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INVESTIGATION OF THE MONTY HALL DILEMMA IN PIGEONS AND RATS

Jessica P. Stagner
University of Kentucky, jpaigeco03@hotmail.com

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Jessica P. Stagner, Student

Dr. Thomas R. Zentall, Major Professor

Dr. David Berry, Director of Graduate Studies

INVESTIGATION OF THE MONTY HALL DILEMMA IN PIGEONS AND RATS

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Sciences
at the University of Kentucky

By
Jessica Paige Stagner

Lexington, KY

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

Lexington, Kentucky

2013

ABSTRACT OF DISSERTATION

INVESTIGATION OF THE MONTY HALL DILEMMA IN PIGEONS AND RATS

In the Monty Hall Dilemma (MHD), three doors are presented with a prize behind one and participants are instructed to choose a door. One of the unchosen doors is then shown to not have the prize and the participant can choose to stay with their door or switch to the other one. The optimal strategy is to switch. Herbranson and Schroeder (2010) found that humans performed poorly on this task, whereas pigeons learned to switch readily. However, we found that pigeons learned to switch at level only slightly above humans. We also found that pigeons stay nearly exclusively when staying is the optimal strategy and when staying and switching are reinforced equally (Stagner, Rayburn-Reeves, & Zentall, 2013).

In Experiment 1, rats were trained under these same conditions to observe if possible differences in foraging strategy would influence performance on this task. In Experiment 2, pigeons were trained in an analogous procedure to better compare the two species. We found that both species were sensitive to the overall probability of reinforcement, as both switched significantly more often than subjects in a group that were reinforced equally for staying and switching and a group that was reinforced more often for staying. Overall, the two species performed very similarly within the parameters of the current procedure.

KEYWORDS: Monty Hall Dilemma, Three-Door Problem, Probability Learning,
Reversal Learning, Probability Matching

Jessica Paige Stagner

October 12, 2013

INVESTIGATION OF THE MONTY HALL DILEMMA IN PIGEONS AND RATS

By

Jessica Paige Stagner

Thomas R. Zentall, Ph.D.
Director of Dissertation

David Berry, Ph.D.
Director of Graduate Studies

October 12, 2013
Date

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Chapter One

Review of Literature

Introduction

The Monty Hall Dilemma (MHD) has been of interest to both researchers and the general public largely because humans consistently fail at using the optimal strategy to perform on this task. The MHD, named after game show host Monty Hall, originated from the show "Let's Make a Deal" which aired for 28 years. Monty Hall would present a contestant on this show with what is commonly referred to as the three-door problem.

Behind two of the three doors would be a goat and choice of either of those doors was considered a loss while behind the remaining door there would be a prize, such as a new car. The goal for a contestant would be to select the correct door and win the new car. The contestant would first be allowed to select one of the three doors. Then Monty Hall would show them what was behind one of the unchosen doors (a goat was always revealed). After this, he would allow the contestant to either stay with their initial door choice or switch to the remaining door.

At this point people tend to make the mistake of misjudging the probability of winning associated with staying and switching. That is, people do not see an advantage to switching to the remaining unchosen door. Because there are two doors left, the probability of winning with either door is perceived to be 50%. Thus, most do not think it matters either way if they stay or switch and many times will stay with their initially chosen door. However, the probability of winning is not equal for the two remaining doors and the perception that it is resulted in many losses on the game show. In fact, if the contestant switched to the unchosen door they would win on average of two-thirds of the time. The reason for this is that the probability of selecting the winning door initially is 33%. Once one of the unchosen doors is revealed, the probability initially associated with that door (33%) shifts to the unchosen door. This is because Monty Hall has knowledge of which door the new car is behind and never reveals the car to the contestant when one of the unchosen doors is opened. The optimal strategy then would be to always switch. To say the least, it is not obvious that this is the best strategy to use and Marilyn vos Savant in Parade magazine wrote "no other problem comes close to fooling all people all of the time" (1997).

Human Findings

While now we better understand how to perceive and solve the MHD, it is of interest to understand why this problem is misunderstood by so many. It is known that humans are often wrong in their intuitions about probabilities and it is likely that certain cognitive errors make this task particularly difficult for humans. While most understand the initial probability of choosing correctly (33%), the unequal probabilities associated with the two remaining doors is recognized much less often and many fail to identify these probabilities in subsequent responses on this task when given experience. In an effort to show subjects the probabilities associated with staying and switching, Granberg and Brown (1995) gave participants 50 trials of experience followed by feedback with the MHD. Initially participants had a bias to stay with their initial door choice but with experience they began switching but quickly plateaued, switching on roughly one half to two-thirds of the trials. Thus, participants never employed the optimal strategy of switching on every trial and persisted in staying with their initial choice more than they should have following experience with the task. Although they could have been correct on as many as 67% of the trials, they were only correct on about 56 % of them.

Non-Human Investigation

In further investigation, Hebranson and Schroeder (2010) conducted a comparative study with humans and pigeons using the MHD. Humans were given 200 trials with feedback to observe whether even more experience with the task increased participants' use of the optimal switching strategy, but instead they found a very similar result to that of Granberg and Brown (1995). Interestingly, even though pigeons showed a stronger initial bias to stay with their initial choice than human participants, they acquired the switching strategy and used it almost exclusively (95% of the time) after 30 sessions of training. From this result it appears that while the initial stay bias is consistent between the two species, only pigeons learned to effectively solve the MHD (Herbranson & Schroeder, 2010). Regarding the above human performance, Klein, Evans, Schultz and Beran (2013) found a very similar effect when they gave both humans and monkeys 500 trials of experience on the MHD task. They found great variability in performance between subjects and as a group; neither humans nor monkeys learned the optimal switching strategy.

Probability Matching

With regard to the above results, it is possible that humans were probability matching to solve the MHD. That is, humans were sensitive to the different probabilities and responded accordingly by both staying 33% of the time and switching 67% of the time. This results in winning around 55% of the time, which is about 12% worse than the optimal switching strategy. The likely explanation for probability matching is that it is the result of humans' attempt to win more than the maximum allowed by the task (2/3rds of the time). This continued attempt to find consistent patterns in the outcomes by employing various response strategies has been reported by Fantino and Asafandiari (2002) and Gaissmaier and Schooler (2008). This may occur because humans are typically accustomed to problems that always have a correct answer. There is no way to win every time with the MHD and striving to do better leads to less than optimal performance.

Equiprobability Bias

The tendency to perceive the probabilities associated with the two remaining doors in the MHD as being equal could be attributed to an equiprobabiity bias (Lecoutre, 1992) in which the odds of winning for either staying or switching are thought to be equal. This is a classic means of probability estimation and DeNeys (2006) found that university students reflected this type of analysis of the MHD while younger children actually learn to switch more often than adults. It seems then that life experience might make solving the MHD more difficult because of the acquired equiprobability bias. However, this does not explain the bias many participants show to stay with their initial choice rather than switch. If indeed staying and switching are thought to have an equal chance at winning (and participants report that they believe this to be true), then there should be no preference for either staying or switching. However, research that has assessed the strategies humans use for solving the MHD have found that they show a bias to stay with their initially chosen door regardless of the perception of equal probability associated with the two remaining doors.

Personal Theory of Regret

This stay bias may arise from a personal theory of regret, or that people find it less aversive to lose with their initial choice rather than to lose when they switched to other remaining door (Gilovich, Medvec, & Chen, 1995). Tubau and Alonso (2003) removed the effects of regret in one of their experiments and found that their participants were more likely to switch when the MHD was turned into an adversarial card game. That is, when a participant would chose initially, the remaining two unchosen options would be given to an opponent. After one of the opponent's cards was shown not to be the winning card, participants were more likely to decide to switch and take the opponent's remaining card rather than to stay with the one they initially chose. The implication is that humans form a more complete representation of the probabilities associated with the task in this case, and perform more optimally and as result.

Illusion of Control

Relatedly, human participants in the MHD may fall victim to the illusion of control. That is, participants may create a personal illusion of control while performing the MHD in which they believe that their initial choice was better than the other two thus creating a stay bias. Given this illusion of control, participants are likely to weight their initially chosen door as more valuable even when their choice and the other option are equally probable of producing a win (Lichtenstein & Slovic, 1971, 1973). Thus in the MHD, humans may be more likely to stay with their initially chosen door just because they chose it and feel some ownership attachment to it. Support for the illusion of control and the influence of ownership on performance in the MHD was found by Granberg and Dorr (1998) when their participants showed a tendency to switch much more often when someone else made the initial door selection. Commonly referred to as the endowment effect, in some instances people will actually demand more for an object they own than what they would pay for it if it were not theirs (Kahneman, Knetsch, & Thaler, 1991; Thaler, 1980; for related research with pigeons see Pattison, Zentall, & Watanabe, 2012).

Ownership Effect

The possible influence of a perception of ownership of the initial choice in the MHD might explain why human participants tend to show a stay bias. Interestingly, this may also have implication for why nonhuman species, such as pigeons, will learn the optimal strategy of switching. It could be simply that nonhuman animals frequently experience situations in which the outcomes following choice are probabilistic and ambiguous. One such situation in nature is the act of foraging for food. Often an area that appears to be depleted may contain a hidden food source while another area that has been previously food rich might have been recently depleted. Being more accustomed to a variable environment, nonhumans may simply be more suited to perform the MHD. However, because humans in our culture are taught through education and general experience that there almost always is a correct answer, they may not be as equipped to deal with a task in which the outcome over trials is variable. When having to sum over trials, humans sometimes show a strong stay bias that might be related to ownership.

To examine the effect of "ownership" on pigeons' choice of strategy to solve the MHD, Stagner, Rayburn-Reeves, and Zentall (2013) gave pigeons the same task as Hebranson and Shroeder (2010) but for one group they increased the effort required to make the initial choice. This can be related to findings supporting "justification of effort" in pigeons in which stimuli following greater effort are often preferred over those following less effort, even when the outcome following each of the stimuli is the same (e.g., Clement, Feltus, Kaiser, & Zentall, 2000). The increased effort required for initial selection in the MHD was used in attempt to create a type of “ownership” effect that they thought would result in performance similar to that observed in humans (Hebranson & Schroeder, 2010). However, when the number of pecks required to make the initial choice was increased from one to 20, pigeons actually acquired the optimal switching strategy faster than those in the control condition that were only required to peck once. By Session 70, both groups were showing an average preference for switching of about 80%. Thus, although both groups performed better than humans tend to, neither group used the switching strategy exclusively. Additionally, the group required to peck more for their initial choice showed no ownership effect.

Although Stagner et. al (2013) found strong use of the switching strategy in pigeons, they did not replicate the exclusive usage of this strategy that Hebranson and Schroeder (2010) found. Interestingly, Mazur and Kahlbaugh (2012) tried to replicate Hebranson and Schroeder’s findings and could not attain the same robust finding. Much like Stagner et. al’s results, they found that pigeons were switching about 60% of the time at Session 30. Mazur and Kahlbaugh (2012) did not train their birds for 70 sessions so no increased usage of the strategy as a function of continued experience was observed as was found by Stagner et al. (2013).

At this point, we have data that suggest pigeons can learn and use the optimal strategy of switching better than human subjects. This could be a function of experience with the MHD, although studies giving humans as many as 500 trials did not find much if any improvement over probability matching as a function of extensive experience (see Hebranson & Schroeder, 2010; Mazur & Kahlbaugh, 2012; Klein et al., 2013). Multiple factors could contribute to this result. There could be more aversion by humans to a loss resulting from choice of switching than there is to a loss incurred following choice of staying. A certain feeling of ownership over an initial choice could also contribute to the relatively poor performance seen by humans on the MHD. Additionally, humans may employ complicated strategies to attempt to win more often than is possible in the MHD. Humans have learned problem solving strategies in an environment in which there is often a response that is always correct, so it is likely that being in a situation in which it is impossible to choose correctly every time might be difficult to learn.

