TRANSFER OF ODDITY-FROM-SAMPLE PERFORMANCE IN THE PIGEON TO NOVEL STIMULUS LOCATIONS

by

ZAUR J. ISAAKOV

A dissertation submitted to the Graduate Faculty in Psychology
in partial fulfillment of the requirements for the degree of Doctor of Philosophy,
The City University of New York
2010

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

Date	Dr. Robert Lanson Chair of Examining Committee
Date	Dr. Maureen O'Connor Executive Officer

Dr. Nancy Hemmes
Dr. Alicia Alvero
Dr. Bertram Ploog
Dr. Gerald Lachter

Supervisory Committee

THE CITY UNIVERSITY OF NEW YORK

Abstract

TRANSFER OF ODDITY-FROM-SAMPLE PERFORMANCE IN THE PIGEON TO NOVEL STIMULUS LOCATIONS

by

Zaur Isaakov

Advisor: Dr. Robert Lanson

The study examined the role of stimulus location in oddity-from-sample conditional discrimination in the pigeon. A three-key discrimination procedure with vertical and horizontal lines was used. The two phases of the experiment were carried out using two groups of four pigeons. One group was trained with the sample stimulus always appearing on the center key. After a response to the sample stimulus, two comparison stimuli were presented on the remaining two keys. The second group was trained with the sample presented on one of the side keys. After a peck to the sample key, the comparisons were presented on the remaining two keys. Following acquisition of oddity, the procedures were reversed between the two groups. The birds' performance was analyzed in terms of both multiple-rule and single-rule models of conditional discrimination. The results show that oddity-from-sample conditional discrimination is best described in terms of specific, sample-comparison associations, where the location of the stimuli must be specified.

Dedication

This work is dedicated to my wife, Emily Summerhays. The intellectual and moral support you have provided me with during the course of this journey is immeasurable. You are, indeed, “too marvelous for words.”

Acknowledgments

First and foremost I would like to express my deepest gratitude to my advisor and mentor, Dr. Robert Lanson. Without his support, and the insight, wisdom, and encouragement he has shared with me over the years, this thesis would not have been possible.

I would also like to thank the members of my committee, Dr. Nancy Hemmes and Dr. Alicia Alvero, for their valuable guidance, comments, and suggestions. In addition, many thanks to the outside readers of my dissertation, Dr. Gerald Lachter and Dr. Bertram Ploog, for their help and willingness to share their expertise.

Special thanks go to Emil Isaakov, for sharing his computer programming expertise, to Joseph Jacobs, for his invaluable help with the research subjects, and to Ami Shah, my incomparable research assistant. I also gratefully acknowledge the support and encouragement of my friends and colleagues, Stacy A. De Vaul, Hiyam Hammad, Dr. Melody Goldman, and Dr. Mary Watanabe, through the duration of my studies.

Finally, I would like to thank my parents, Larisa and Tofik Isaakov, for all that they have done for me.

Table of Contents

List of Figures

List of Tables

TRANSFER OF ODDITY-FROM-SAMPLE PERFORMANCE IN THE PIGEON TO NOVEL STIMULUS LOCATIONS

by

ZAUR ISAAKOV

In a typical 3-key conditional discrimination procedure, a pigeon is presented with a sample stimulus on the center key. In both matching and oddity procedures, a response on the sample stimulus (known as the observing response) produces a set of comparison stimuli on the side keys, where one comparison matches the sample and the other does not. In a matching-to-sample procedure, a response to the matching comparison is reinforced by access to food; a response on the nonmatching stimulus is not reinforced. A reversal in the reinforcement contingency results in an oddity problem, whereby the response on the nonmatching stimulus is reinforced. For example, on a trial where the presentation of the sample (green hue) is followed by the simultaneous presentation of the comparison stimuli (green and red hues), a response on the red hue is reinforced; a response on the green comparison is not reinforced. Irrespective of the location of the comparisons, such a trial type may be diagrammed as G→G/R*, with the stimulus marked by an asterisk being associated with reinforcement.

Generally, the interpretation of the pigeons' performance on oddity tasks is described as governed by either a set of sample-specific rules (multiple-rule model) or a universal concept (single-rule model). As Berryman, et al. (1965) pointed out, the rules could refer to correct as well as incorrect choices in an oddity-from-sample procedure. As a conditional discrimination, the sample is viewed as an S^D for the choice of comparisons. According to the multiple-rule model, acquisition of an oddity task would consist of acquisition of individual stimulus / stimulus associations. For example, in a two-hue (such as red and green) oddity-from-sample procedure, the pigeon acquires two sample-specific rules, R→G and G→R. Each of the S^D associations could then be expressed as, "after pecking red on the center key, peck green on the side key, and after pecking green on the center key, peck red on the side key" (Carter & Werner, 1978). Alternatively, the presence of the matching stimulus may become an S^Δ for responding to that stimulus, where it appears as a comparison, and an occasion for some other behavior (Cumming & Berryman, 1965). Thus, according to the single-rule model, the sample may serve as a cue designating which of the comparisons is an S^Δ. The S^Δ rule may then be expressed as "after pecking red on the center key, avoid pecking red on the side keys."

To further assess pigeons' performance on oddity tasks, researchers frequently use some form of transfer test, where a novel stimulus is substituted for a trained one (e.g., Cumming & Berryman, 1965; Pisacreta, Lefave, Lesneski, & Potter 1985; Urcuioli, 1977). For example, in a two-hue oddity-from-sample procedure with red (R) and green (G) hues, following acquisition, a yellow hue (Y) may be substituted for a green hue, as both a sample and a comparison. Of particular interest are the post-transfer trials where the novel stimulus appears as a comparison stimulus (Carter & Werner, 1978). Based on the predictions of a single-rule (S^Δ) model, the pigeon's performance on R→R/Y* should not be affected, as it would simply continue to respond on the "nonmatching" stimulus. Correspondingly, if the birds' behavior is governed by a set of S^D rules, then substituting a novel stimulus for one of the trained stimuli should result in a drop in accuracy to performance rates closely resembling those observed during initial acquisition trials, as R→Y would represent a novel association.

To test this hypothesis, Berryman, et al. (1965) trained their subjects on oddity-from-sample with red, green, and blue hues. The researchers tested transfer of oddity by substituting yellow lights for the blue lights, as both samples and comparisons, following the twentieth session. Berryman, et al. observed that on the initial post-transfer trials, when the sample was either red or green and one of the comparisons was yellow, as in R→R/Y*, accuracy dropped to 61.6 percent, which was substantially lower than the pre-transfer rate a session earlier on R→R/B* trials. Furthermore, when the sample and the comparisons were either red or green, the performance remained intact, as expected, at near 90 percent. Based on this apparent failure of the birds' performance to transfer to a novel stimulus, the authors concluded that the pigeons learned to respond to several different comparison stimuli, and that the function of the sample stimulus was not to cue the animal which comparison is incorrect, but to cue the response to the correct stimulus (Cumming & Berryman, 1965). In effect, the data supported the multiple-rule hypothesis.

On the assumption that conditional discrimination performance is governed by a set of S^D associations (Cumming & Berryman, 1965), the following questions can be addressed: How specific are these associations, and to what extent will performance transfer to novel conditions when some of the original experimental parameters used during training are manipulated?

