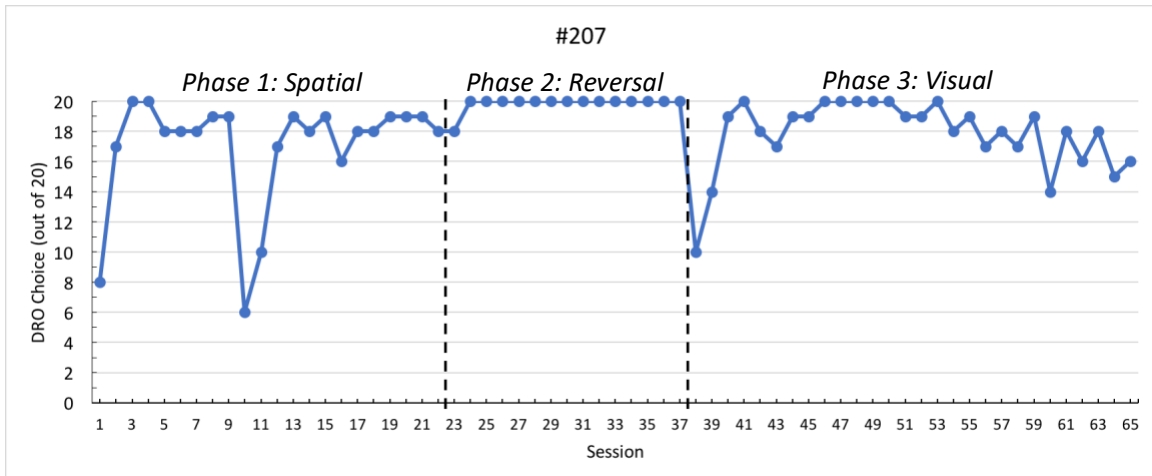


Figure 17. The number of DRO choices made by Subject #207 each session of all 3 Phases.

Subject #234 did not show a schedule preference and was classified as indifferent (see Figure 18). During the last 10 sessions of Phase 1 it chose the DRO alternative 100% of the time, during Phase 2 it completely reversed and chose the DRO 0% of the time, and during Phase 3 it chose the DRO alternative 50% of the time. During the last 10 sessions of Phase 3, #234 pecked the DRO an average of 0.10 times per trial. This bird pecked the DRO terminal link and moved back and forth between the keys and the hopper. During observation, this bird had difficulty waiting 10 s during the DRO terminal link. In order for the DRO trial to elapse, it either pecked the DRO key insufficiently hard to register or it paced, moving the pigeon away from the key long enough for the 10 s to elapse and the trial to end. Perhaps the reinforcement of below-threshold responses during DRO trials lead to responding with minimal force consistently because this bird would take a long time to register its choice of schedule because it would not

peck hard enough for it to register. During FI terminal links, #234 only pecked 4.5 times/trial on average compared to the group mean of over 10 pecks/trial.

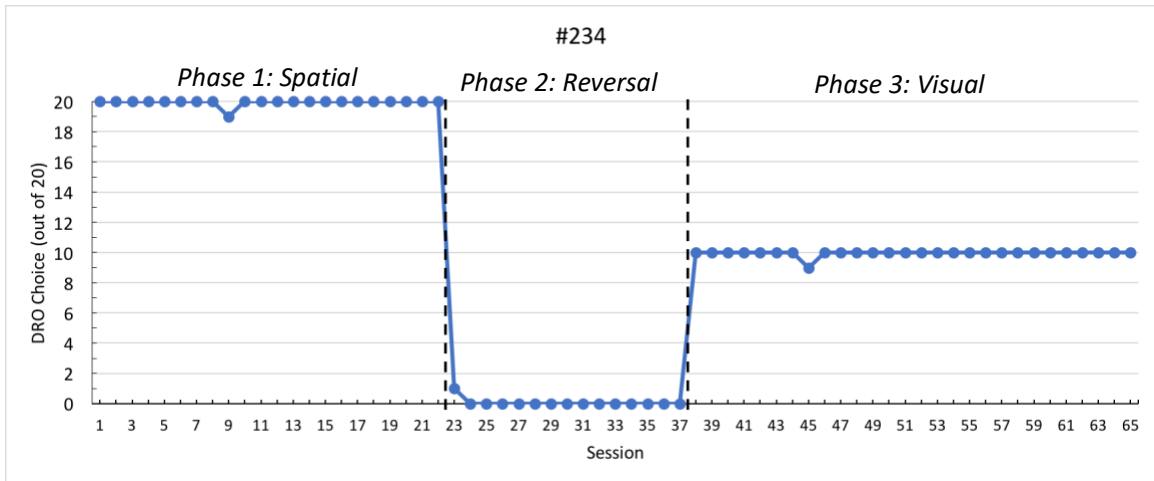


Figure 18. The number of DRO choices made by Subject #234 each session of all 3 Phases.