Reversal Learning

It may not be feasible to tease apart what makes the MHD a difficult task for human subjects, given their decision-making biases. However, nonhuman subjects provide a way to test different aspects of the MHD free of these influences. Recently we have found evidence that rats show more behavioral flexibility and will alternate and switch choices more readily than pigeons (Rayburn-Reeves, Stagner, Kirk & Zentall, 2013). This result was found after giving rats experience with a spatial midsession reversal-learning task. For the first half of a test session, one response lever would be correct. Midway through the session, responses to this lever were no longer reinforced and responses to the previously incorrect lever were reinforced. When given a similar task, pigeons' showed perseverative errors in that they would continue to choose the first correct stimulus after it was no longer reinforced. Unlike pigeons, rats showed very little perseveration associated with the previously correctly lever and also, little anticipation of the reversal point in that there were few choices to the second lever before feedback was given that it was correct. Rats performed very well on this reversal learning task in which switching was a crucial part of optimal performance, whereas pigeons previously have shown difficulty switching (Cook & Rosen, 2010; Rayburn-Reeves, et al., 2013, Stagner, Michler, Rayburn-Reeves, Laude, & Zentall, 2013).

This may be because rats have a different foraging strategy than pigeons. Rats tend to deplete their food source in one feeding, while pigeons will return to the same patch of food many times before they deplete it. Thus, rats have a natural tendency to vary their choices whereas pigeons tend to return to the same location or stimulus (Olton & Samuelson, 1976). Additionally, rats are omnivores and are occasionally predators whereas pigeons are preyed upon in nature. This often results in neophobic behavior in pigeons that is observed less in rats. Thus, rats appear to be better prepared than pigeons to shift to an alternative not recently chosen and may perform better on an MHD task. The goal of investigating the MHD with rats was to allow for testing free of the decision-making biases and previous experience that might interfere with human performance on this task. Another goal of the current experiments was to observe performance by rats on the MHD (Switch) task as well as two modified MHD tasks, one that will be referred to as the Stay condition in which staying was reinforced 67% of the time and another in which both staying and switching were equally reinforced 50% of the time (Control group). Additionally, the same three conditions were run with pigeons in order to allow for better comparison of the performance of the two species.

Research Questions

In the Switch condition, if rats demonstrate the same ability to use local feedback cues from reinforcement and nonreinforcement following choice of staying or switching as has been previously observed in reversal learning, and they are able to sum probabilities over trials, rats should learn the optimal switching strategy readily. It was predicted that rats would perform better than humans have in past research and may also perform better than pigeons have previously. Alternatively, rats may be less sensitive to the differences in the probability of reinforcement for staying and switching and like humans, show a variety of different behavioral patterns while attempting to maximize reinforcement.

In the Stay condition, if rats use local feedback cues and are able to sum over trials, they should learn to stay with their initial choice. However, rats' natural tendency alternate may make it more difficult and take them longer to acquire the optimal stay strategy (Montgomery, 1952a; Montgomery, 1952b). It is possible that rats will learn to stay with their initially chosen lever but will not perform as well as pigeons have on this task because pigeons have a natural tendency to stay (Mazur & Kahlbaugh, 2012). Alternatively, it may be that rats are more sensitive to the probabilities of reinforcement associated with staying and switching and consequently learn to stay as quickly as pigeons.

In the Control condition, there would be no obvious advantage for staying or switching because reinforcement is the same for either response. The results of this condition will tell us if rats have a natural tendency to switch when they are not differentially reinforced for doing so. Stagner et al. (2013) gave pigeons this same task and found that pigeons chose to stay 65% of the time, even though there was no advantage for them to do so. This result supports the hypothesis that pigeons have a bias to stay with their initial choice. Rats, on the other hand, may show a propensity to switch even though it perhaps would require a bit of additional effort to move from lever to lever when there is no additional reinforcement incentive to do so.

Chapter 2

Experiment 1 (Rats) Methodology

Subjects

Subjects were 13 albino rats (*Sprague-Dawley*) from 12-14 weeks old, obtained from another laboratory on the university campus (Lexington, KY). They were previously used as control subjects and had never been in any lever pressing task. All subjects were trained to lever press. The rats were maintained on a feeding schedule that allowed for continued growth but also did not impact their level of motivation throughout the experiment. They were housed during the day consistently in either pairs or sets of three. They were individually housed overnight in polystyrene cages with free access to water in a colony room maintained on a 12-hr/12-hr light/dark cycle. They were single housed over night to allow for measurements of each individual rat's overnight food consumption. The rats were maintained in accordance with a protocol approved by the Institutional Animal Care and Use Committee at the University of Kentucky.

Apparatus

The experiment was conducted in a standard rodent operant chamber (Coulbourn Instruments, Lehigh Valley, PA) measuring 25.7 cm across the response panel, 33 cm from ceiling to floor, and 31 cm from response panel to the back wall. The chamber had a white houselight, mounted on the left hand side of the response panel and located 1.3 cm from the ceiling. A pellet dispenser delivered pellets to a food well centered on the response panel, 5.6 cm from the floor. The response panel contained three retractable response levers, 3.6 cm wide. Two located on either side of and one was located below the food well, each 2.3 cm from the side wall and 5.6 cm from the floor. Reinforcement consisted of one pellet (MLab Rodent Tablet 45mg 1811156, Test Diet, Richmond, IN). The experimental chamber was located in a small isolated room to reduce extraneous visual and auditory stimulation. The experiment was controlled by a microcomputer and interface located in an adjacent room.

Procedure

Pretraining. All rats were pretrained to press each of the three levers to receive reinforcement. Each session consisted of 15 trials, five trials with each lever. A single response retracted the lever and resulted in one pellet of reinforcement. Trials were separated by a 5-s intertrial interval. Following reinforcement, the houselight stayed on for 2 s, and then turned off for the remaining 3-s of the intertrial interval (ITI). Rats received two sessions of pretraining.

Training. Rats randomly were placed in one of three conditions that differed based on how often rats were reinforced for switching. Regardless of the condition, at the start of each experimental session, the house light was illuminated, indicating that all three levers were operable. A lever press to any of the three levers resulted in all levers retracting for 1-s. The initially chosen lever and one of the unchosen levers (randomly selected) were then presented. For rats in the Switch condition (*n=5*), if the rat pressed the lever not initially chosen (i.e., a switch response), it received a single pellet delivered to the food well for reinforcement with a probability of .67. If the rat pressed the lever that it had initially chosen again (i.e., a stay response), it received a single pellet delivered to the food well for reinforcement with a probability of .33.

For rats in the Stay condition (*n=4*), if the rat pressed the lever not initially chosen (i.e., a switch response), it received a single pellet delivered to the food well for reinforcement with a probability of .33. If the rat pressed the initially chosen lever (i.e., a stay response), it received a single pellet delivered to the food well for reinforcement with a probability of .67.

For rats in the Control condition (*n=4*), if the rat pressed the lever not initially chosen (i.e., a switch response), it received a single pellet delivered to the food well for reinforcement with a probability of .5. If the rat pressed the lever that it had initially chosen again (i.e., a stay response), it received a single pellet delivered to the food well for reinforcement with a probability of .5. Trials were separated by a 5-s intertrial interval.

Following reinforcement, the houselight stayed on for 2 s, and then turned off for the remaining 3-s of the intertrial interval (ITI). If reinforcement was not provided, the house light was turned off for a 5-s dark ITI. Immediately following the ITI, the house light turned on indicating the start of the next trial and the three levers were extended. All rats received a total of 96 trials per session and were trained six days a week for 40 sessions.

Results

Switch Group

Figure 1 shows the percentage of switch responses as a function of session for 40 sessions. As can be seen in the figure, rats in the Switch group (filled circles) switched on 22.5% of the trials on Session 1, 39.6% on Session 20, 47.1% on Session 30 and 59.6% by Session 40. As can be seen by the error bars, there was great variability between subjects in the Switch group. By Session 40, Rat 3 and Rat 2 were choosing to switch the majority of the time, 97.9% and 80.2% respectively. Rats 11 and 1 were slightly above chance performance, with Rat 11 choosing to switch 61.5% of the time and Rat 1 at 58.3%. However, Rat 7 never acquired the optimal switching strategy and was switching on 0% of the trials by Session 40. Performance by each rat in this condition can be seen in Figure 2.

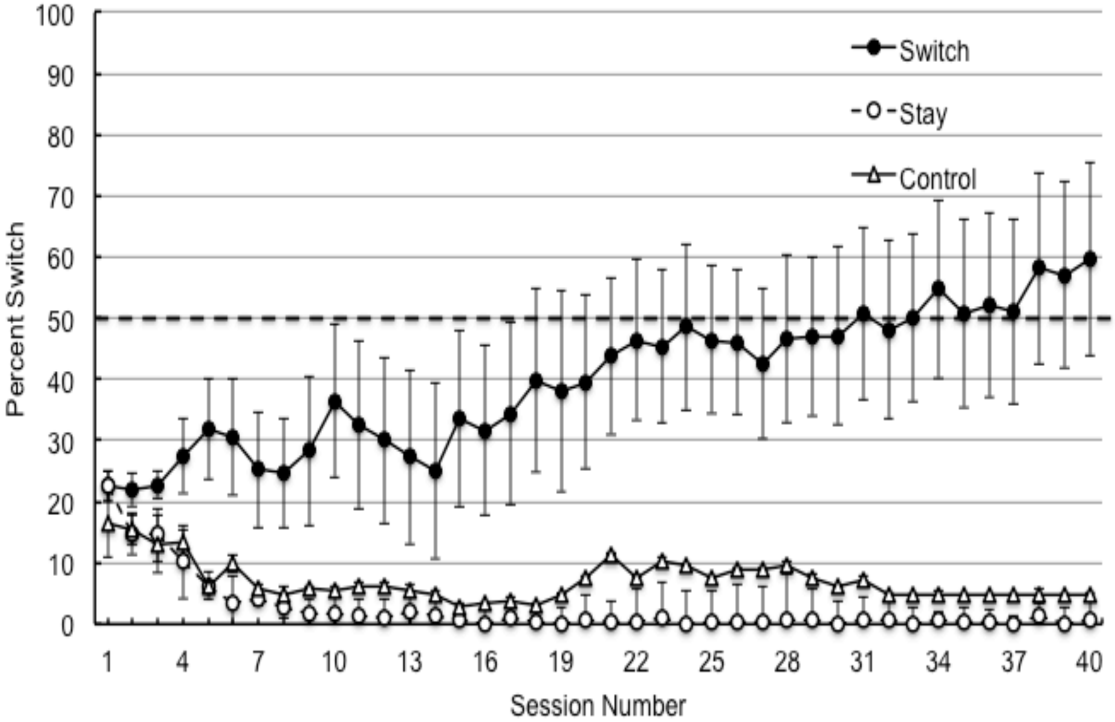

Figure 1. Percentage choice of switches by rats for all 30 sessions in Experiment 1 for the Switch group (solid circles), Stay group (open circles, dotted line) and the Control group (open triangles).