Several studies examined the role of stimulus location in matching. Iversen, Sidman, and Carrigan (1986) conducted a study on matching-to-sample performance in monkeys using hue and line stimuli. In a two-alternative conditional discrimination procedure, two rhesus monkeys were trained on identity matching with three horizontally aligned stimulus / response keys. Experimental conditions were categorized as either *baseline* (where the sample stimulus always appeared on the center key) or *moving sample* (where the sample appeared on any of the three keys). Both rhesus monkeys were trained with hue and line stimuli within the same experiment. On hue trials, the task was to select the comparison key that was identical to the sample key (red if the sample was red and green if the sample was green). On line trials, the task was to select the comparison line that matched the sample line (horizontal if the sample was horizontal; vertical if the sample was vertical). The sequence of experimental conditions was different for each monkey. Baseline and moving sample sessions were comprised of either hues alone, lines alone, or hues and lines (where the order of hues and lines differed from trial-to-trial). Hue and line stimuli were never presented simultaneously in a given trial. Acquisition criterion was set at 95% accuracy over two consecutive sessions.

Following acquisition of the matching-to-sample performance with the sample always appearing on the center key, the subjects were transferred to a novel condition where the sample appeared on any of the three keys. Iversen et al. (1986) reported a breakdown in the matching performance following transfer of the line stimuli to novel locations. Accurate performance was maintained following the transfer of the hue stimuli to novel locations. The data obtain by Iversen and his colleagues suggest that conditional line discrimination in a matching-to-sample procedure is itself dependent on the location of the stimuli. Similarly, a pilot study with pigeons done by this author, which involved systematic replication of the experimental design used by Iversen and his colleagues, also demonstrated a breakdown of matching-to-sample following the transfer to novel stimulus locations. This breakdown of accurate matching performance was shown to occur with both hue and line stimuli (the data of the two birds trained on line oddity task are shown in the Appendix). The findings of Iversen et al. (1986) and the pilot data obtained by this author underscore the importance of specification of stimulus locations in matching-to-sample procedures.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) also investigated the extent to which accurate matching-to-sample performance in pigeons would transfer to novel sample locations. The authors were interested in whether the type of procedure used during the initial, pre-transfer training is responsible for the failure of the subjects to transfer matching performance to novel locations, observed by earlier researchers (e.g., Iversen et al., 1986). The authors questioned whether the post-transfer breakdown in matching performance (demonstrated by Iversen et al., 1986) may have been exacerbated by other factors, such as a bias to respond to the closest comparison stimulus on trials where the sample was presented in novel side-key locations. Lionello-DeNolf and Urcuioli questioned whether a modification to the training procedure would facilitate greater transfer to novel, post-transfer stimulus locations.

An important procedural difference between Lionello-DeNolf and Urcuioli's experimental design and the one used by Iversen et al. (1986) was that during the first phase in Lionello-DeNolf and Urcuioli's study, the sample always appeared on either side key and the comparisons appeared on the remaining two keys, whereas in the study conducted by Iversen and his colleagues, the sample always appeared on the center key and the comparisons appeared on the side keys.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) used a two-alternative conditional discrimination procedure. The stimuli were three black vertical or horizontal lines on a white background presented on a three-key horizontal panel. The study involved two groups of pigeons. For both groups, the training procedures consisted of a conditional discrimination with vertical and horizontal lines appearing as samples and comparisons. The sample stimuli were presented on the side keys and the comparison stimuli were presented on the remaining two keys. The samples appeared on each key with equal probability. The difference between the two groups was the *type* of conditional discrimination they were exposed to during training. "Group Identity" was trained on identity matching-to-sample, while "Group Oddity" was trained on oddity-from-sample. Each training session consisted of 96 trials. The sessions were conducted 6 days per week. For each bird, the acquisition criterion was set at 90% accuracy over 5 of the 6 weekly sessions. The testing phase began immediately following acquisition of the criterion. The testing phase consisted of a matching-to-sample task for both groups, with the sample appearing on the center key and the comparison stimuli being presented on the side keys. For both groups, the testing phase of the experiment was comprised of 10 reinforced sessions. Each 96-trial session included 64 baseline trials, where the sample appeared on the side keys and the comparisons on the remaining two keys (as during training). The reinforcement contingencies for each group were the same as during training. The baseline trials were intermixed with 32 test trials, where the sample appeared on the center key and the comparisons were presented on the side keys. The trials were presented in four consecutive blocks, where each block consisted of 16 baseline trials and 8 test trials.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) found that the novel-location performance for Group Identity was above chance (ranging from 60% to 87%). As Sidman (1980) pointed out, accuracy alone may not always be the best measure of conditional discrimination. In an analysis of various forms of stimulus control that may be generated in a conditional discrimination procedure, Sidman noted that stimulus or position preference may interfere with the acquisition of conditional discrimination as specified by the experimenter, stressing the importance of a more complete analysis than that offered by accuracy alone. In their analysis of the matching performance of Group Identity birds on the first post-transfer session, Lionello-DeNolf and Urcuioli reported no substantial differences in the accuracies between vertical and horizontal stimuli. The transfer of Group Oddity to a novel location, as well as to novel (matching-to-sample) procedure, resulted in performance that was well below chance (ranging from 16% to 22%). The authors reported that Group Oddity continued to choose the odd comparison on at least 50% of the post-transfer test trials. Group Oddity served as a comparison / control group for Group Identity on post-transfer trials, to determine whether the relatively fast acquisition of identity-matching on novel center-key sample trials was the result of prior training with left- and right-key samples or simply reflected nonspecific factors (e.g., any conditional discrimination task, such as “oddity-from-sample”). It should be noted that for Group Oddity, it is difficult to separate the effect of location change from the effect of change in contingency. The authors’ report of generalization of matching performance to novel locations appears to contradict pilot findings noted earlier with pigeons, as well earlier studies with other species (Iversen et al, 1986; Iversen, 1997), where a breakdown of matching following transfer to novel stimulus locations was reported. Lionello-DeNolf and Urcuioli noted that while previous studies (e.g., Iversen et al, 1986; Iversen, 1997) had indicated that physically identical stimuli are not functionally the same to the animals when they appear in new locations, their own results contradicted such claims by demonstrating that, to Group Identity, vertical and horizontal line stimuli were, in fact, functioning as the same sample and comparison stimuli to the pigeons, irrespective of location. Lionello-DeNolf and Urcuioli argued that the type of modification to the typical matching-to-sample procedure during training (i.e., training with the sample appearing on either of the side keys) was responsible for the discrepancy between their findings and the data obtained by Iversen and his colleagues. The authors concluded that such a modification resulted in the pigeons actually acquiring identity matching *independent* of stimulus location. Lionello-DeNolf and Urcuioli reasoned that training with side-key samples and testing with center-key samples eliminated the possibility of the Group Identity birds developing a bias to peck on the comparison key nearest to the sample, thus improving the chances of location-independent stimulus control in a matching-to-sample conditional discrimination task.

Although the data obtained by Lionello-DeNolf and Urcuioli (2000, Experiment 1) appear to be in favor of the single rule model, it is possible to examine their results in terms of the multiple-rule model. Lionello-DeNolf and Urcuioli initially trained their birds on matching tasks with vertical and horizontal lines appearing as samples and comparisons. The sample was presented on the left key during half of the trials and on the right key during the other half. A response on the sample stimulus was followed by the presentation of the comparison stimuli on the two remaining keys. For example, $V_L \rightarrow V_C$, $V_R \rightarrow V_L$, $H_R \rightarrow H_C$, $H_L \rightarrow H_R$ where V designates the vertical line, H designates the horizontal line and the subscripts C, R, and L designate center, right, and left stimulus locations, respectively.