Subject #135 did not show a clear schedule preference. During the last 10 sessions of Phase 1, #135 chose the DRO schedule 98.5% of the time, however once the spatial locations were reversed this preference disappeared and it only chose the DRO schedule 15.5% of the time. This pigeon's indifference is shown in the visual discrimination with only 53% choice of the DRO contingency. The number of DRO choices made during individual sessions are shown in Figure 19. #135 pecked FI terminal links an average of 4.3 times/trial. During DRO terminal links it displayed a head-bobbing motion as if pecking the air, far enough from the response key to avoid contact. Occasionally it would peck the metal of the panel surrounding the key or the edge of the key without it registering. It also pecked the edge of the center orienting stimulus and FI response key. When the DRO

stimulus would appear #135 would often immediately peck the key a few times. This bird reset the DRO timer an average of 0.23 times/trial.

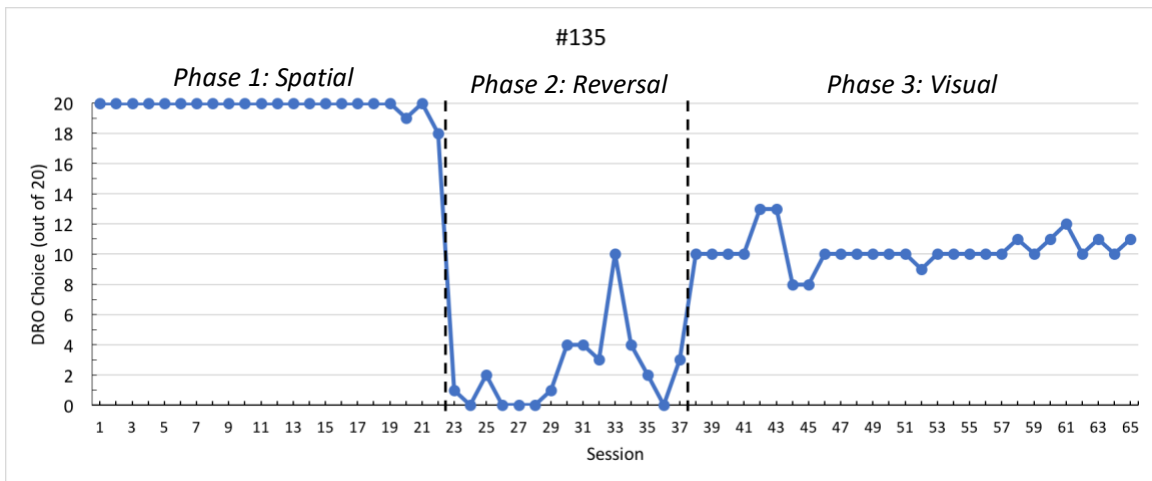


Figure 19. The number of DRO choices made by Subject #135 each session of all 3 Phases.

Subject #728 showed a strong preference for the DRO schedule; Phase 1  $M = 94\%$ , Phase 2  $M = 97.5\%$ , Phase 3  $M = 96.5\%$  (see Figure 20). This bird reset the DRO schedule more than once per trial on average (DRO Resets  $M = 1.18$ ) and responded more to the FI schedule than any of the other pigeons, FI Pecks  $M = 24.6$ . This bird pecked the FI 20.8 times for each time it reset the DRO. During DRO trials #728 was observed pecking the unlit center key, pecking the metal around the DRO response key, and head-bobbing. As seen in some other pigeons, this bird would look to the hopper before the FI terminal link would end.