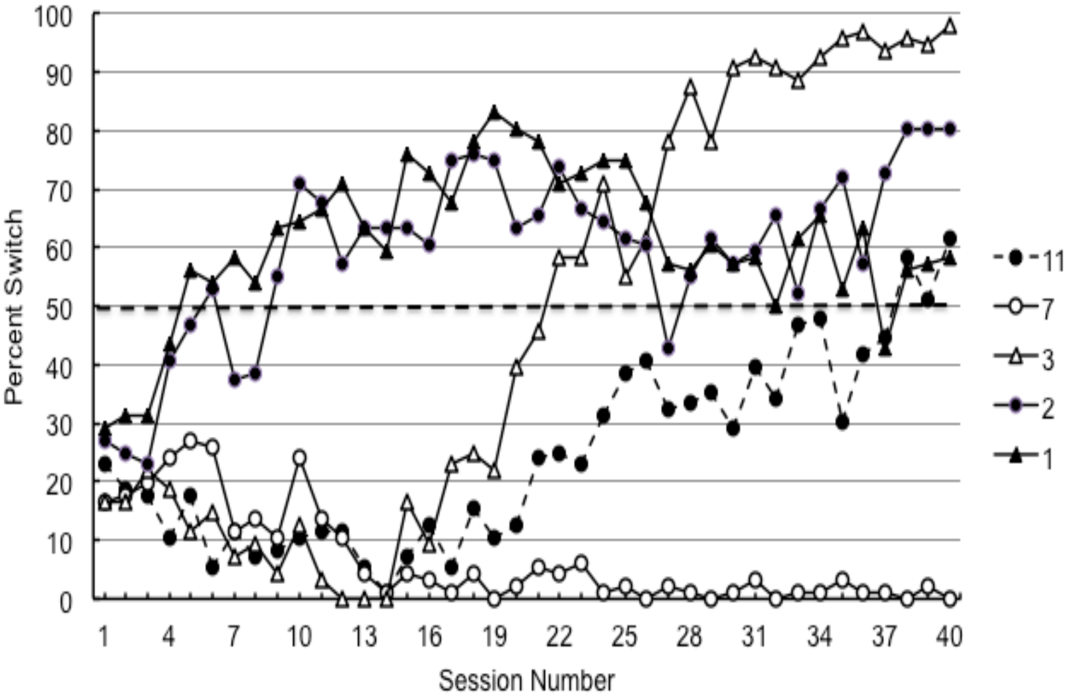

Figure 2. Percentage choice of switches for each individual rat in the Switch group across 30 sessions.

Stay Group

Figure 1 shows the percentage of switch responses as a function of session for the Stay group. As can be seen in the figure, rats in the Stay group (open circles) switched on 22.7% of the trials on Session 1, 0.5% on Session 20, 0% on Session 30 and 0.5% on Session 40. There was far less variability of choice in the stay condition, all rats were staying almost 100% of the time by Session 40. Rats 12 and 9 were staying 100% of the time while Rats 8 and 6 stayed 99% of the time on Session 40. Each rat’s choice performance in this condition appears in Figure 3.

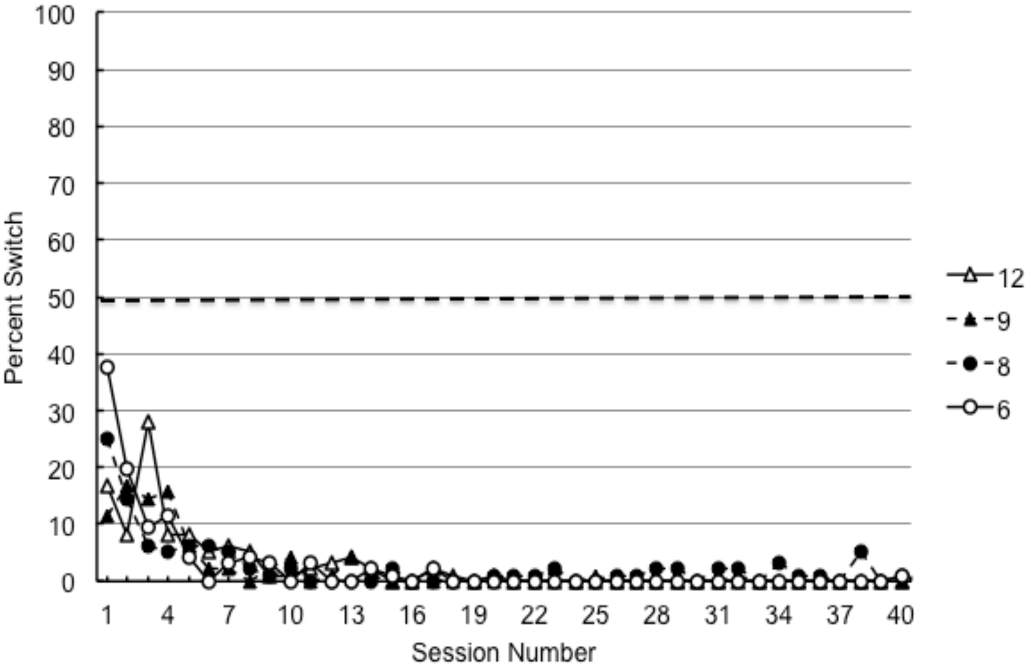

Figure 3. Percentage choice of switches for each individual rat in the Stay group across 30 sessions.

Control Group

Figure 1 shows the percentage of switch responses as a function of session for the Control group. As can be seen in the figure, rats in the Control group (open triangles) switched on 16.4% of the trials on Session 1, 7.6% on Session 20, 5.9% on Session 30 and 4.7% by Session 40. Like the Stay group, there was much less variability of choice in the Control group than was found in the Switch group. Rats 5 and 4 stayed on 100% of trials and Rat 10 only switched 5.21% of the time on Session 40. Rat 13 looked a bit different from the other three, choosing to switch 16.7% of the time on Session 40. Overall, all rats in the Control group were choosing to stay on the majority of all trials by Session 40. Individual performance of rats in the 50/50 condition can be found in Figure 4.

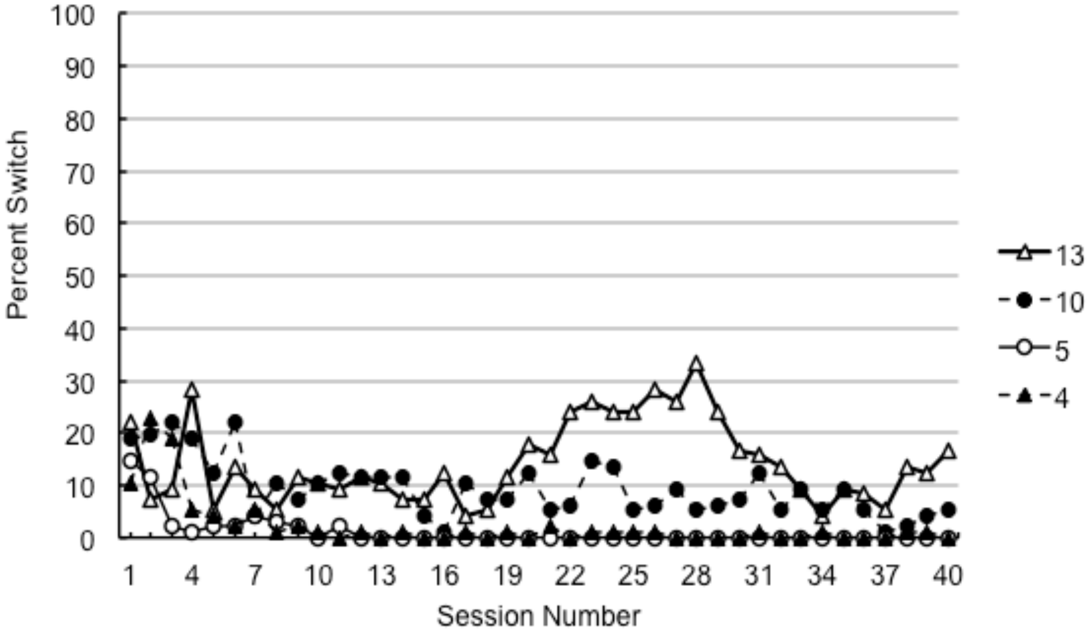

Figure 4. Percentage choice of switches for each individual rat in the Control group across 30 sessions.

Comparison of the Three Groups

To determine if there was a statistically significant difference among the three groups, the average of the last five sessions of switching performance was compared. A one-way ANOVA for independent samples indicated that the difference among the three groups in preference for switching was significant, $F(2,10) = 8.71$, p=.006. To take a closer look at the difference between the groups, two planned comparisons were performed. The first compared performance of rats in these two groups with rats in the Switch group. A significant effect was found in this contrast whether assuming equal variances, $t(10) = 4.17$, p=.002*,* or unequal variances, $t(4.06) = 3.38$, p =.027. Thus, on the last five sessions of training, rats in the Switch group switched more often than rats in the Control and Stay groups on the last five sessions of training.

The second planned comparison was done to find any difference between the Stay group and the Control group. No significant difference was found between the two whether we assume equal variances, $t(10) = 0.21$, p = .84, or assume unequal variances, $t(3.11) = 1.29$, p =.29.

Patterns of Responding

The pattern of choices by individual rats in each group was also analyzed. More specifically, which of the levers was initially chosen and whether the second choice was to stay or switch depending on which nonselected lever was presented.

Table 1 shows the response patterns from Sessions 1, 20, 30 and 40 for rats in the Switch group, Table 2 shows the same results for rats in the Stay group and Table 3 shows patterns of responding for the same sessions in the Control group. Many of the rats developed an identifiable response pattern.

Table 1

Proportion of Each Response Sequence for Rats in the Switch Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
11	1	*0.06*	0.05	0.01	*0.46*	0.03	0.04	*0.25*	0.01	0.08	*0.77*	0.23
	20	*0.00*	0.03	0.05	*0.27*	0.00	0.03	*0.60*	0.00	0.01	*0.88*	0.13
	30	*0.05*	0.10	0.11	*0.20*	0.00	0.00	*0.46*	0.01	0.06	*0.71*	0.29
	40	*0.23*	*0.05*	*0.10*	*0.28*	*0.04*	*0.02*	*0.00*	*0.00*	*0.27*	*0.39*	*0.61*
7	1	*0.00*	0.00	0.01	*0.53*	0.00	0.04	*0.30*	0.00	0.11	*0.83*	0.17
	20	*0.50*	0.01	0.00	*0.35*	0.00	0.00	*0.13*	0.00	0.01	*0.98*	0.02
	30	*0.01*	0.00	0.01	*0.93*	0.00	0.00	*0.05*	0.00	0.00	*0.99*	0.01
	40	*0.93*	*0.01*	*0.06*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
3	1	*0.00*	0.01	0.00	*0.52*	0.00	0.05	*0.31*	0.00	0.10	*0.83*	0.17
	20	*0.14*	0.22	0.13	*0.24*	0.00	0.01	*0.23*	0.01	0.03	*0.60*	0.40
	30	*0.03*	0.40	0.38	*0.17*	0.00	0.01	*0.02*	0.00	0.00	*0.22*	0.78
	40	*0.02*	*0.00*	*0.00*	*0.49*	*0.00*	*0.00*	*0.00*	*0.00*	*0.49*	*0.02*	*0.98*
2	1	*0.13*	0.04	0.01	*0.48*	0.01	0.01	*0.13*	0.04	0.16	*0.73*	0.27
	20	*0.06*	0.03	0.00	*0.21*	0.00	0.00	*0.09*	0.32	0.28	*0.36*	0.64
	30	*0.05*	0.00	0.00	*0.13*	0.00	0.00	*0.25*	0.26	0.31	*0.43*	0.57
	40	*0.15*	*0.00*	*0.05*	*0.00*	*0.41*	*0.00*	*0.40*	*0.00*	*0.00*	*0.20*	*0.80*
1	1	*0.07*	0.04	0.02	*0.28*	0.00	0.03	*0.35*	0.07	0.13	*0.71*	0.29
	20	*0.04*	*0.27*	*0.24*	*0.14*	*0.15*	*0.00*	*0.02*	*0.06*	*0.08*	*0.20*	*0.80*
	30	*0.02*	0.13	0.11	*0.41*	0.24	0.04	*0.00*	0.02	0.03	*0.43*	0.57
	40	*0.34*	*0.03*	*0.04*	*0.11*	*0.03*	*0.15*	*0.00*	*0.16*	*0.14*	*0.42*	*0.58*

Note. Numbers in italics represent stay responses.