As the data obtained by Iversen et al. (1986) suggest, location may be a part of the rule learned by the pigeon in a conditional discrimination task. Accordingly, when a pigeon trained on matching tasks with the sample appearing on the side keys is tested for generalization with the sample appearing on the center key, for each stimulus, it must now acquire two additional rules to demonstrate matching-to-sample, namely $V_C \rightarrow V_L$, $V_C \rightarrow V_R$ and $H_C \rightarrow H_L$, $H_C \rightarrow H_R$. However, according to the multiple-rule model, a bird trained with the sample on the center key must acquire four novel rules for each stimulus when transferred to the condition with the sample appearing on the side keys. Namely, $V_L \rightarrow V_R$, $V_L \rightarrow V_C$, $V_R \rightarrow V_L$, $V_R \rightarrow V_C$ and $H_L \rightarrow H_R$, $H_L \rightarrow H_C$, $H_R \rightarrow H_L$, $H_R \rightarrow H_C$. Therefore, the difference between the post-transfer data obtained by Iversen et al. (1986) and those data obtained by Lionello-DeNolf and Urcuioli (2000, Experiment 1) may be in the number of novel rules the subjects had to acquire to demonstrate matching performance, with Iversen's monkeys having to learn twice as many rules.

Iversen et al. (1986) showed that stimulus location is an important variable in the acquisition of matching-to-sample performance with line stimuli in the monkeys. Failure of the monkeys to transfer matching performance to novel stimulus locations suggested that the monkey's performance on the matching tasks was governed by specific sample / comparison associations which included stimulus locations. Accordingly, the matching-to-sample findings of Iversen and his colleagues support the multiple rule model of conditional discrimination.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) argued that training the pigeons on a matching task with sample stimuli on the side keys and testing the birds with the samples on the center key enables the pigeons to learn nominal associations between samples and comparisons (i.e., irrespective of the locations). As noted earlier, although Lionello-DeNolf and Urcuioli's data appear to favor the single-rule model, it is possible to examine their findings in terms of the multiple-rule model. Nevertheless, a direct comparison of the findings of Lionello-DeNolf and Urcuioli and those of Iversen and his colleagues (1986) is difficult, due to the possibility of species-specific differences.

Using a single species, the pigeon, the present study addressed oddity-from-sample performance in the pigeon and the extent to which such performance would transfer to novel stimulus locations. One of the goals of the present study was to assess the data in terms of the predictions of the single-rule and multiple rule models of conditional discrimination.

As noted earlier, previous findings on oddity-from-sample performance in the pigeon support the multiple rule model of conditional discrimination (Cumming & Berryman, 1965). To investigate generalization of oddity performance in the pigeon to novel sample locations, the present study consisted of two groups of birds being exposed to two consecutive experimental phases. Both groups were trained using a standard oddity-from-sample procedure with vertical and horizontal lines. In Phase 1 of the procedure, Group A was trained with the sample always appearing on the center key and the comparisons on the side keys. Concurrently, Group B was trained with the sample appearing on one of the side keys and the comparisons on the center and the remaining side key. The transfer test (i.e., Phase 2) consisted of reversal of the procedures between the two groups, where Group A was exposed to the sample on the side keys and Group B was exposed to the sample on the center key.

The multiple-rule model predicts that the greater the number of rules, the longer the acquisition of an oddity task will take (Carter & Werner, 1978). For example, this prediction could account for the difference between the rates of acquisition of a matching task and of an oddity task, using a three-alternative conditional discrimination procedure. While both matching and oddity tasks may involve the same three hues, acquisition of the matching problem requires acquisition of three rules (R→R, G→G, B→B), while acquisition of an oddity problem requires six rules, depending on the availability of the correct comparison (R→G, R→B, G→R, G→B, B→R, B→G). Furthermore, when only two alternatives are used, there should be no difference in the rate of acquisition of matching and oddity. In subsequent research, the data obtained by Zentall and Hogan (1974) offered empirical support for this assumption. Using two hues, the authors demonstrated no apparent difference between the rate of acquisition of matching and the rate of acquisition of oddity.

If the birds' performance on line oddity tasks is governed by a universal concept, where the pigeons acquire sample / comparison associations irrespective of location (namely, V→H and H →V), no substantial between-group differences in the number of sessions to reach Phase 1 criterion should be observed. Alternatively, multiple-rule model, which assumes that location is a part of what the birds learn about the associations, allows for the prediction that Group A birds should require substantially fewer sessions to reach accuracy criterion in Phase 1 than should the birds in Group B, given the double the number of rules to subjects in Group B would have to learn to reach the accuracy criterion.

Similarly, multiple rule model predicts that in Phase2, the birds in Group B should require substantially fewer sessions to reach oddity criterion than will the birds in Group A, again, as a function of the difference in the number of rules each group would have to learn to reach the criterion. Single rule model fails to make such a prediction, as it disregards location as a potential variable, taking into account only V→H and H→V presentations. The number of such presentations in Phase 2 is equal between the two groups.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) argued that training the birds with side samples and testing with center samples enhances the probability of the transfer of matching performance to novel locations by eliminating the probability of the bias to respond to the closest (i.e., center-key) stimulus. However, if, as the authors pointed out, the center-key bias is an inherent phenomenon on trials with side-key samples and correct side-key comparisons, such a bias should similarly be demonstrated by Group B birds in Phase 1 of the present study. Lionello-DeNolf and Urcuioli did not report the presence of the center-key bias during the training phase of their procedure. Additionally, if the center-key bias is alone responsible for the overall breakdown in oddity performance on novel locations, the transfer should only affect Group A's performance on trials with side-key samples and correct side-key comparisons. Group A's accuracies on trials with side-key samples and correct *center*-key comparisons should not be affected by the transfer, as the distance between the sample and the correct comparison on such post-transfer trials would remain the same as on pre-transfer trials.

Lionello-DeNolf and Urcuioli (2000, Experiment 1) argued that the modification to the typical training procedure resulted in a transfer of matching performance to novel locations, something that previous research failed to demonstrate. Using oddity-from-sample, the present study tested Lionello-DeNolf and Urcuioli's argument by directly comparing the procedure used by the authors to that used by Iversen and his colleagues (1986). Importantly, multiple rule model necessitates the specification of not only the type of training but also the type of a test used in the procedure; namely, in terms of the number of rules a pigeon has to acquire to reach mastery criterion.

Method

Subjects

Eight naive male White Carneaux pigeons were maintained at approximately 80% of their free-feeding weights. Each bird was randomly assigned a unique experimental chamber. The eight birds were divided into two groups (A and B), consisting of four birds each. Each bird was assigned an arabic numeral 1 through 4, preceded by the letter associated with that group (for example, A1 or B3). Bird A4 died during the early stages of the first phase of the experiment and was replaced by a female bird (assigned the same designation, A4). The data for the original bird are not reported. For the duration of the experiment, the birds had continuous access to water and grit in their home cages.