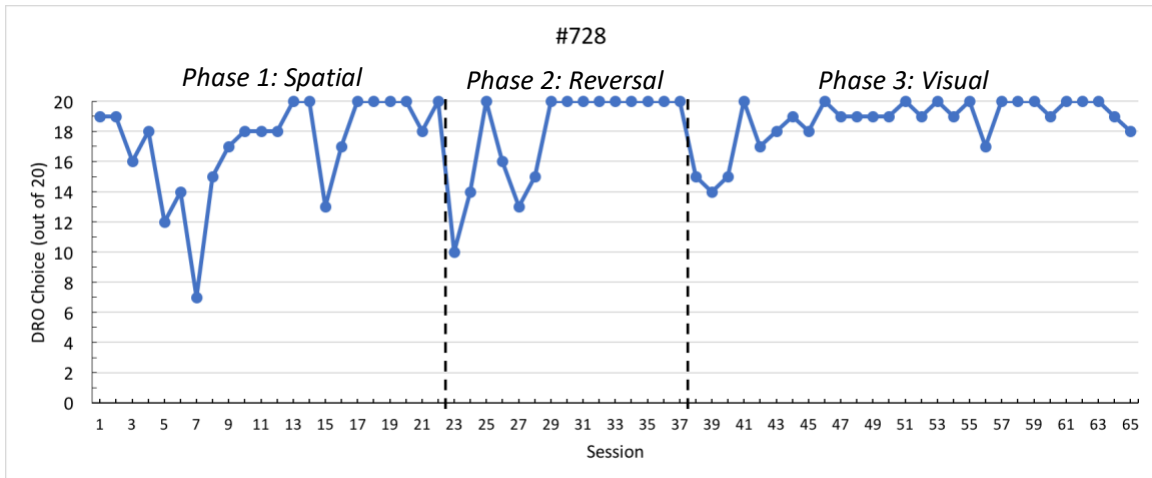


Figure 20. The number of DRO choices made by Subject #728 each session of all 3 Phases.

Subject #23644 showed a strong preference for the DRO schedule although the choices became more variable in Phase 3; Phase 1  $M = 100\%$ , Phase 2  $M = 97\%$ , Phase 3  $M = 90.5\%$  (see Figure 21). This subject was the most successful in avoiding extending the duration of the DRO schedule, only resetting the DRO an average of 0.07 times/trial, less than any of bird. During DRO trials, it was observed standing in place, bobbing its head in the direction of the key but remaining approximately 1 inch away from the response key. This bird was observed pecking through the entire FI terminal link until reinforcement, FI Pecks  $M = 13.7$ .

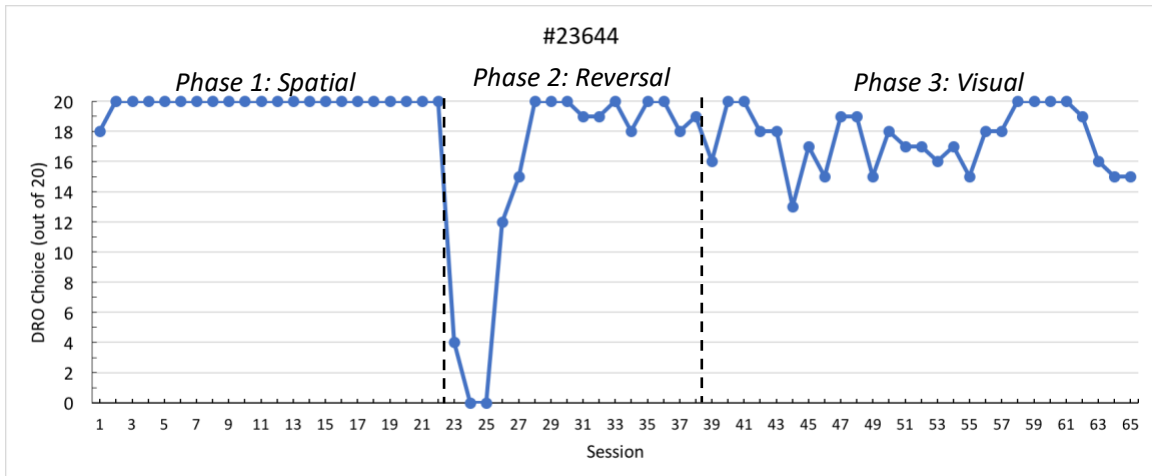


Figure 21. The number of DRO choices made by Subject #23644 each session of all 3 Phases.

Subject #23793 showed a DRO preference, although the proportion of DRO choice was variable; Phase 1  $M = 67\%$ , Phase 2  $M = 99.5\%$ , Phase 3  $M = 82.5\%$  (see Figure 22). It responded to the FI schedule an average of 8.1 pecks/trial and reset the DRO timer on average 0.2 times/trial. During the DRO schedule it was observed pecking at the floor of the operant box. This behavior may be attributable to the distraction of the illuminated houselight necessary for observation of the behavior. Unlike some of the other pigeons observed, this bird was not seen to peck the unlit keys.