Table 2

Proportion of Each Response Sequence for Rats in the Stay Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
12	1	*0.06*	0.02	0.02	*0.73*	0.01	0.01	*0.09*	0.00	0.05	*0.89*	0.11
	20	*0.01*	0.01	0.00	*0.98*	0.00	0.00	*0.00*	0.00	0.00	*0.99*	0.01
	30	*0.96*	*0.04*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
	40	*0.99*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
9	1	*0.06*	0.02	0.02	*0.73*	0.01	0.01	*0.09*	0.00	0.05	*0.89*	0.11
	20	*0.02*	0.00	0.00	*0.72*	0.00	0.00	*0.26*	0.00	0.00	*1.00*	0.00
	30	*0.01*	0.00	0.00	*0.89*	0.00	0.00	*0.10*	0.00	0.00	*1.00*	0.00
	40	*0.97*	*0.00*	*0.03*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
8	1	*0.07*	0.06	0.02	*0.42*	0.02	0.02	*0.26*	0.02	0.10	*0.75*	0.25
	20	*0.04*	0.01	0.00	*0.21*	0.00	0.00	*0.74*	0.00	0.00	*0.99*	0.01
	30	*0.00*	0.00	0.00	*0.52*	0.00	0.00	*0.48*	0.00	0.00	*1.00*	0.00
	40	*0.76*	*0.01*	*0.22*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.99*	*0.01*
6	1	*0.16*	0.14	0.03	*0.34*	0.02	0.00	*0.13*	0.06	0.13	*0.63*	0.38
	20	*0.00*	0.00	0.00	*0.69*	0.00	0.00	*0.31*	0.00	0.00	*1.00*	0.00
	30	*0.00*	0.00	0.00	*0.09*	0.00	0.00	*0.91*	0.00	0.00	*1.00*	0.00
	40	*0.99*	*0.00*	*0.00*	*0.00*	*0.01*	*0.00*	*0.00*	*0.00*	*0.00*	*0.99*	*0.01*

Note. Numbers in italics represent stay responses.

Table 3

Proportion of Each Response Sequence for Rats in the Control Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
13	1	*0.13*	0.06	0.01	*0.55*	0.04	0.00	*0.10*	0.04	0.06	*0.78*	0.22
	20	*0.00*	0.04	0.06	*0.40*	0.00	0.00	*0.43*	0.00	0.07	*0.82*	0.18
	30	*0.03*	0.00	0.00	*0.60*	0.00	0.06	*0.20*	0.00	0.10	*0.83*	0.17
	40	*0.55*	*0.02*	*0.26*	*0.02*	*0.08*	*0.00*	*0.00*	*0.06*	*0.00*	*0.83*	*0.17*
10	1	*0.21*	0.09	0.00	*0.34*	0.01	0.00	*0.26*	0.02	0.06	*0.81*	0.19
	20	*0.03*	0.02	0.03	*0.72*	0.00	0.00	*0.13*	0.01	0.06	*0.88*	0.13
	30	*0.04*	0.03	0.00	*0.76*	0.00	0.00	*0.13*	0.02	0.02	*0.93*	0.07
	40	*0.88*	*0.00*	*0.07*	*0.03*	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*	*0.95*	*0.05*
5	1	*0.01*	0.01	0.02	*0.72*	0.00	0.03	*0.13*	0.01	0.07	*0.85*	0.15
	20	*0.00*	0.00	0.00	*0.96*	0.00	0.00	*0.04*	0.00	0.00	*1.00*	0.00
	30	*0.00*	0.00	0.00	*1.00*	0.00	0.00	*0.00*	0.00	0.00	*1.00*	0.00
	40	*1.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
4	1	*0.02*	0.03	0.01	*0.80*	0.02	0.01	*0.07*	0.00	0.03	*0.90*	0.10
	20	*0.00*	0.00	0.00	*0.96*	0.00	0.00	*0.04*	0.00	0.00	*1.00*	0.00
	30	*0.00*	0.00	0.00	*1.00*	0.00	0.00	*0.00*	0.00	0.00	*1.00*	0.00
	40	*1.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*

Note. Numbers in italics represent stay responses.

On Session 1 in the Switch group, four of the rats (11, 7, 3 and 2) showed a preference to initially select the center lever and stay with it rather than switch to the unchosen lever. Rat 1 preferred to initially select and remain with the right lever, and rats 7 and 3 also chose and remained with the right lever on a portion of trials.

By Session 20, one rat (11) chose and remained with the right lever, one rat (7) either chose the left or center lever initially and remained with the chosen lever through the trial. Rat 3 chose the left lever then switched to the center lever, Rat 2 chose the right lever and switched to the left and Rat 1 chose the left lever and switched to either the center or right levers almost equally.

At Session 30, Rat 11 chose and remained with the right lever and Rat 7 chose and stayed with the center lever. Rat 3 chose the left lever and then switched to either the center or right levers equally, while Rat 2 chose the right lever initially and then switched to the center and left levers equally and occasionally chose to remain with the right lever. Rat 1 chose the center lever and switched to the left lever.

Finally, by Session 40, Rat 7 chose and remained with the left lever almost exclusively. Rat 2 either chose and remained with the right lever or initially chose the center lever and switched to the left lever. Rat 3 either chose the right lever and switched to the center lever or chose and stayed with the center lever. Rat 1 chose and remained with the left lever more than any of the other response pattern alternatives. Rat 11 distributed her responses fairly equally with no real discernable pattern.

In the Stay group, all rats (12, 9, 8 and 6) showed a bias to choose and stay with the center lever on Session 1. Only Rat 8 occasionally chose and remained with the right lever.

At Session 30, Rats 12 and 9 were still choosing and remaining with the center lever, Rat 8 was as well but was also choosing and staying with the right lever, and Rat 6 was choosing and staying with the right lever on the majority of the trials. By Session 40, all rats were showing a preference to choose and remain with the left lever.

Rats in the Control group showed patterns of responding similar those in the Stay group. All Rats (13, 10, 5 and 4) chose the center lever and stayed with it on Session 1. This continued through Session 30 for Rats 10, 5 and 4. Rat 13 began to choose and stay with the right lever during Session 20 but was also still choosing and staying with the center lever on some trials. By Session 30, Rat 13 showed the same tendency as the other rats in this group by choosing and staying with the center lever on the majority of the trials. On Session 40, all rats in this group preferred to initially choose and then remain with the left lever.

Discussion

On Session 1, the three groups of rats did not differ from one another in terms of preference for switching. This is not at all surprising, given that none of the rats had adequate experience with the contingencies associated with the different tasks at this point. However, within 40 sessions, there was a significant difference among the three groups. The planned comparisons conducted shed light on specifically which groups differed from one another. The Stay and Control groups did not differ from one another, but the Switch group chose to switch significantly more than the other two groups. Although finding a bias to switch in the control group was a possibility given that some past research has found evidence of rats switching when there is no benefit to doing so (Olson & Samuelson, 1976), results from Experiment 1 do not support this hypothesis.

However, the current finding is understandable given that there was no advantage to switching. For the Control group, arguably, staying would still be optimal as it results in the same amount of reinforcement and requires less effort than switching.

However, rats in the Switch group differed significantly in their preference for the switching strategy from both the Stay and the Control group by Session 40. Thus, rats appear to be sensitive to the overall probability of reinforcement in this task. For the Switch group, switching was the most optimal strategy and rats in this group switched significantly more than rats in the other two groups.

In looking at patterns of responding, overall it seems that the majority of rats did have a preferred lever, especially in their initial choice portion of the task. Most rats initially preferred the center lever and continued to prefer it throughout training, while some more evenly distributed their responses across levers. More variability in initial lever selected and switching to an unchosen lever was observed in the Switch group over sessions, which is understandable given the probability of reinforcement for switching.

Chapter 3: Experiment 2 (Pigeons) Methodology

Experiment 2 consisted of three conditions and used pigeons as subjects. The Switch condition of this experiment was similar to Stagner et. al (2013), with the exception that the stimuli remained unchanged in appearance from initial choice to the choice of whether to stay with the initially selected key or switch. In the original procedure, the three key lights were initially presented as white keys and then for the second choice, the selected key and one of the unselected keys were then presented in blue. In Experiment 2 of the present research, the keys were initially presented in white and were white after the initial response to make the procedure more similar to the rat procedure in Experiment 1, given that the levers did not change in appearance between the initial and terminal responses. Pigeons were also run in Stay and Control conditions so pigeons' performance could be compared to rats' performance in all three conditions.

Subjects

Nine white Carneau pigeons (*Columbia Livia*) and six homing pigeons (*Columbia Livia Domestica*) ranging in age from 2 to 12 years served as subjects. All pigeons had received experience in previous, unrelated studies involving simple simultaneous and successive hue discriminations but had never been exposed to a probability-learning task. The pigeons were maintained at 85% of their free-feeding weight throughout the experiment. They were individually housed in wire cages with free access to water and grit in a colony room that was maintained on a 12:12-hr light/dark cycle. The pigeons were maintained in accordance with a protocol approved by the Institutional Animal Care and Use Committee at the University of Kentucky.

Apparatus

The experiment was conducted in a BRS/LVE (Laurel, MD) sound-attenuating standard operant test chamber measuring 34 cm high, 30 cm from the response panel to the back wall, and 35 cm across the response panel. Three circular response keys (2.5 cm diameter) were aligned horizontally on the response panel and separated from each other by 6.0 cm. The bottom edge of each response keys was 24 cm from the wire-mesh floor. A 12-stimulus in-line projector (Industrial Electronics Engineering, Van Nuys, CA) with 28-V, 0.1-A lamps (GE 1820) that projected white lights was mounted behind each response key. Mixed grain reinforcement (Purina Pro Grains, a mixture of corn, wheat, peas, kefir, and vetch) was provided from a raised and illuminated grain feeder located behind a 5.1 × 5.7 cm aperture horizontally centered and vertically located midway between the response keys and the floor of the chamber. Reinforcement consisted of 3s access to mixed grain. The experiment was controlled by a microcomputer and interface located in an adjacent room.

Procedure

Pretraining. All pigeons were pretrained to peck at each of the three keys to receive reinforcement. Each session consisted of 15 trials, five trials with each key. A single response turned off the key light and result in 3.0 s of reinforcement. All trials were separated by a 5-s intertrial interval with the houselight illuminated. Pigeons received two sessions of pretraining.

Training. Pigeons were randomly assigned to one of the three conditions, making sure that an equal number of each strain was assigned to each condition, 3 white Carneau and 2 homing pigeons to each group. At the start of each trial regardless of condition, all three response keys were illuminated white. A single peck to any key turned off all three keys for 1 s. At the end of the delay, two white keys were illuminated, the key that the pigeon initially had chosen and one of the two keys (randomly selected) that the pigeon had not initially selected. For the Switch condition (*n=5*), if the pigeon pecked the key that it initially chose again (i.e., a stay response), it received 3.0 s of reinforcement with a probability of .33. If the pigeon chose the key not originally selected (i.e., a switch response), it received 3.0 s of reinforcement with a probability of .67. For the Stay condition (*n=5*), if the pigeon chose it's initially selected key again (i.e., a stay response), it received 3.0 s of reinforcement with a probability of .67. Alternatively, if the pigeon chose the other key (i.e., a switch response), it received 3.0 s of reinforcement with a probability of .33. For the Control condition (*n=5*), if the pigeon chose to stay with it's initially selected key (i.e., a stay response), it received 3.0 s of reinforcement with a probability of .50. If the pigeon chose the other key (i.e., a switch response), it received 3.0 s of reinforcement with a probability of .50. In all conditions, trials were separated by a lit 5-s intertrial interval and each training session consisted of 96 trials. Pigeons were trained six days a week for 40 sessions.