Apparatus

Sessions were conducted in four pigeon chambers equipped with three-key front panels (Coulburn Instruments; Model E10-109F). A vertical or horizontal white line on black background was presented on each key by means of a projector (IEE One-Plane Readout) mounted behind each key. The chambers also contained automated feeders and were equipped with a houselight. White noise was delivered through speakers positioned behind of the front panels. All experimental contingencies and recording were controlled by a computer in an adjacent room, using software and programming language developed by MED Associates, Inc. (MED-PC v. 1.15). The experimental chambers were run simultaneously but independently of each other.

Procedure

Preliminary training. The pigeons were magazine trained over the course of three daily sessions (with approximately 20 food presentations per session). Following magazine training, the pigeons were exposed to three daily sessions of key-peck training. The intertrial interval (ITI) was 15 seconds. A white key light was used as a stimulus. Autoshaping procedure was used to train the pigeons to peck on the center key. Autoshaping trials consisted of the presentation of white light on the center key for a period of 8 sec followed immediately by the termination of the key-light and a 3 sec access to food. A peck on the lit key at any time during the 8 sec interval resulted in immediate key-light termination and access to food (Brown & Jenkins, 1968). Two of the birds (A3 and B2) failed to autoshape and were manually shaped to peck the center key. For the remaining six birds, center-key pecking was obtained within the first key-peck training session. The remaining key-peck training sessions consisted of 120 FR1 trials, where the white light was presented on either of the three keys (40 randomized presentations per key). A single key-peck on the illuminated key produced a 3-second access to grain. Responding on the dark key had no programmed consequence.

Oddity procedure. Each condition consisted of two phases. For Group A, Phase 1 consisted of oddity-from-sample training with the sample stimulus always appearing on the center key. This condition was termed Fixed Location Sample (FLS). A response on the sample stimulus produced comparison stimuli on the two side keys, while the sample key remained illuminated. A peck on the key with the comparison stimulus that did not match the sample line resulted in a 3-second access to mixed grain. A peck on the comparison key with the matching stimulus resulted in a blackout, during which no food was delivered and all the chamber lights were turned off for a period of 3 seconds. The procedure was noncorrectional, that is, an “incorrect” response did not result in re-exposure to the same condition. Following either food or a blackout a new trial immediately began. Pressing a key that was not illuminated had no programmed consequences at any point in the procedure. Phase 1 remained in effect until the birds met a 90% accuracy criterion (i.e., demonstrated oddity-from-sample) on 3 consecutive training sessions. At that time, Phase 2 was put in effect.

During Phase 2, the sample was presented on either left or right side keys and the comparisons were presented on the remaining two keys. This condition was termed Varied Location Sample (VLS). Both the initial performance (immediately following transfer) and the recovery of accuracy (performance on subsequent trials until criterion is met) were assessed. Phase 2 was in effect until each bird met a 90% accuracy criterion on 3 consecutive sessions. At that time, Phase 2 was terminated.

In both experimental phases, trials were presented in randomized blocks order, where each stimulus configuration appeared once in a given block before a new block of trials began. The number of trials in a given block was determined by the number of possible stimulus configurations under a given condition. Under both conditions, a session terminated once a bird was presented with 120 trials. A maximum of 2 hours was allowed to complete each session; if a bird failed to complete the trials, the session for that bird would terminate for the day.

For Group B, the experimental phases were presented in the opposite order. Phase 1 consisted of VLS training. Following the acquisition of a 90% accuracy criterion on 3 consecutive sessions, Phase 2 was put in effect. During Phase 2, the sample appeared on the center key and the comparisons appeared on the side keys (FLS). As with Group A, both the initial performance and the recovery of accuracy were assessed. Phase 2 ended when each bird met a 90% accuracy criterion on 3 consecutive sessions.

In both experimental phases, the birds were run six to seven days a week at approximately the same time each day. At the end of each daily session the birds were returned to the vivarium and fed according to their weight.

Results

The data were analyzed in terms of trial-types, as summarized in Table 1. The three trial-types in the present study correspond to the Iversen et al. (1986) classifications of “baseline,” “old,” and “new,” which were based on how closely the trial-types approximated the baseline condition. Because in the present study Group B was exposed to the “old” and “new” trial-types during the first phase of the procedure, Iversen et al.’s classification does not apply to the present findings. The trial-types in the present study were categorized as “center-side” (C→S), “side-center” (S→C), or “side-side” (S→S), irrespective of the side. In effect, FLS sessions consisted of C→S trial-type and VLS sessions were comprised of S→C and S→S trial types.

Table 1. Experimental conditions and the trial-types associated with them. FLS condition consisted of a single trial-type: C→S (when the sample was presented on the center key, the correct comparison was presented on the side key). VLS condition consisted of two trial types: S→C (where the sample was presented on the side key and the correct comparison was presented on the center key) and S→S (where the sample was presented on a side key and the correct comparison was presented on the remaining side key). Each of the three trial-types was associated with four sample / comparison rules.

Condition	Trial-Type	Rule
Fixed-Location Sample (FLS)	C→S	$V_C \rightarrow H_L$ $V_C \rightarrow H_R$ $H_C \rightarrow V_L$ $H_C \rightarrow V_R$
Varied-Location Sample (VLS)	S→C	$V_L \rightarrow H_C$ $V_R \rightarrow H_C$ $H_L \rightarrow V_C$ $H_R \rightarrow V_C$
	S→S	$V_L \rightarrow H_R$ $V_R \rightarrow H_L$ $H_L \rightarrow V_R$ $H_R \rightarrow V_L$

Acquisition of oddity

The birds in Group A began acquisition of oddity at an average of 53% correct (range, 50% to 58%). As shown in the top panel of Figure 1, following session 5, Bird A1 followed a pattern of rapid acceleration in accuracy, reaching the FLS condition criterion by session 9. As shown in top panels of Figures 2 through 4, Birds A2, A3, and A4, respectively, followed a similar pattern of acquisition, demonstrating a rapid increase to high levels of performance. The rapid increase was particularly notable in Bird A2. Following 9 sessions at near chance levels (50%), the bird demonstrated an improvement in performance by 31% from session 9 to session 10. Group A reached Phase 1 (FLS) criterion within an average of 25 sessions (range, 9 to 44).

Figure 1. Bird A 1.Top panel: Overall percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases. Bottom panel: Percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.