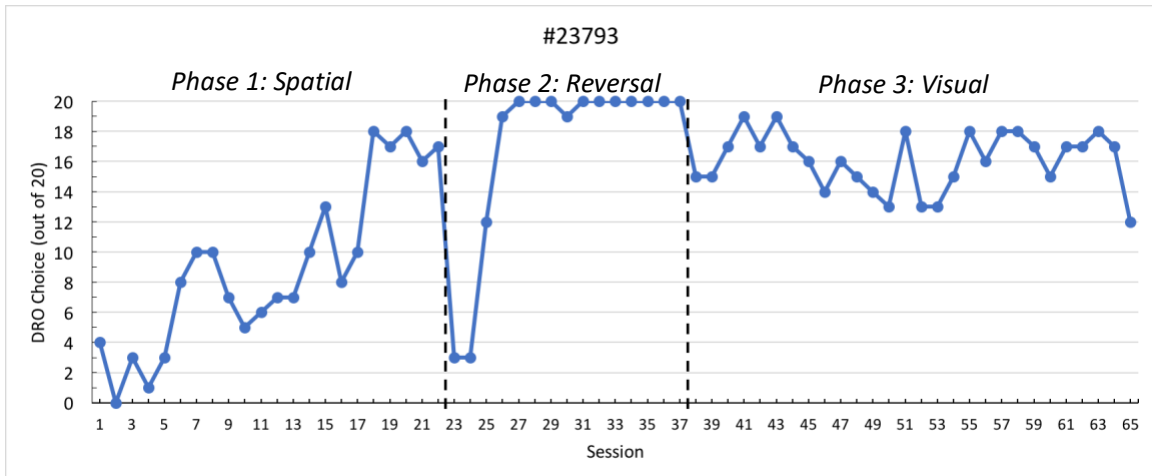


Figure 22. The number of DRO choices made by Subject #23793 each session of all 3 Phases.

Subject #727 was considered to have a spatial preference during the first two phases but during the final phase this was the only subject to show a tendency to prefer the FI schedule, DRO Choice Proportion Phase 1  $M = 13\%$ , Phase 2  $M = 94\%$ , Phase 3  $M = 36.5\%$ . Subjects choosing one schedule more than 80% of the time were considered to show a clear schedule preference, whereas those that chose one schedule between 40 and 60% of the time were judged to be indifferent. This subject chose the FI schedule slightly greater than the criterion for indifference, with average choice of the DRO schedule 36.5% of the time during Phase 3 (see Figure 23). This bird experienced the longest DRO schedule compared to the other subjects and reset the DRO timer more than any other bird, DRO Resets  $M = 1.42$ , DRO Duration  $M = 12.38$  s. This bird pecked FI terminal links an average of 11.2 times/trial. During observation, this bird was slow to complete each trial and would often stall prior to making the orienting

response. This bird only completed the DRO schedule when it would move toward the hopper and look at it long enough for 10 s to elapse.

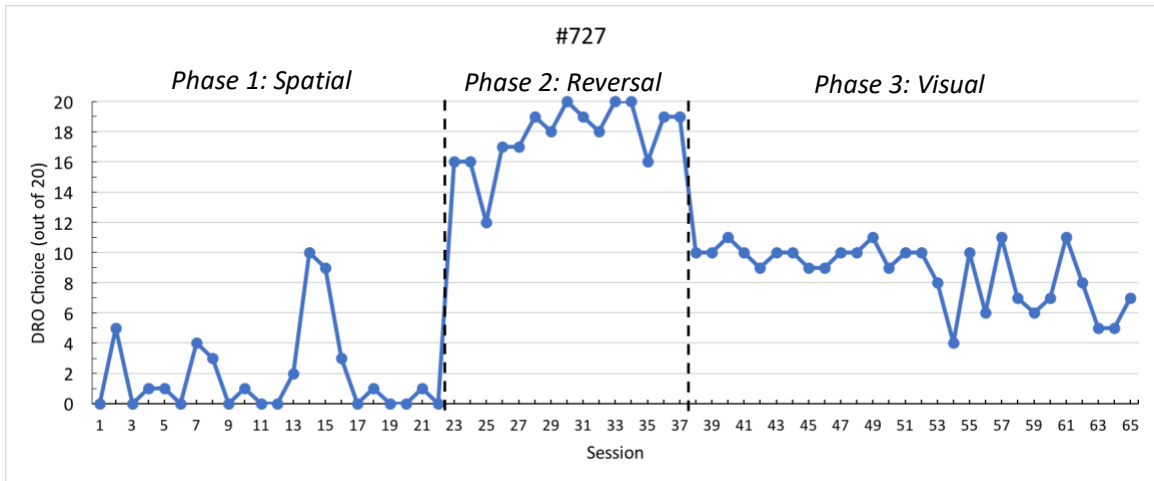


Figure 23. The number of DRO choices made by Subject #727 each session of all 3 Phases.

Subject #1869 had a strong spatial preference for the left side and thus was classified as indifferent between the two schedules (see Figure 24). During the last 10 sessions, of Phase 3 it chose the DRO schedule 51% of the time, Phase 1  $M = 1\%$ , Phase 2  $M = 98.5\%$ . During observation, this bird would wait during the DRO schedule although during the experimental sessions this subject pecked an average of 0.35 times/trial. It is possible that the houselight disrupted behavior normally exhibited during experimental sessions. During FI trials, it responded 13.2 times/trial on average. Occasionally this pigeon would delay making the orienting or schedule choice response.