Results

Switch Group

Figure 5 shows the percentage of switch responses as a function of session for the Switch group.

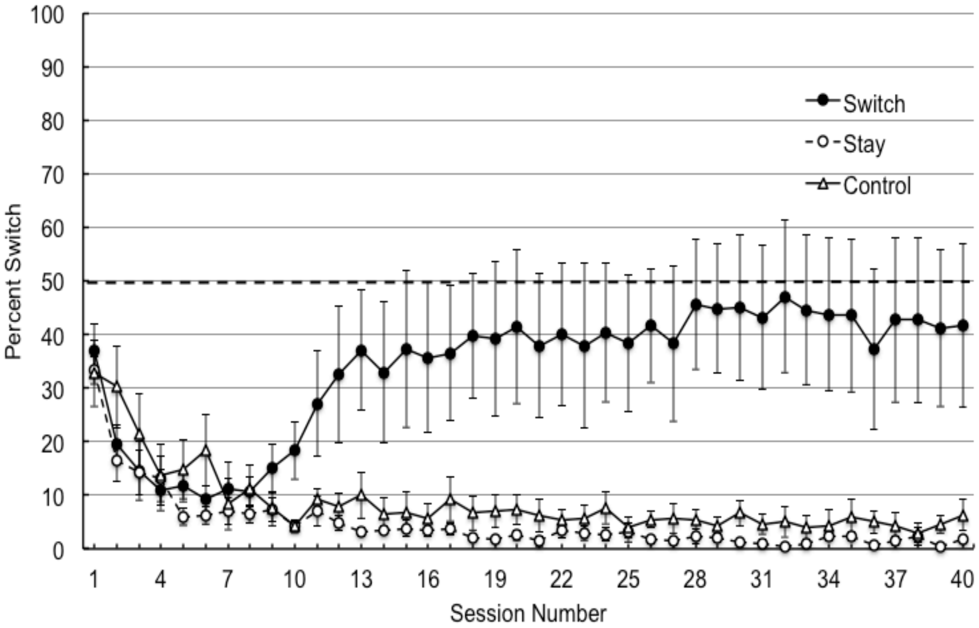

Figure 5. Percentage choice of switches by pigeons for all 30 sessions in Experiment 2 for the Switch group (solid circles), Stay group (open circles, dotted line) and the Control group (open triangles).

As can be seen in the figure, pigeons in the Switch group (filled circles) switched on 37.1% of the trials on Session 1, 41.4% on Session 20, 45% on Session 30 and 41.67% on Session 40. Like the rats in the Switch group in Experiment 1, pigeons in the Switch group showed a lot of variability. By Session 40, Pigeon 19272 was choosing to switch the majority of the time (96.88%). Pigeon 234 choose to switch 47.92% of the time on Session 40, slightly less than what would be by chance. Pigeons 1886 and 188 chose to switch roughly around a third of the time on Session 40, with 1886 switching 36.46% of the time and 188 at 26.04%. Lastly, Pigeon 19836 never acquired the optimal switching strategy and was choosing to stay on 1.04% of the time on Session 40. Performance by individual pigeons in this condition can be seen in Figure 6.

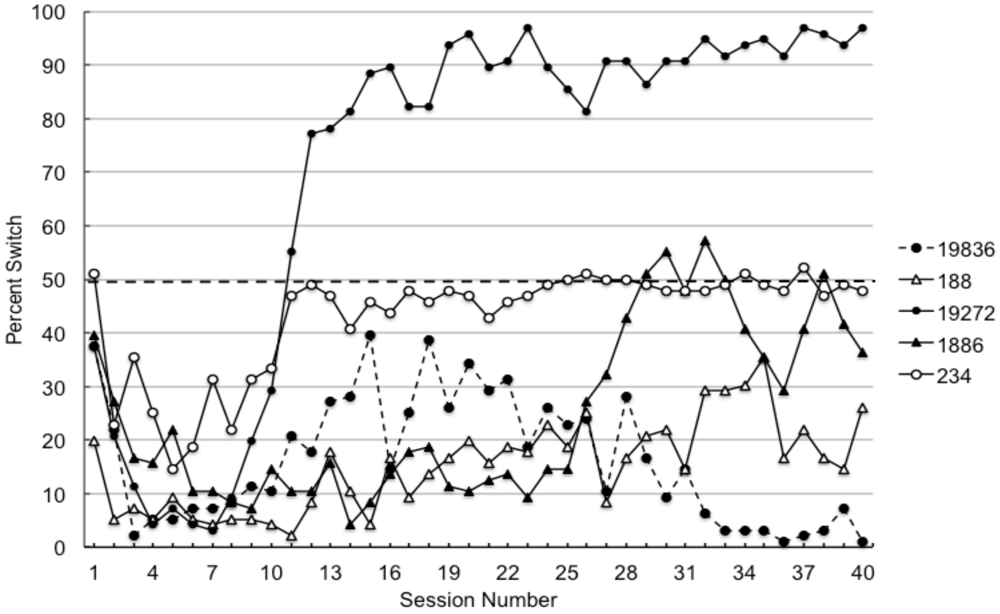

Figure 6. Percentage choice of switches for each individual pigeon in the Switch group across 30 sessions.

Stay Group

Figure 5 shows the percentage of switch responses as a function of session number for the Stay group. As can be seen in the figure, pigeons in the Stay group (open circles) switched on 33.3% of the trials on Session 1, 2.5% on Session 20, 1.25% on Session 30 and 1.67% on Session 40. There was little variability with in this group in that all pigeons chose to stay almost exclusively. On Session 40, Pigeon 1016 never chose to switch and Pigeon 19334 was at 1.04% switching. Pigeons 19229 and 135 were at 2.08% preference for switching and Pigeon 2998 was at 3.13%. The choices to switch made by each pigeon in this group appear in Figure 7.

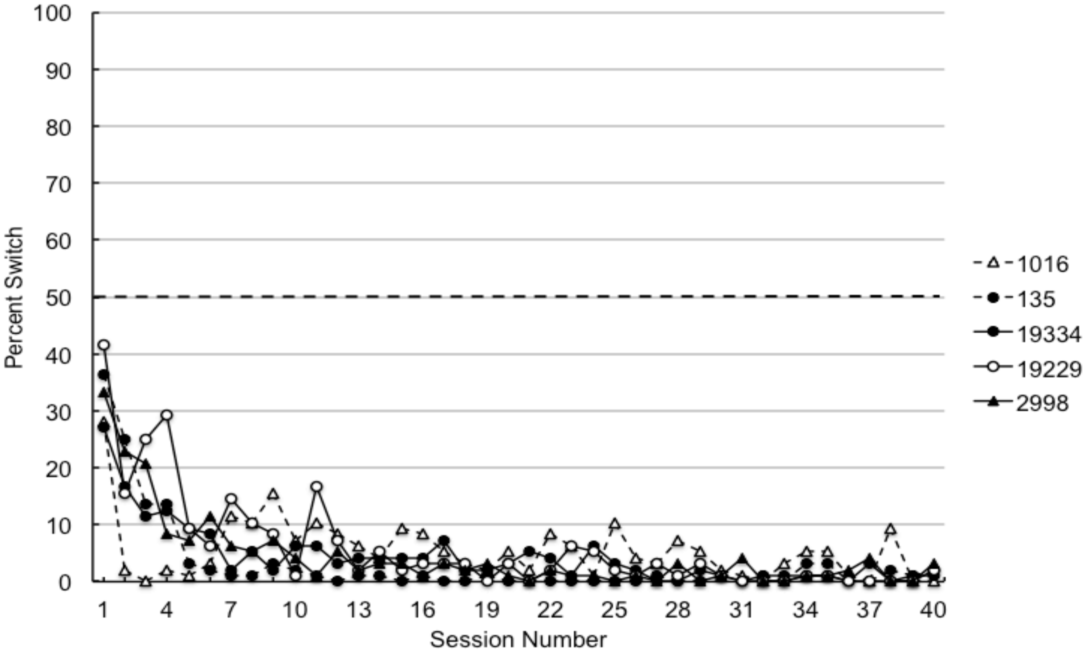

Figure 7. Percentage choice of switches for each individual pigeon in the Stay group across 30 sessions.

Control Group

Figure 5 shows the percentage of switch responses as a function of session number for the Control group. As can be seen in the figure, pigeons in the Control group (open triangles) switched on 32.7% of the trials on Session 1, 7.29% on Session 20, 6.67% on Session 30 and 6.25% by Session 40. A bit more variability between pigeons was found in this group but all showed a clear preference for staying by Session 40. Pigeon 18 chose to stay exclusively during Session 40, while Pigeon 19384 chose to switch 1.04% of the time and Pigeon 278 2.13% of the time. Pigeons 1140 and 237 chose to switch a bit more often on Session 40, 13.54% of the time respectively. Individual performance from pigeons in the 50/50 condition can be found in Figure 8.

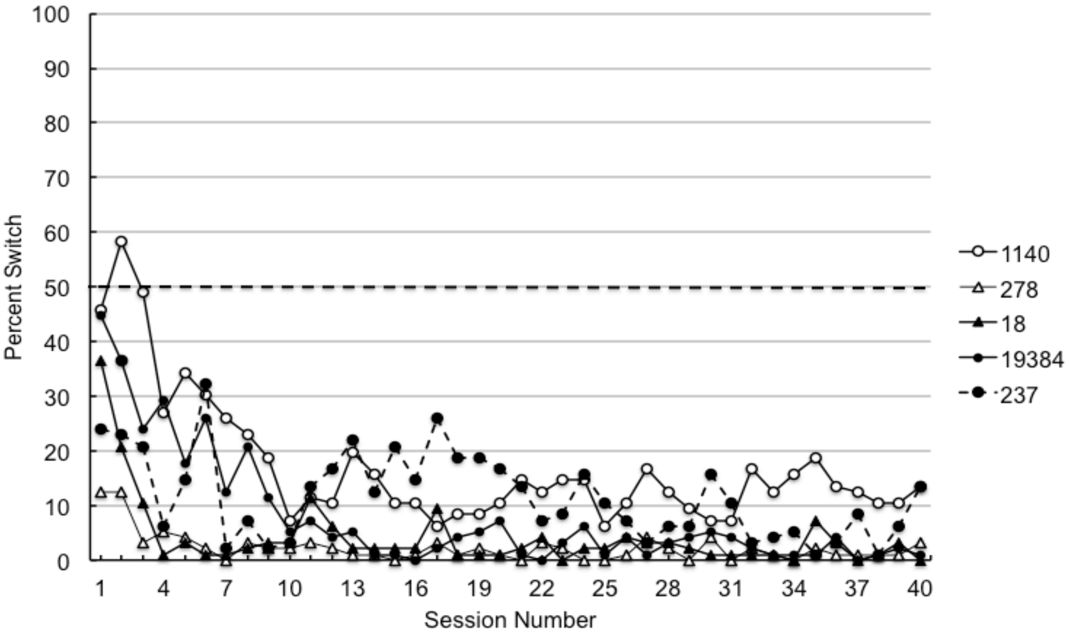

Figure 8. Percentage choice of switches for each individual pigeon in the Control group across 30 sessions.

Comparison of the Three Groups

As in Experiment 1, the average of the last five sessions of switching performance by each pigeon was compared. A one-way ANOVA for independent samples indicated that the difference between the three groups in preference for switching was significant, $F(2,12) = 5.87$, $p=.017$. To take a closer look at where the difference between the groups, two planned comparisons were performed. The first compared performance of pigeons in these two groups with pigeons in the Switch group. A significant effect was found in this contrast if assuming equal variances, $t(12) = 3.42$, $p=.005$, but was not significant if assuming unequal variances, $t(4.04) = 2.43$, $p=.071$. It appears that, like the rats, pigeons in the Switch group chose to switch more often than pigeons in the Control and Stay groups on the last five sessions of training.