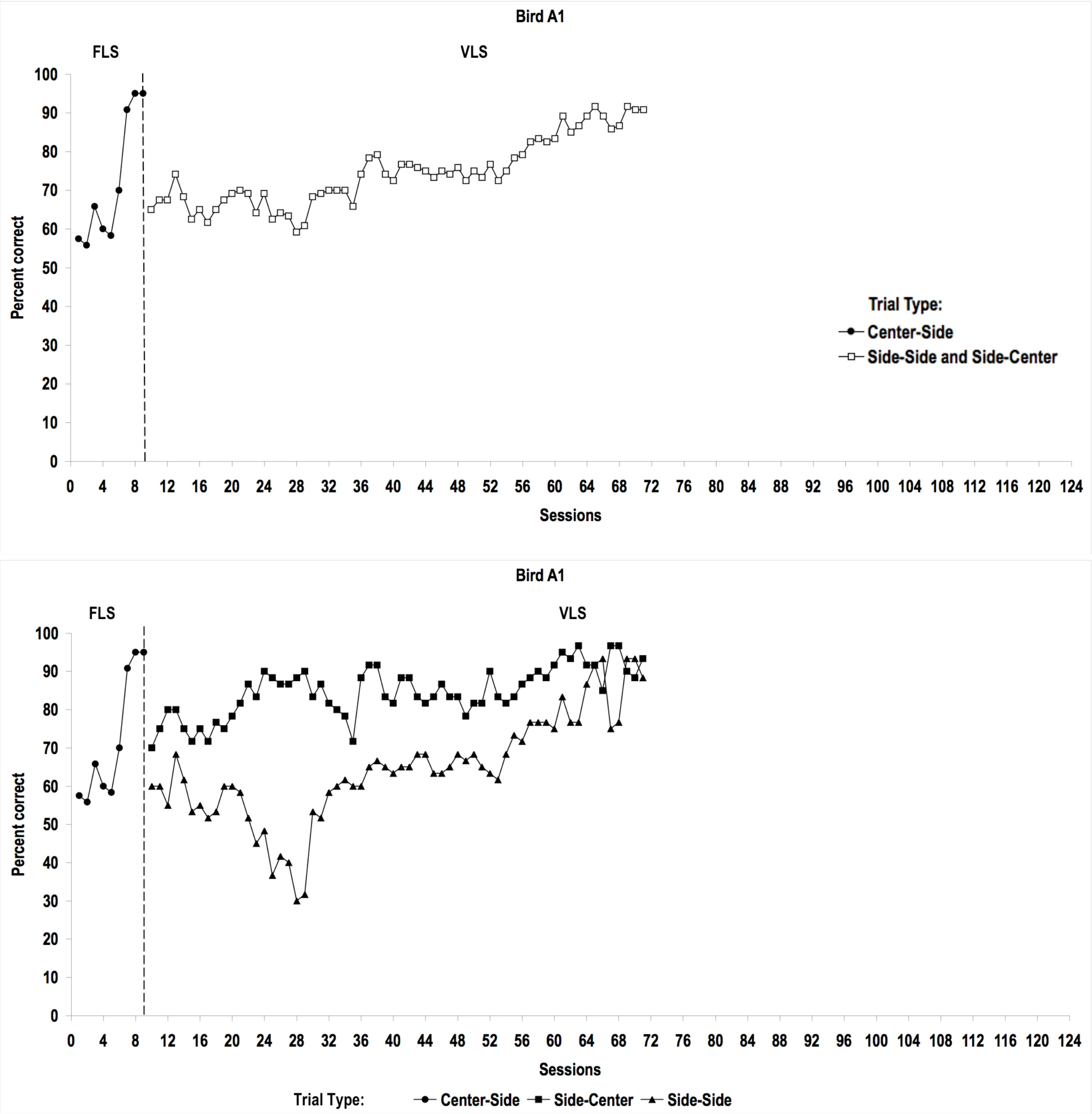


Figure 2. Bird A2. Top panel: Overall percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases. Bottom panel: Percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.

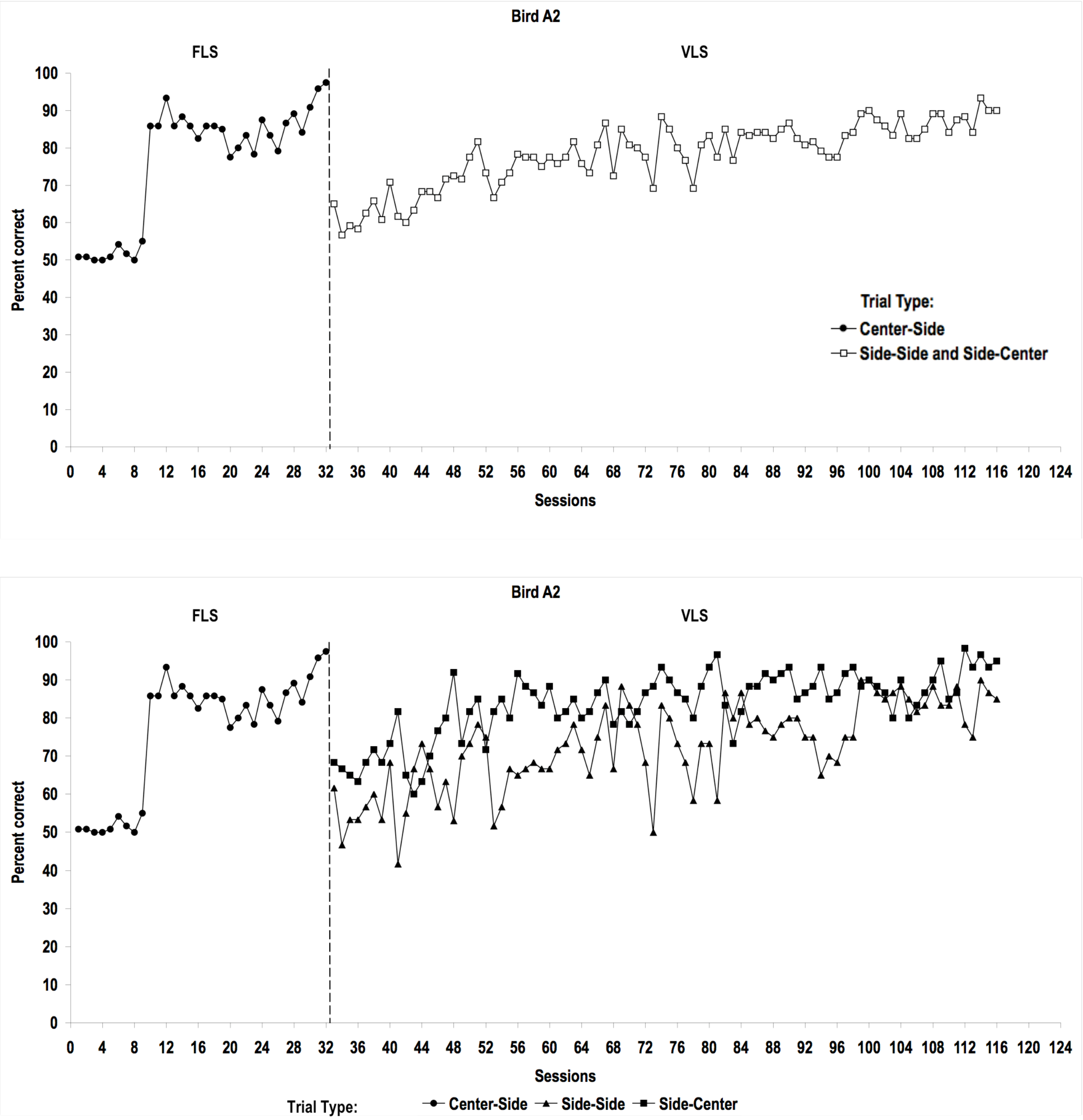
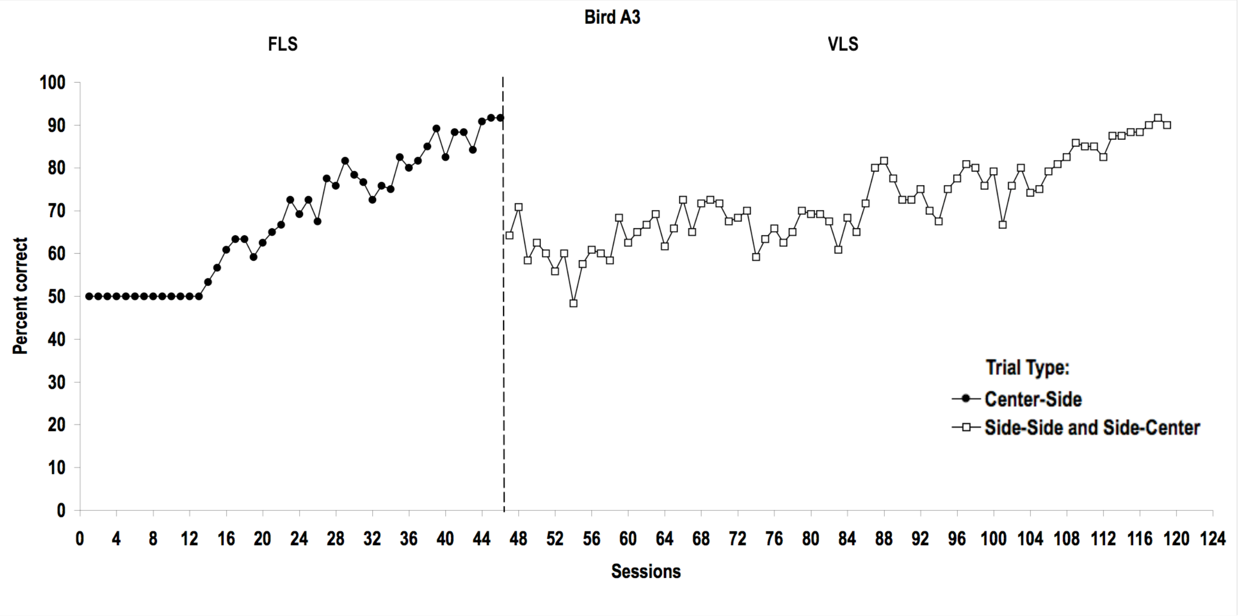