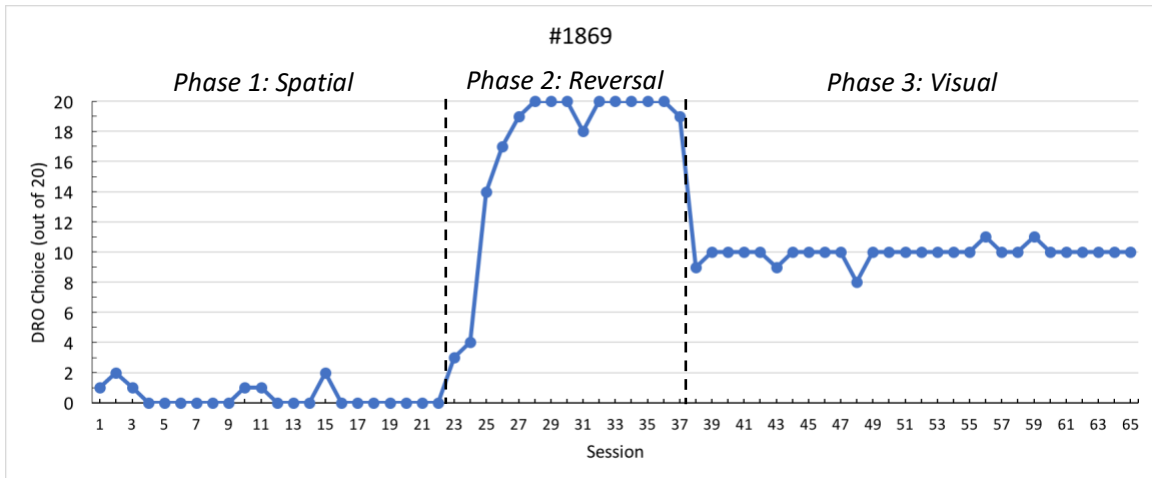


Figure 24. The number of DRO choices made by Subject #1869 each session of all 3 Phases.

Subject #19229 was just above criterion for a DRO preference, choosing the DRO alternative 82% of the time. As shown in Figure 25, the number of DRO choices made in Phase 1 suggested a DRO preference (99.5% DRO choice) but choices in Phase 2 were highly variable (47% DRO choice), appearing to show a preference for the DRO schedule after a brief adjustment to the schedule but then reverting to a tendency to choose spatially again toward the end of the phase. During Phase 3 this subject remained variable but the number of DRO choices increased over time. This bird experienced the second longest DRO duration compared with the other pigeons, DRO Duration,  $M = 11.07$  s. This bird reset the DRO an average of 0.45 times/trial and pecked FI terminal links an average of 10.42 times/trial. During observation, it would peck at the start of the DRO schedule and gradually begin to peck more but not hard enough to operate

the microswitch. As the session progressed, it began waiting during the DRO schedule.

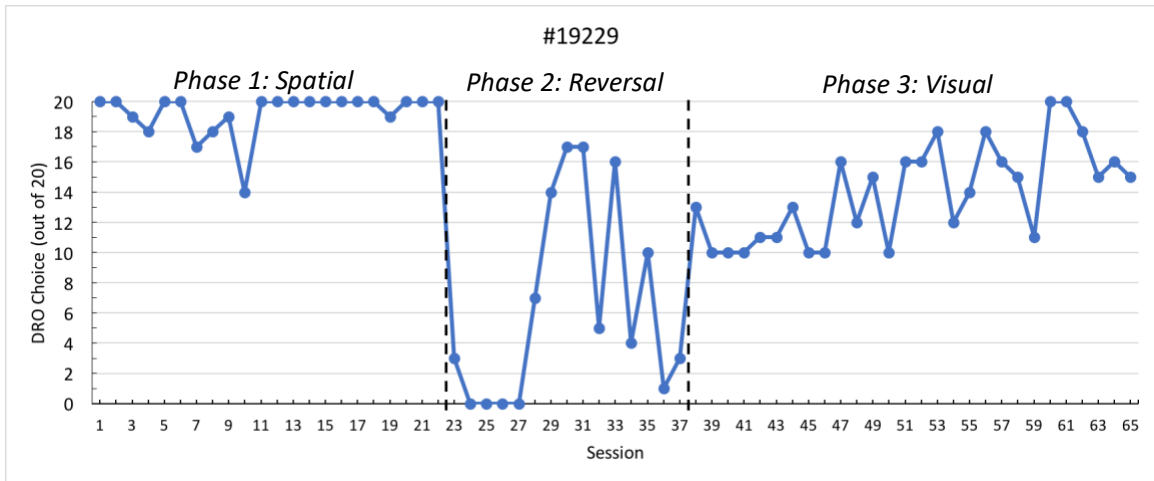


Figure 25. The number of DRO choices made by Subject #19229 each session of all 3 Phases.