The second compared the Stay group with the Control group and no significant difference was found between the two whether we assume equal variances, $t(12) = 0.26$, $p = .800$, or assume unequal variances, $t(4.17) = 1.58$, $p =.187$.

Patterns of Responding

As in Experiment 1, the pattern of choices by individual pigeons in each group was analyzed. Table 4 shows the response patterns from Sessions 1, 20, 30 and 40 for pigeons in the Switch group, Table 5 shows similar results for pigeons in the Stay group and Table 6 shows the patterns of responding for the same sessions in the Control group. Like the rats, many of the pigeons developed an identifiable response pattern.

Table 4

Proportion of Each Response Sequence for Pigeons in the Switch Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
19836	1	*0.13*	0.02	0.00	*0.46*	0.09	0.01	*0.04*	0.11	0.14	*0.63*	0.38
	20	*0.00*	0.11	0.13	*0.53*	0.00	0.05	*0.13*	0.00	0.05	*0.66*	0.34
	30	*0.00*	0.02	0.02	*0.85*	0.00	0.01	*0.05*	0.00	0.04	*0.91*	0.09
	40	*0.00*	0.00	0.00	*0.95*	0.00	0.01	*0.04*	0.00	0.00	*0.99*	0.01
188	1	*0.14*	0.08	0.00	*0.64*	0.07	0.00	*0.03*	0.00	0.04	*0.80*	0.20
	20	*0.00*	0.01	0.00	*0.67*	0.00	0.00	*0.14*	0.04	0.15	*0.80*	0.20
	30	*0.00*	0.00	0.00	*0.69*	0.00	0.02	*0.09*	0.05	0.15	*0.78*	0.22
	40	*0.00*	0.01	0.00	*0.57*	0.00	0.00	*0.17*	0.03	0.22	*0.74*	0.26
19272	1	*0.09*	0.10	0.08	*0.36*	0.04	0.02	*0.17*	0.00	0.13	*0.63*	0.38
	20	*0.02*	0.00	0.00	*0.02*	0.02	0.00	*0.00*	0.47	0.47	*0.04*	0.96
	30	*0.02*	0.00	0.00	*0.07*	0.07	0.00	*0.00*	0.41	0.43	*0.09*	0.91
	40	*0.00*	0.00	0.00	*0.02*	0.01	0.00	*0.01*	0.49	0.47	*0.03*	0.97
1886	1	*0.10*	0.04	0.07	*0.27*	0.07	0.09	*0.23*	0.02	0.09	*0.60*	0.40
	20	*0.01*	0.02	0.00	*0.51*	0.02	0.01	*0.38*	0.00	0.05	*0.90*	0.10
	30	*0.17*	0.34	0.20	*0.24*	0.00	0.01	*0.04*	0.00	0.00	*0.45*	0.55
	40	*0.04*	0.09	0.08	*0.49*	0.00	0.18	*0.10*	0.00	0.01	*0.64*	0.36
234	1	*0.03*	0.05	0.03	*0.31*	0.06	0.06	*0.15*	0.11	0.19	*0.49*	0.51
	20	*0.06*	0.00	0.00	*0.47*	0.45	0.00	*0.00*	0.01	0.01	*0.53*	0.47
	30	*0.03*	0.00	0.00	*0.49*	0.48	0.00	*0.00*	0.00	0.00	*0.52*	0.48
	40	*0.06*	0.00	0.00	*0.46*	0.45	0.00	*0.00*	0.01	0.02	*0.52*	0.48

Note. Numbers in italics represent stay responses.

Table 5

Proportion of Each Response Sequence for Pigeons in the Stay Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
1016	1	*0.09*	*0.07*	*0.02*	*0.50*	*0.03*	*0.04*	*0.13*	*0.03*	*0.08*	*0.72*	*0.28*
	20	*0.02*	*0.02*	*0.00*	*0.78*	*0.00*	*0.00*	*0.15*	*0.00*	*0.03*	*0.95*	*0.05*
	30	*0.00*	*0.00*	*0.00*	*0.98*	*0.01*	*0.01*	*0.00*	*0.00*	*0.00*	*0.98*	*0.02*
	40	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*1.00*	*0.00*
135	1	*0.39*	*0.02*	*0.00*	*0.22*	*0.16*	*0.00*	*0.03*	*0.08*	*0.10*	*0.64*	*0.36*
	20	*0.00*	*0.00*	*0.00*	*0.97*	*0.00*	*0.00*	*0.03*	*0.00*	*0.00*	*1.00*	*0.00*
	30	*0.00*	*0.00*	*0.00*	*0.91*	*0.00*	*0.00*	*0.08*	*0.00*	*0.01*	*0.99*	*0.01*
	40	*0.01*	*0.00*	*0.00*	*0.96*	*0.01*	*0.01*	*0.01*	*0.00*	*0.00*	*0.98*	*0.02*
19334	1	*0.16*	*0.07*	*0.06*	*0.13*	*0.00*	*0.03*	*0.45*	*0.04*	*0.06*	*0.73*	*0.27*
	20	*0.46*	*0.00*	*0.00*	*0.34*	*0.00*	*0.00*	*0.17*	*0.01*	*0.02*	*0.97*	*0.03*
	30	*0.55*	*0.01*	*0.00*	*0.39*	*0.00*	*0.00*	*0.05*	*0.00*	*0.00*	*0.99*	*0.01*
	40	*0.43*	*0.00*	*0.00*	*0.55*	*0.00*	*0.00*	*0.01*	*0.00*	*0.01*	*0.99*	*0.01*
19229	1	*0.03*	*0.03*	*0.04*	*0.24*	*0.05*	*0.11*	*0.31*	*0.08*	*0.09*	*0.58*	*0.42*
	20	*0.00*	*0.00*	*0.00*	*0.96*	*0.00*	*0.00*	*0.01*	*0.00*	*0.03*	*0.97*	*0.03*
	30	*0.00*	*0.00*	*0.00*	*0.92*	*0.00*	*0.02*	*0.06*	*0.00*	*0.00*	*0.98*	*0.02*
	40	*0.00*	*0.00*	*0.00*	*0.98*	*0.00*	*0.02*	*0.00*	*0.00*	*0.00*	*0.98*	*0.02*
2998	1	*0.11*	*0.02*	*0.01*	*0.42*	*0.14*	*0.03*	*0.14*	*0.04*	*0.09*	*0.67*	*0.33*
	20	*0.00*	*0.00*	*0.00*	*0.81*	*0.00*	*0.01*	*0.18*	*0.00*	*0.00*	*0.99*	*0.01*
	30	*0.01*	*0.00*	*0.00*	*0.96*	*0.01*	*0.00*	*0.02*	*0.00*	*0.00*	*0.99*	*0.01*
	40	*0.00*	*0.00*	*0.00*	*0.96*	*0.02*	*0.00*	*0.01*	*0.00*	*0.01*	*0.97*	*0.03*

Note. Numbers in italics represent stay responses.

Table 6

Proportion of Each Response Sequence for Pigeons in the Control Group:

	Session	*L-L*	L-C	L-R	*C-C*	C-L	C-R	*R-R*	R-L	R-C	*Stay*	Switch
1140	1	*0.10*	0.00	0.00	*0.20*	0.08	0.02	*0.24*	0.13	0.23	*0.54*	0.46
	20	*0.06*	0.01	0.00	*0.82*	0.07	0.00	*0.01*	0.01	0.01	*0.90*	0.10
	30	*0.48*	0.00	0.00	*0.45*	0.06	0.00	*0.00*	0.00	0.01	*0.93*	0.07
	40	*0.50*	0.00	0.00	*0.35*	0.08	0.00	*0.01*	0.02	0.03	*0.86*	0.14
278	1	*0.00*	0.01	0.00	*0.52*	0.00	0.08	*0.35*	0.00	0.03	*0.88*	0.13
	20	*0.00*	0.00	0.00	*0.03*	0.00	0.01	*0.96*	0.00	0.00	*0.99*	0.01
	30	*0.01*	0.01	0.00	*0.01*	0.01	0.02	*0.94*	0.00	0.00	*0.96*	0.04
	40	*0.11*	0.00	0.00	*0.04*	0.00	0.03	*0.81*	0.00	0.00	*0.97*	0.03
18	1	*0.09*	0.10	0.07	*0.34*	0.09	0.05	*0.20*	0.00	0.04	*0.64*	0.36
	20	*0.00*	0.00	0.00	*0.95*	0.00	0.00	*0.04*	0.00	0.01	*0.99*	0.01
	30	*0.00*	0.00	0.00	*0.98*	0.00	0.00	*0.01*	0.00	0.01	*0.99*	0.01
	40	*0.00*	0.00	0.00	*0.97*	0.00	0.00	*0.03*	0.00	0.00	*1.00*	0.00
19384	1	*0.33*	0.05	0.09	*0.02*	0.02	0.04	*0.20*	0.15	0.09	*0.55*	0.45
	20	*0.01*	0.03	0.01	*0.92*	0.03	0.00	*0.00*	0.00	0.00	*0.93*	0.07
	30	*0.00*	0.00	0.00	*0.73*	0.00	0.04	*0.22*	0.00	0.01	*0.95*	0.05
	40	*0.00*	0.00	0.00	*0.99*	0.00	0.00	*0.00*	0.01	0.00	*0.99*	0.01
237	1	*0.03*	0.03	0.02	*0.39*	0.00	0.16	*0.34*	0.00	0.03	*0.76*	0.24
	20	*0.06*	0.02	0.00	*0.61*	0.04	0.02	*0.16*	0.01	0.07	*0.83*	0.17
	30	*0.05*	0.03	0.00	*0.69*	0.02	0.04	*0.10*	0.00	0.06	*0.84*	0.16
	40	*0.01*	0.02	0.00	*0.80*	0.00	0.08	*0.05*	0.00	0.03	*0.86*	0.14

Note. Numbers in italics represent stay responses.

In the Switch group, all five pigeons (19836, 188, 19272, 1886 and 234) showed a preference to initially select the center key and stay with it rather than switch to the unchosen key on Session 1. Pigeon 1886 occasionally chose the right key and remained with it on some trials in Session 1. Pigeons 19836, 188 and 234 continued to show a bias to choose and remain with the center key through Session 40. Pigeon 19272 chose the right key initially and chose to switch to the left and center keys fairly equally by Session 30 and continued to do so on Session 40. Pigeon 1886 either chose the center key initially and switched to the left key or initially chose the left key and then switched to the center key during trials on Session 30. By Session 40, Pigeon 1886 was choosing and staying with the center key on the majority of the trials.

In the Stay group, Pigeons 1016 and 2998 had a bias to initially select and remain with the center key on Session 1 and Session 30. Pigeon 135 initially either chose the left key and then switched to the center key or the center key initially and switched to the left key during Session 1. By Sessions 30 and 40, 135 was consistently choosing the center key and staying with it. Pigeon 19334 chose and stayed with the right key during Session 1. By Sessions 30 and 40, 19334 was either choosing and staying with the left key or choosing and staying with the center key. Lastly, Pigeon 19229 either chose and stayed with the right key or chose and stayed with the center key during trials on Session 1. Pigeon 19229 chose and remained with the center key on the majority of trials in Sessions 30 and 40.

Lastly, Pigeons 19384 and 237 in the Control group chose the center key and stayed with it on Session 1 and continued to do so by Session 40. Pigeons 278 and 18 either chose and stayed with the right key or chose and stayed with the center key during trials on Session 1. On Sessions 30 and 40, Pigeon 278 chose and stayed with the right key while Pigeon 18 chose and stayed with the center key. Pigeon 1140 chose and stayed with the center key, chose and stayed with the right key, or chose the right key and switched to the center key during trials on Session 1. By Sessions 30 and 40, Pigeon 1140 was either choosing and staying with the left key or choosing and staying with the center key.