Figure 3. Bird A3. Top panel: Overall percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases. Bottom panel: Percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.



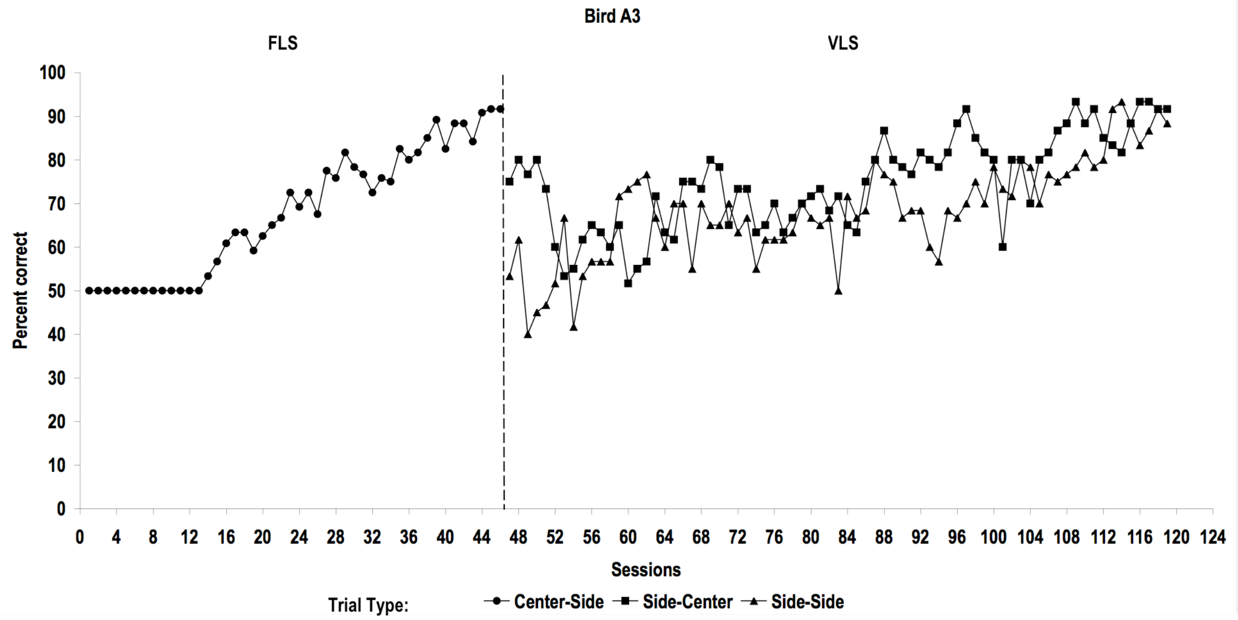
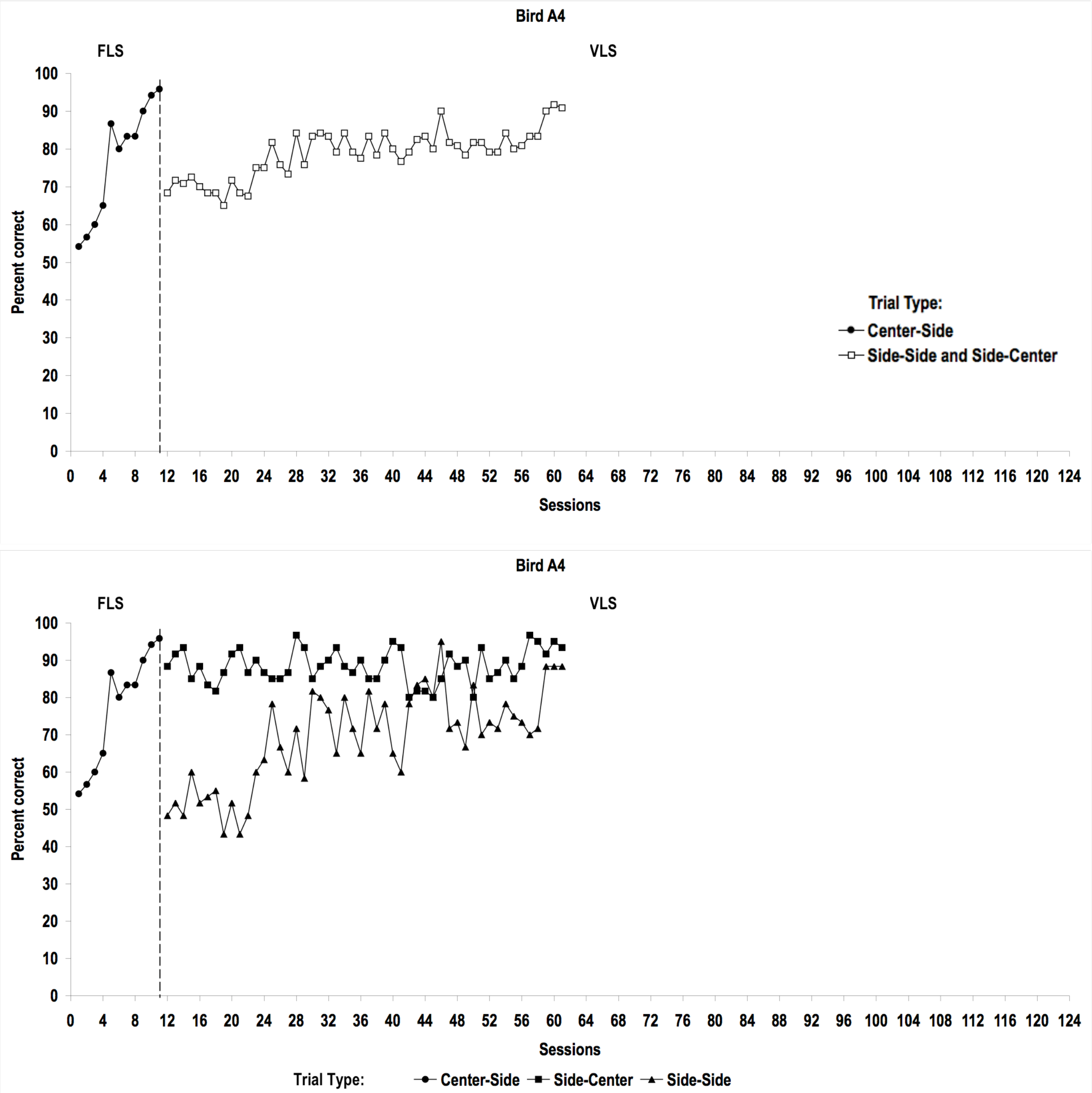
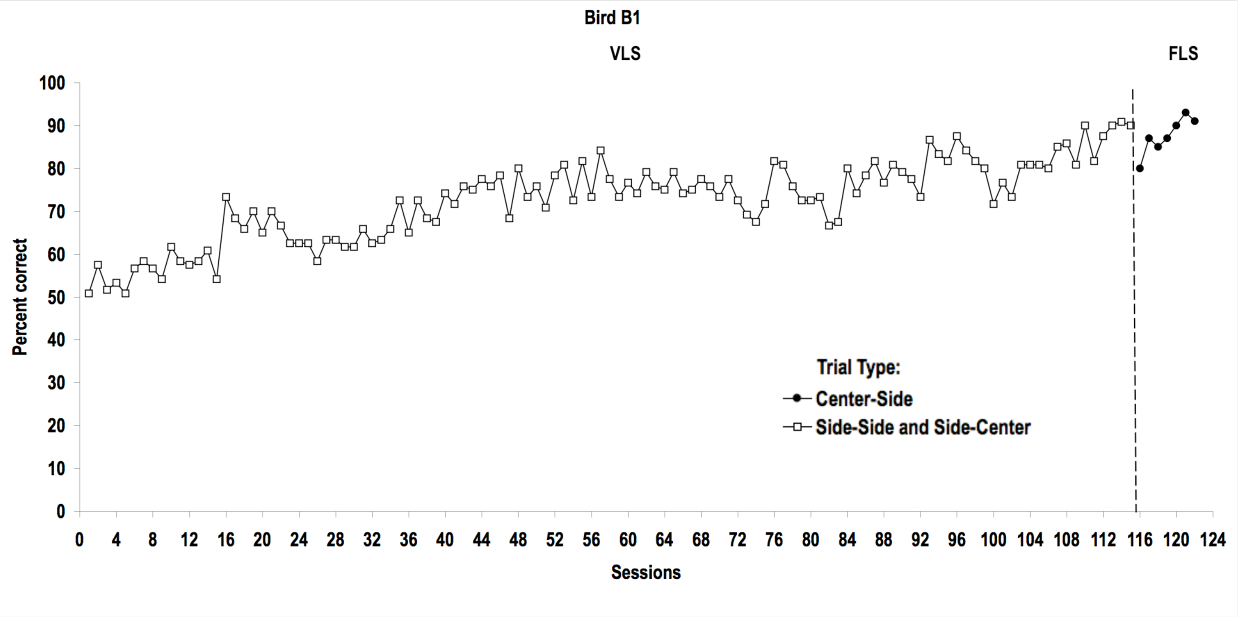