Subject #723 did not show a schedule preference, choosing the DRO only 52% of the time during the last 10 sessions of Phase 3, Phase 1  $M = 23.5\%$ , Phase 2  $M = 99.5\%$ . The number of DRO choices made during individual sessions are shown in Figure 26. During DRO trials, this subject was observed waiting or gently pecking the DRO response key insufficiently to operate the microswitch (DRO Resets  $M = 0.19$ ) and it did not peck at a high rate on FI schedule trials, 4.5 times/trial on average.

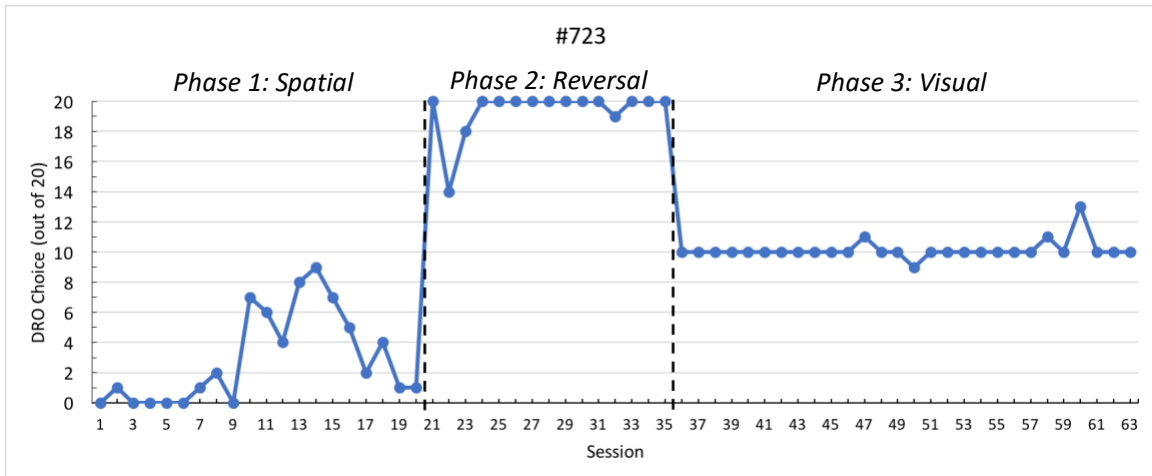


Figure 26. The number of DRO choices made by Subject #723 each session of all 3 Phases.

## 5. Discussion

### 5.1 General Discussion:

Although several of the pigeons preferred the DRO schedule over the FI schedule, the main finding of the experiment was there were clear individual differences in reinforcement schedule preference. Six birds showed a clear preference for the DRO schedule over the FI schedule and 6 birds did not. Figures 3-7 show distinct preference subgroups within our sample.

Preference was defined as choosing one schedule 80% or more of the time. Since there were 20 choice trials in each session, preference would be consistent with choosing one alternative at least 16 times per session.

Indifference was categorized as 40% to 60% choice of the DRO schedule. Five birds were categorized as indifferent between the two schedules (or their spatial preference was stronger than their schedule preference).

One bird was indeterminate because it fell between the two criteria of indifference and preference. This bird showed a preference in the direction of the FI schedule and was the only bird observed to have any preference in that direction.

Individual differences in our data are in line with Singer, Berry and Zentall (2007). Singer et al. found individual differences in schedule preference (DRO vs. FI) when the delay to reinforcement was controlled as in the present experiment. Of seven pigeons in their sample, four were indifferent between the two schedules, one preferred the FI schedule, and two pigeons preferred the DRO schedule. Thus, they found most pigeons did not prefer to avoid pecking and one actually showed a preference for pecking, whereas I found that half of our pigeons preferred to refrain from pecking.

Preference for the DRO schedule supports the Principle of Least Effort (Gengerelli, 1930; Tsai, 1932; Waters, 1937). One possible explanation for DRO preference in this experiment is the possibility for DRO trials to have a shorter delay to reinforcement than FI trials. With the present procedure it was not possible to control both the duration of the DRO and FI schedules. From observational data only, it appeared that some pigeons did not peck immediately at the end of the FI and remained on the schedule longer than necessary. Although it is possible that the FI schedules were longer than the DRO during the training phases, it is likely that the effect found during observation was affected by the need to illuminate the houselight to observe the pigeons. Preference for the DRO schedule is surprising because the DRO schedule is typically more



difficult to learn, as indicated by the amount of pre-training required to get to DRO 10 s duration. Also, the relation between DRO pecking and lengthening the DRO should be easier to detect than the effect of DRO pecking on the duration of the FI schedule because extension of the FI schedule due to DRO pecking would have been delayed to the next trial. Thus, it should have been more difficult for the pigeons to attribute the longer FI schedules to pecking during the DRO schedule. This should have increased the pigeons' tendency to prefer the FI schedule, yet none was found.