Discussion

Overall, findings in Experiment 2 with pigeons were very similar to those found in Experiment 1 with rats. A significant difference in choice of switching was found among the three groups for both rats in Experiment 1 and pigeons in Experiment 2. Additionally, the Control and Stay groups did not differ significantly for either species. Lastly, both pigeons and rats in the Switch groups showed more usage of the switch response than the other two groups did. From these results, pigeons in the Stay and Control groups appear to be sensitive to the overall probability of reinforcement in these conditions and chose to stay with their initially chosen key accordingly. Pigeons in the Switch condition did switch more often than pigeons in the other two groups, but did not perform optimally.

With regard to patterns of responding, overall it seems that the majority of pigeons did have a preferred key throughout training, especially in their initial choice. Many initially preferred the center key and continued to throughout sessions, while some more evenly distributed their responses across keys. More variability in initial key selected and switching to an unchosen key was observed in the Switch group over sessions, a similar result to that found with the rats.

Chapter Four: General Discussion and Conclusions

Overall Summary of Findings

While pigeons in the Switch group in Experiment 2 did switch more often than pigeons in the Stay and Control groups, their preference for switching was not as strong as what has been previously observed (Herbranson & Schroeder, 2010; Mazur & Kahlbaugh, 2012; Stagner et al., 2013). Finding individual variability within subjects in the MHD task is not uncommon, although the reduced preference for switching by pigeons in Experiment 2 may be due to a small change in the procedure. In previous work examining the MHD with pigeons, the color of the keys in for the initial choice was different from the two keys that were available for the second choice. That is, the stimuli changed in appearance from the initial choice to the second choice in the earlier research procedure in which subjects were required to either stay or switch. In the current procedure, stimuli did not change visually from the initial choice to the second choice. This change in the current procedure was made in an attempt to make the procedure used for the pigeons as similar to the rat procedure as possible, given that the levers did not change in appearance between the initial and final choices.

Rats in the Switch group in Experiment 1 were switching less than pigeons were initially, but this difference dissipated over sessions (a comparison of the rats and pigeons in the switch groups appears in Figure 9).

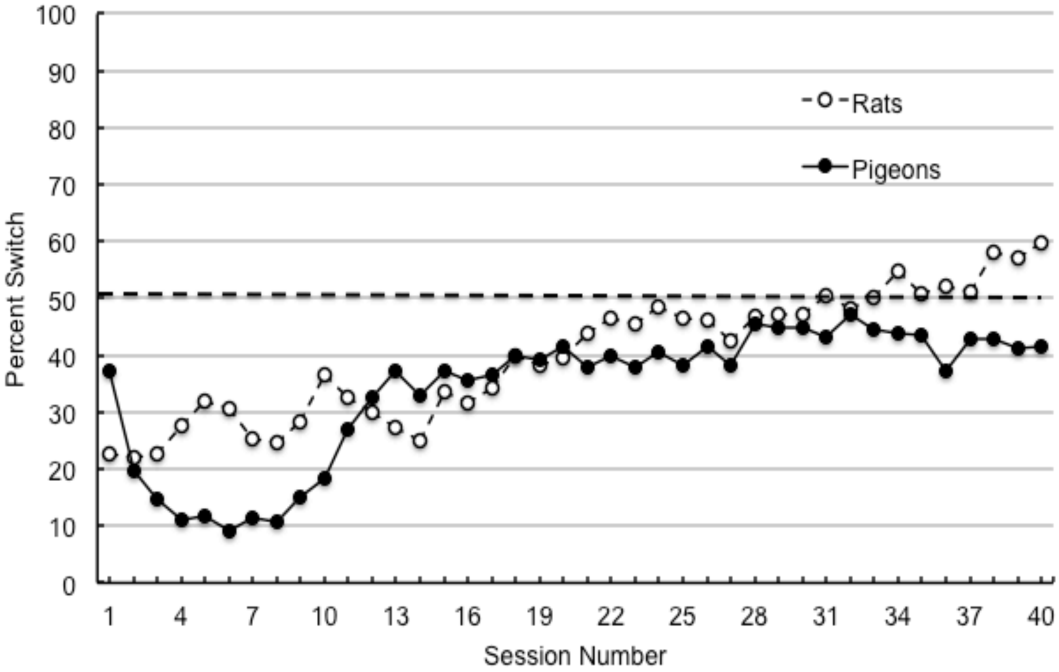

Figure 9. Percentage choice of switches for rats (open circles) and pigeons (closed circles) in the Switch groups across 40 sessions.

This indicates that rats did change their behavioral pattern and began to switch more often with further experience with the task. It is possible that were not as sensitive to the difference in the probabilities of reinforcement because there was no visual change that occurs with the stimuli between the initial choice and terminal choice.

In the Control condition, pigeons and rats performed similarly in that when staying and switching were equally reinforcing, both species chose to stay with their initial choice the vast majority of the time (see Figure 10 for comparison).

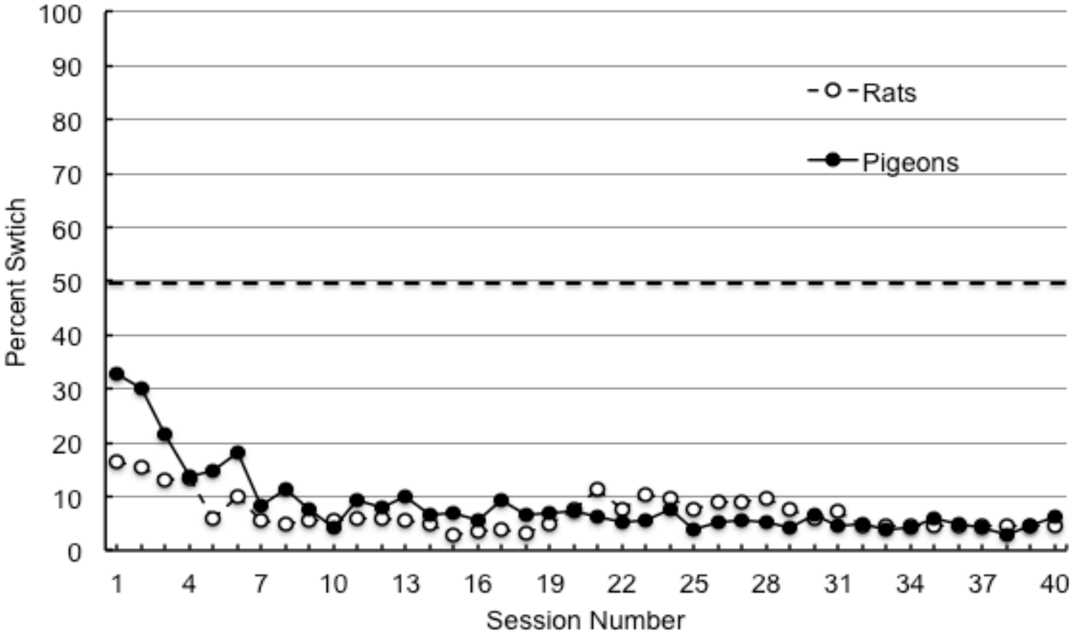

Figure 10. Percentage choice of switches for rats (open circles) and pigeons (closed circles) in the Control groups across 40 sessions.

This could possibly be attributed to behavioral inertia, and in this procedure there was no benefit for the subjects to switch from their initial choice. This finding is very similar to what has been observed in humans when they are given a task in which choice of either staying or switching is equally likely to produce a win. Lichtenstein and Slovic (1971, 1973) found that, like pigeons and rats in the current experiments, humans will favor their initial choice when the probabilities of winning associated with staying and switching are equated.

It is not surprising that pigeons and rats in the Stay group did not differ from one another. In this procedure, the optimal strategy was to stay with the initially chosen stimulus on every trial and both pigeons and rats learned this quickly (see Figure 11 for comparison).

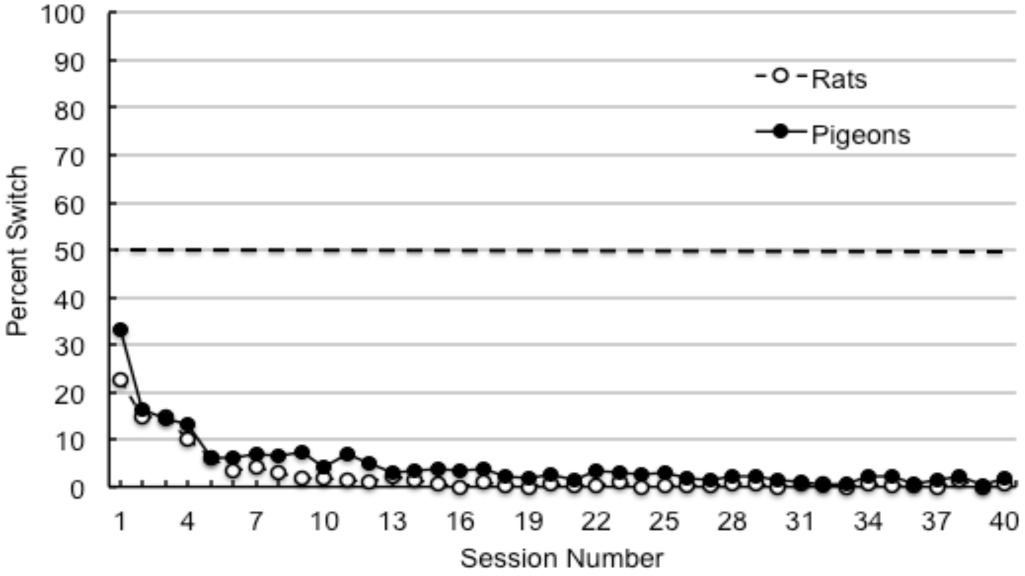

Figure 11. Percentage choice of switches for rats (open circles) and pigeons (closed circles) in the Stay groups across 40 sessions).

There was also much less variability within this condition for both species. Although this result is not unexpected, it makes the results found in the Switch groups more difficult to interpret. The Stay condition was just the opposite of the Switch condition in that staying was reinforced two-thirds of the time whereas switching was reinforced two-thirds of the time in the Switch condition. Because both species quickly learned to stay consistently in the Stay condition, it would have been reasonable for both species to have learned to switch quickly and consistently in the Switch group. That was not the result that was found in the current experiments and this is consistent with previous findings in both non-humans and humans (Granberg & Brown, 1995; Herbranson & Schroeder, 2010; Mazur & Kahlbaugh, 2012; Stagner et al., 2013, Klein et al., 2013).

The current experiments with rats and pigeons and previous work testing humans and pigeons have all found that subjects have difficulty learning when the optimal strategy is to switch. Additionally, a large amount of within species variability is a consistent finding in this condition.

The variability found in MHD tasks in previous research has sometimes been explained by probability matching. More specifically, when looking at the average of a group of subjects rather than individual performance, preference for switching is sometimes at about two-thirds of the time. Probability matching occurs when choices are allocated accordingly with how often they are reinforced. Putting this into the context of the MHD task, subjects should switch two-thirds of the time because switching is reinforced two-thirds of the time. Accordingly, staying is reinforced one-third of the time so subjects should stay one-third of the time. In past research, probability matching has been observed in both goldfish and pigeons (Bullock & Bitterman, 1962; Behrend & Bitterman, 1966). When looking at overall group performance in some of the past work, choice of switching can resemble what would be probability matching. However, when performance by individuals is examined, it becomes clear that probability matching does not explain the results of individual subjects. In fact, as in the present experiments, there is generally considerable variability among subjects. That is, humans and perhaps nonhuman subjects may sample many different behavioral patterns attempting to find one that will result in more reinforcement than what the task actually allows (Fantino, & Asafandiari, 2002; Gaissmaier & Schooler, 2008). Additionally, if every subject were to probability match, the variability across subjects would be quite low. As seen in the present experiments and in previous research, this is not the case. Thus, while we see fairly consistent performance by individual subjects, there is much variability among subjects that cannot be accounted for by probability matching.