Figure 4. Bird A4. Top panel: Overall percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases. Bottom panel: Percentage of correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.



Group B birds required substantially greater number of sessions to reach the Phase 1 (VLS) criterion than did the birds in Group A. As shown in the top panels of Figures 5 through 8, Group B pigeons began acquisition of oddity at an average of 50% correct (the range was 48% to 51%). Unlike the birds in Group A, Group B birds followed a pattern of slow and steady acquisition, reaching the Phase 1 (VLS) criterion within an average of 105 sessions (range, 95 to 115).

Figure 5. Bird B1. Top panel: Overall percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases. Bottom panel: Percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.



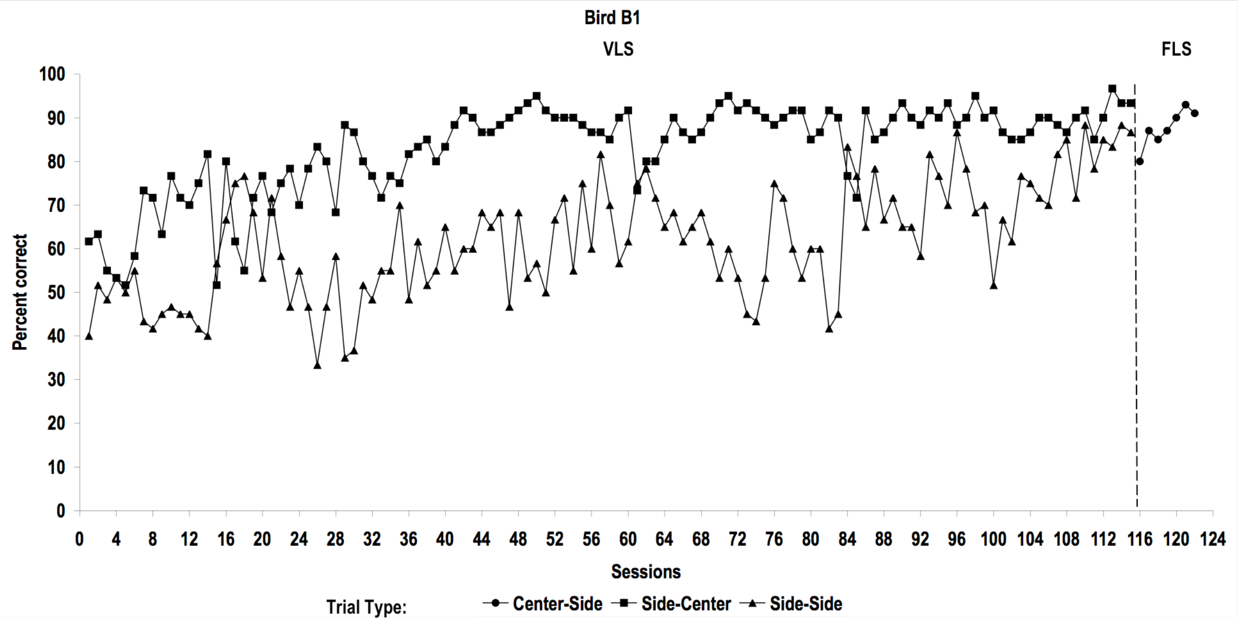
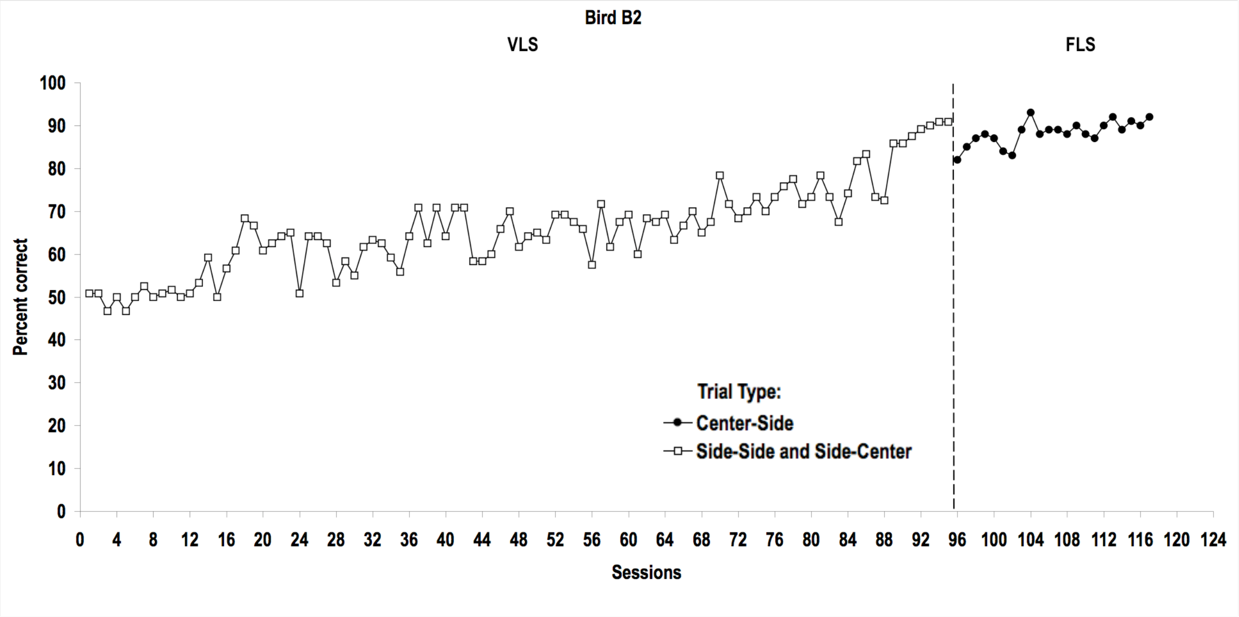