Pigeons that were indifferent between the two schedules provide support for the idea that preference is a function of the immediacy of reinforcement rather than the response requirements associated with the schedule. Indifference between reinforcement schedules in pigeons has been reported in past experiments. For example, Killeen (1968) found that pigeons were indifferent between schedules, despite very different response requirements when attempting to control for the delay of reinforcement. Neuringer (1969) found no differential preference between FI and FT schedules when the duration of inter-reinforcement intervals were controlled. Moore and Fantino (1975) found that the pigeons were indifferent between response-dependent and response-independent schedules of similar durations. In the present experiment, 5 of 12 birds showed indifference between the DRO schedule and the FI schedule, of the same duration.

Individual differences were evident in response rates during FI terminal links, and in the number of errors made during DRO terminal links that reset the

timer (DRO Resets). Response rates varied between subjects but did not vary across experimental phases. During Phase 3, the number of DRO resets was positively correlated with the number of responses to the FI schedule,  $r(12) = .61$ ,  $p = .04$ . This suggests another individual difference among the birds, however this was only observed in Phase 3. This result may reflect the presence of behavioral syndromes (differential tendencies to peck) although it did not appear to affect schedule preference. Birds that are more active or impulsive in general may be those that peck the keys more frequently. Others may have performed better during the DRO and were able to refrain from pecking but they also did not peck as often during the FI. Since we found the number of responses made during DRO terminal links that reset the timer (DRO Resets) and the number of responses to the FI terminal links were correlated, it may be worth investigating if response rate is a stable characteristic that could be associated with impulsivity. It would be of interest to know if pecking during the DRO or FI schedules is related to impulsivity as assessed by the slope of delay discounting functions (Ainslie, 1975).

We also found that schedule preference was not related to the duration of DRO terminal links, the number of DRO resets, or the number of responses to FI terminal links. An understanding of the requirements of the DRO schedule did not show a significant association with schedule preference. The number of DRO resets and schedule preference were not significantly related. This suggests that pecks during DRO terminal links, were unrelated to schedule preference. This is surprising because one would expect birds that continue to reset the DRO timer,

and as a result continue to increase the delay to reinforcement, would not prefer the DRO schedule. However, the schedules were matched in duration on a trial by trial basis, thus the delay to reinforcement would have remained the same for the following FI trial.

### *5.2 Limitations:*

Due to the design of the study, DRO trials always preceded FI trials. This biased the birds toward choosing the FI alternative on choice trials because the FI schedule would appear in the same location as the lit key on the previous trial, however we did not find any clear FI schedule preference to suggest such a bias had much of an influence on choice behavior.

During Phase 3, the schedules would alternate sides (left and right) but not within a triplet of trials (two forced trials and one choice trial). At the beginning of each block of three trials the DRO would appear on one side, and the FI on the other, for the next triplet, the spatial location of the two schedules would likely change.

### *5.3 Conclusion:*

Overall, we found large individual differences in the preference for differential-reinforcement-of-other-behavior (DRO) and fixed-interval (FI) reinforcement schedules that were matched in duration. Half of our sample ( $n = 6$ ) showed a preference for the DRO schedule, whereas 5 birds were indifferent, and 1 tended to prefer the FI schedule but was indeterminate.

Pigeons that were indifferent between the two schedules provide support for the idea that preference is a function of the immediacy of reinforcement rather

than the response requirements associated with the schedule. While preference for the DRO schedule supports the Principle of Least Effort (Gengerelli, 1930; Tsai, 1932; Waters, 1937).

We found that schedule preference was not related to the duration of DRO terminal links, the number of DRO resets, or the number of responses to FI terminal links.