Thus, probability matching also does not adequately explain the overall outcome and individual variability found in the Switch groups from the current experiments. When we look more closely at individual subjects in the current experiments, three of the rats were consistently switching more often by Session 40 but one was one switching roughly one-third of the time and the fifth showed a stay bias. Only one pigeon was switching the majority of time by Session 40, but one pigeon was roughly at chance, two were choosing to stay more often and one showed a stay bias.

From the current experiments, it is apparent that the vast amount of individual differences in performance is exclusive to the MHD or Switch conditions. Mazur and Kahlbaugh (2012) found a similar result when they tested groups of adult humans and pigeons in a modified MHD task. Both species were divided into conditions, one being a condition in which switching was reinforced 80% of the time and another in which switching was reinforced 90% of the time. Both species learned to switch the vast majority of the time, even more so in the 90% condition, as one would expect. Additionally, little variability was found within subjects in these conditions.

Taking the above points into account, the variability between subjects in the Switch condition in the current experiments is not likely due to an aversion to switching. When the probabilities of winning associated with staying and switching are manipulated such that switching is reinforced almost all the time (80% and 90%), both pigeons and humans will readily switch (Mazur and Kahlbaugh, 2012). Thus, in conditions in which switching is reinforced much more often than staying, subjects will begin to choose optimally. However, in the traditional MHD task in which switching is reinforced less often than the above study (67%), subjects may show a stay bias and this is perhaps why we find preference to stay even when it is not advantageous to do so.

When similar results have been found with human participants, the ownership or endowment effect has been provided as a possible explanation for why humans tend to stay with their initial choice (Lichtenstein & Slovic, 1971, 1973). That is, people feel ownership of their initial choice. However, pigeons tested in a modified MHD task attempting to observe an “ownership-like” effect by requiring additional effort invested in the initial choice showed no evidence of this effect (Stagner et al., 2013). It is not likely that nonhumans would show this type of bias, yet both rats and pigeons perform very similarly to humans in the MHD task. Because we did not find an ownership-like effect, it is reasonable to propose there is an alternative explanation.

Limitations

It could be that switching must overcome behavioral inertia and the difference between 67% reinforcement for switching and 33% reinforcement for staying was not substantial enough to encourage the exclusive use of a switching strategy in either species. Giving up additional food in order to stay may not seem adaptive but non-human animals (Amsel, 1958; Capaldi, 1957) and in some cases humans (Shigley & Guffey, 1978; Horsley, Osborne, Norman, & Wells, 2012) will readily work for a lower amount of reinforcement that does not happen consistently. Within the context of the MHD task, pigeons and rats may be more willing to receive a reduced amount of food and choose to stay with their initial choice some of the time simply because it's easier to remain in the same location rather than to move within the test chamber to switch. Alternatively, it is possible that rats and pigeons were sampling different patterns of behavior throughout sessions in attempt to attain more reinforcement than what is possible in the task. The increased amount of different response types that was observed in both rats and pigeons in the Switch group might support this, although this same behavior was not observed in the other two groups. If pigeons and rats do attempt to obtain more reinforcement than is possible within this MHD task, then they are not dissimilar to humans that are suggested to show this behavior.

Lastly, perhaps the current procedures did not allow for optimal performance by rats and pigeons in the Switch group. Experiments 1 and 2 produced a result that continues to make the MHD such an interesting task. Currently, every species that has been tested has shown less than optimal performance and a wide range of within group variability with only one exception (Herbranson & Schroeder, 2010). In terms of the current experiments, rats and pigeons were not much different from one another in the Switch group. Rats have been proposed to be much faster to learn to switch than pigeons (Rayburn-Reeves, et al., 2013), so it was thought that perhaps rats would perform better than pigeons on the MHD task. This hypothesis was not supported by the current results. The MHD task is not a typical foraging task and requires subjects to sum the probabilities of reinforcement over trials rather than using feedback from the most recent trial. When considering this, it may not be surprising that rats and pigeons treated the current task in the same way, although there is evidence that both species are sensitive to probability of reinforcement.

Implications and Future Directions

Future investigation of the MHD in any species may be most successful in finding increased use of the optimal switching strategy by making the outcomes associated with staying and switching more discriminable. Mazur and Kahlbaugh (2012) did this by changing the probability of reinforcement for switching from 67% to 80% and 90%. They found almost that pigeons and humans switched almost exclusively in these conditions. However, it is important to note that this is not the traditional MHD design with regards to probabilities of reinforcement.

We have found that pigeons will learn to switch when switching is reinforced 67% of the time, although not exclusively, when the peck requirement to the initial choice is increased (Stagner et al, 2013). This is most likely because pigeons attended more to the outcome following their effort. Something similar to this increased effort requirement might encourage switching behavior in humans as well. Additionally, a timeout could be added following a non-reinforced trial. This would delay the next opportunity for reinforcement and perhaps make the outcome of choices more salient. Pretraining each key with 33% reinforcement may also familiarize subjects with the probabilities or reinforcement associated with the actual task, rather than pretraining with 100% reinforcement that has been done in past research.

Lastly, one could associate a stimulus such as a tone with reinforcement following choices of staying or switching. That is, when reinforcement following a choice to stay occurs, for example, a tone would sound. There would be no tone or a different tone associated with reinforcement following a choice to switch. This would be a way to provide subjects with a way to discriminate between staying and switching and the outcomes associated with both strategies. This could make the difference in reinforcement between staying and switching more salient without changing the actual task.

Although it can be difficult to compare across species given that there is so much variability, it appears that the MHD task is a good equalizer for a variety of species in that despite their differences, all seem to show similar variability on the task collectively. That is, we find a great amount of variability across subjects and there does not seem to be a clear explanation why. Species type, sex, age, experience, etc., really do not seem to play a substantial role because there is not one factor that seems to be a predictor of optimal performance on the MHD task. From what has been observed in humans, monkeys, pigeons and rats, there seem to be three discernable types of performance by subjects (Granberg & Brown, 1995; Herbranson & Schroeder, 2010; Mazur & Kahlbaugh, 2012; Klein, et al., 2013; Stagner, et al., 2013). Some subjects learn to switch almost exclusively, some show fluctuation as to what behavioral pattern to use and resemble probability matching, and some show a clear stay bias. Further observation of more species and exploration of these different approaches subjects employ to determine their choices on this task may shed light on what makes some subjects successful by learning to switch exclusively, despite perhaps a predisposition to do otherwise.

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Vita

Author's Name – Jessica Paige Stagner

Education

Preparing Future Faculty Teaching Certificate, University of Kentucky, Lexington, KY, 2012

Master of Science, *Experimental Psychology*, University of Kentucky, Lexington, KY, 2010

Thesis: Suboptimal Choice in Pigeons
Advisor: Dr. Thomas R. Zentall

Bachelor of Arts, *Psychology*, University of Kentucky, Lexington KY, 2007

Research Experience

Jan. 2013 – July 2013 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice in pigeons, observing pigeons' performance in Monty hall dilemma (three-door task), and mentor an honors student.

Aug. 2012 – Dec. 2012 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continuing my research on suboptimal choice in pigeons, observing pigeons' performance in Monty hall dilemma (three-door task), and began mentoring our new honors student.

May – Aug. 2012 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice in pigeons, and began a contextual equivalence experiment with human participants.

Jan. – May 2012 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice, preference for information, and reversal learning in pigeons.

Aug. – Dec. 2011 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice, preference for information, reversal learning in pigeons and the effect of ownership in pigeons.

May – Aug. 2011 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice, preference for information, and reversal learning in pigeons. I also began researching the effect of ownership in pigeons.

Jan. – May 2011 **Laboratory Supervisor/Research Assistant,**
University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice, preference for information, and reversal learning in pigeons. I also studied reversal learning in rats as well.

May – Aug. 2010 **Laboratory Supervisor/ Research Assistant,**
University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice and preference for information by pigeons. In addition, I began investigating reversal learning in rats, as well as metacognition in dogs.

Jan. – May 2010 **Laboratory Supervisor,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I was responsible for scheduling research assistants and undergraduate students, and for organizing and supervising all activity in the pigeon lab. I continued my research on suboptimal choice. I also started and am continuing to investigate preference for information by pigeons.

May – Aug. 2009 **Research Assistant,** University of Kentucky
Supervisor: Dr. Thomas R. Zentall

I continued working on my master's thesis involving maladaptive gambling and suboptimal choice by pigeons. I was also responsible for supervising laboratory activity in our pigeon lab.

Peer Reviewed Publications (N=14)

Laude, J.R., **Stagner, J.P.,** & Zentall, T.R. (in press). Suboptimal choice may result from the diminishing effect of reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes.*

Laude, J.R., **Stagner, J.P.**, Rayburn-Reeves, R., & Zentall, T.R. (*in press*). Midsession reversals with pigeons: Visual versus spatial discriminations and the intertrial interval. *Learning and Behavior.*

Stagner, J.P., Rayburn-Reeves, R. & Zentall, T.R. (2013). The monty hall dilemma in pigeons: Effect of investment in initial choice. *Psychonomic Bulletin and Review Online First.*

Rayburn Reeves, R., **Stagner, J.P.**, Kirk, C.R., & Zentall, T.R. (2012). Reversal learning in rats (rattus norvegicus) and pigeons (columba livia): Qualitative differences in behavioral flexibility. *Journal of Comparative Psychology, online first.*

Stagner, J.P., Laude, J.R., & Zentall, T.R. (2012). Pigeons prefer discriminative stimuli independently of the overall probability of reinforcement. *Journal of Experimental Psychology: Animal Behavior Processes, 38(4),* 446-452.

Zentall, T.R. & **Stagner, J.P.** (2012). Do pigeons prefer information in the absence of differential reinforcement? *Learning and Behavior, 40(4),* 465-475.

Stagner, J.P., Michler, D.M., Rayburn-Reeves, R., Laude, J.R., & Zentall, T.R. (2012). Midsession reversal learning: Why do pigeons anticipate and perseverate? *Learning and Behavior, online first.*

Molet, M., **Stagner, J.P.**, Miller, H.C., Kosinski, T., & Zentall, T.R. (2012). Guilt by association and honor by association: The role of acquired equivalence. *Psychonomic Bulletin and Review, online first.*

Zentall, T.R. & **Stagner, J.P.** (2011). Sub-Optimal Choice by Pigeons: Failure to support the allais paradox. *Learning and Motivation.*

Zentall, T.R., & **Stagner, J.P.** (2011). Maladaptive choice behaviour by pigeons: An animal analogue and possible mechanism for gambling (sub-optimal human decision-making behaviour). *Proceedings of the Royal Society B: Biological Sciences, 278,* 1203-1208.

Stagner, J.P., Laude, J.L., & Zentall, T.R. (2011). Sub-optimal choice in pigeons does not depend on avoidance of the stimulus associated with the absence of reinforcement. *Learning and Motivation, 42(2),* 282-287.

Zentall, T.R., & **Stagner, J.P**. (2010). Pigeon's prefer information over its absence. *Journal of Experimental Psychology: Animal Behavior Processes, 36,* 506-509

Stagner, J.P., & Zentall, T.R. (2010). Suboptimal choice behavior by pigeons. *Psychonomic Bulletin and Review, 17,* 412-416.

Singer, R.A., Zentall, T.R. & **Stagner, J.P**. (2008). Episodic-like memory: Pigeons can report location pecked when asked unexpectedly. *Behavioural Processes, 79,* 93-98.

In Preparation:

Stagner, J.P., Sticklen, M., & Zentall, T.R. The effect of a "near hit" on pigeons' preference for a suboptimal choice task.

Stagner, J.P., & Zentall, T.R. Investigation of the monty hall dilemma in pigeons and rats.