## References

- Ainslie, G. (1975). Specious reward: A behavioral theory of impulsiveness and impulse control. *Psychological Bulletin*, 82, 463-496.
- Brinker, R. P., & Treadway, J. T. (1975). Preference and discrimination between response dependent and response-independent schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 24(1), 73-77.
- Fantino, E. (1968). Effects of required rates of responding upon choice. *Journal of the Experimental Analysis of Behavior*, 11(1), 15-22.
- Fantino, E. (1969). Choice and rate of reinforcement. *Journal of Experimental Analysis of Behavior*, 12, 723-730.
- Ferster, C. B., & Skinner, B. F. (1957). Schedules of reinforcement. New York, NY: Appleton Century-Crofts.
- Friedrich, A. M., & Zentall, T. R. (2004). Pigeons shift their preference toward locations of food that take more effort to obtain. *Behavioural Processes*, 67(3), 405-415.
- Gengerelli, J. A. (1930). The principle of maxima and minima in animal learning. *Journal of Comparative Psychology*, 11(2), 193.
- Hearst, E. (1987). Extinction reveals stimulus control: Latent learning of feature negative discriminations in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 13(1), 52-64.
- Herrnstein, R. J., & Morse, W. H. (1957). Some effects of response-independent positive reinforcement on maintained operant behavior. *Journal of Comparative and Physiological Psychology*, 50(5), 461.
- Hinnenkamp, J. E., Shahan, T. A., & Madden, G. J. (2017). How suboptimal is suboptimal choice? *Journal of the Experimental Analysis of Behavior*, 107(1), 136-150.
- Killeen, P. (1968). Response rate as a factor in choice. *Psychonomic Science*, 12(1), 34-34.
- Moore, J., & Fantino, E. (1975). Choice and response contingencies. *Journal of the Experimental Analysis of Behavior*, 23(3), 339-347.
- Neuringer, A. J. (1969). Delayed reinforcement versus reinforcement after a fixed interval. *Journal of the Experimental Analysis of Behavior*, 12(3), 375-383.

- Pontes, T. N., Abreu-Rodrigues, J., & Souza, A. S. (2012). Choice between contingencies of variation: Effects of the requirement of variation upon preference. *Behavioural Processes*, *91*(3), 214-222.
- Reynolds, G. S. (1961). Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, *4*(1), 57-71.
- Sih, A., Bell, A. M., Johnson, J. C., & Ziemba, R. E. (2004). Behavioral syndromes: An integrative overview. *The Quarterly Review of Biology*, *79*(3), 241-277. doi:10.1086/422893.
- Singer, R. A., Berry, L. M., & Zentall, T. R. (2007). Preference for a stimulus that follows a relatively aversive event: contrast or delay reduction? *Journal of the Experimental Analysis of Behavior*, *87*(2), 275-285.
- Stagner, J. P., & Zentall, T. R. (2010). Suboptimal choice behavior by pigeons. *Psychonomic Bulletin & Review*, *17*(3), 412-416.
- Sumpter, C. E., Foster, M. T., & Temple, W. (2002). Assessing animals' preferences: Concurrent schedules of reinforcement. *International Journal of Comparative Psychology*, *15*(2).
- Tatham, T.A. & Zurn, K.R. (1989). The Med-PC experimental apparatus programming system. *Behavior Research Methods, Instruments, and Computers*, *21*, 294-302.
- Tsai, L. S. (1932). *The laws of minimum effort and maximum satisfaction in animal behavior*. National Research Institute of Psychology.
- Waters, R. H. (1937). The principle of least effort in learning. *The Journal of General Psychology*, *16*(1), 3-20.
- Williams, D. R., & Williams, H. (1969). Auto-maintenance in the pigeon: sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, *12*(4), 511-520.
- Zentall, T. R., & Singer, R. A. (2008). Required pecking and refraining from pecking alter judgments of time by pigeons. *Learning & Behavior*, *36*(1), 55-61.
- Zentall, T. R., & Laude, J. R. (2013). Do pigeons gamble? I wouldn't bet against it. *Current Directions in Psychological Science*, *22*(4), 271-277.

## VITA

### Danielle Michelle Andrews

#### EDUCATION

B.S. Psychology, Biology minor

*Magna cum laude*

Grand Valley State University, Frederick Meijer Honors College

Allendale, Michigan

December 2012

#### PROFESSIONAL EXPERIENCE

August 2016 to present:

Lab Manager of the Comparative Cognition lab  
University of Kentucky, Lexington, Kentucky

August 2016 to present:

Teaching Assistant  
Taught Introductory Psychology lab and Cognitive Processes lab  
University of Kentucky, Lexington, Kentucky

#### RESEARCH PUBLICATIONS

Zentall, T.R., Case, J.P. & Andrews, D.M. (in press). Sameness: The basis for same/different concept learning in pigeons. *Psychological Science*.

Zentall, T.R., Case, J.P., & Andrews, D.M. (2017). Procrastination in the pigeon: Can conditioned reinforcement increase the likelihood of human procrastination? *Psychonomic Bulletin & Review*, 1-6.  
<https://doi.org/10.3758/s13423-017-1409-2>

Zentall, T.R., Andrews, D.M., & Case, J.P. (2017). Prior commitment: Its effect on suboptimal choice in a gambling-like task. *Behavioural Processes*, 145, 1-9. <http://dx.doi.org/10.1016/j.beproc.2017.09.008>

Andrews, D.M. (2013). Factors influencing local recruitment in Tree Swallows, *Tachycineta bicolor*. *Honors Projects*. Paper 213.  
<http://scholarworks.gvsu.edu/honorsprojects/213>