Figure 6. Bird B2. Top panel: Overall percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases. Bottom panel: Percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.



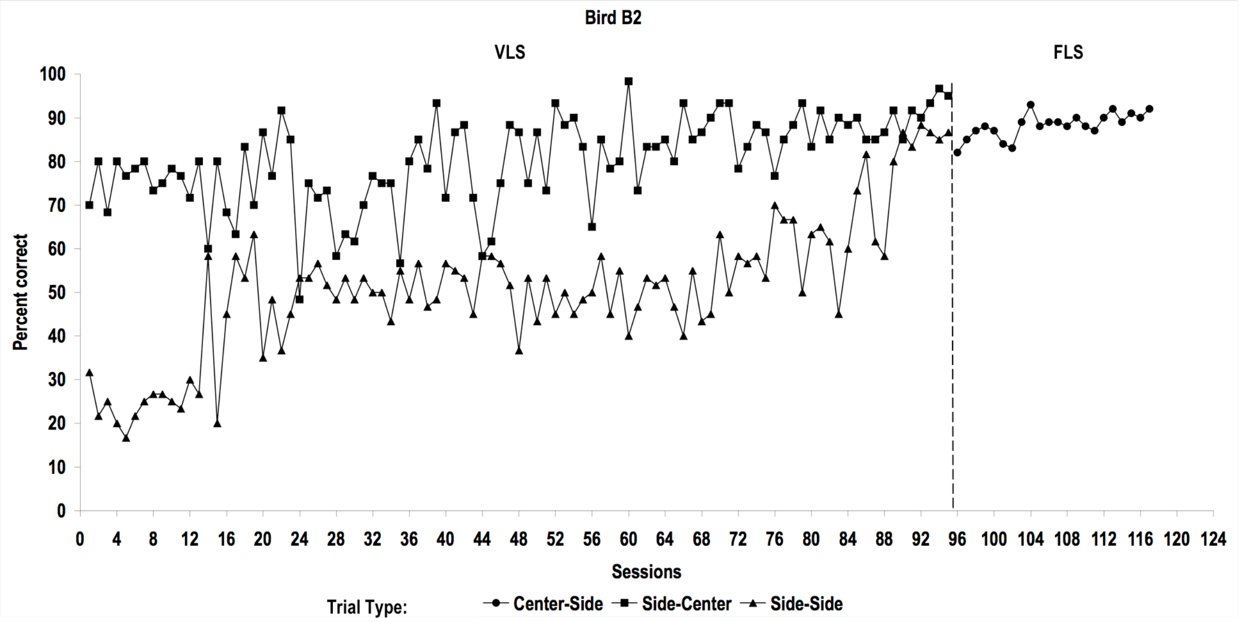
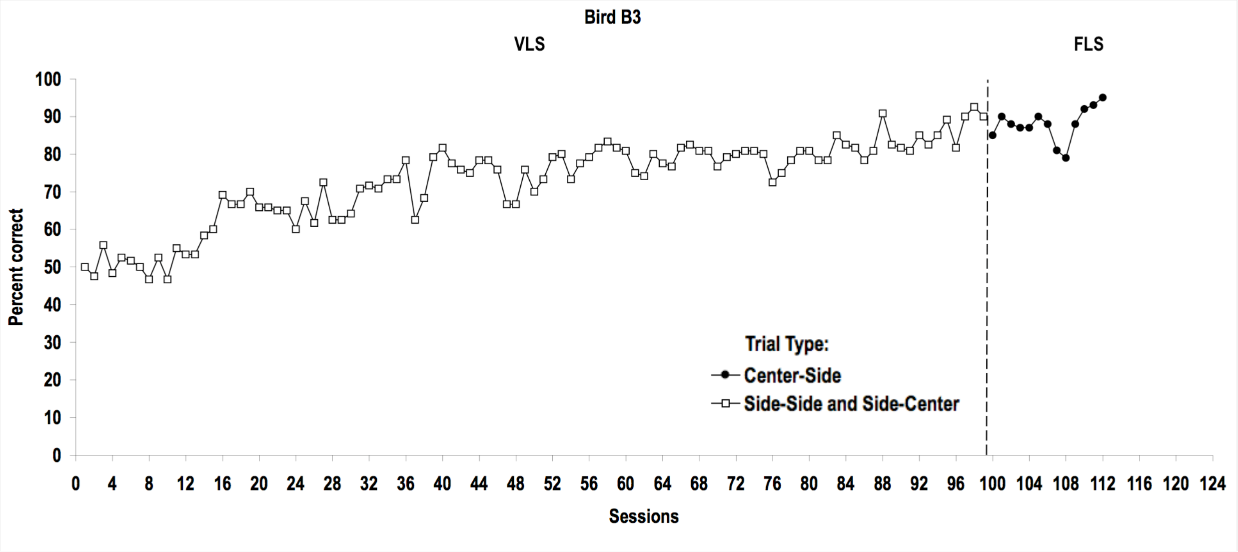


Figure 7. Bird B3. Top panel: Overall percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases. Bottom panel: Percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.



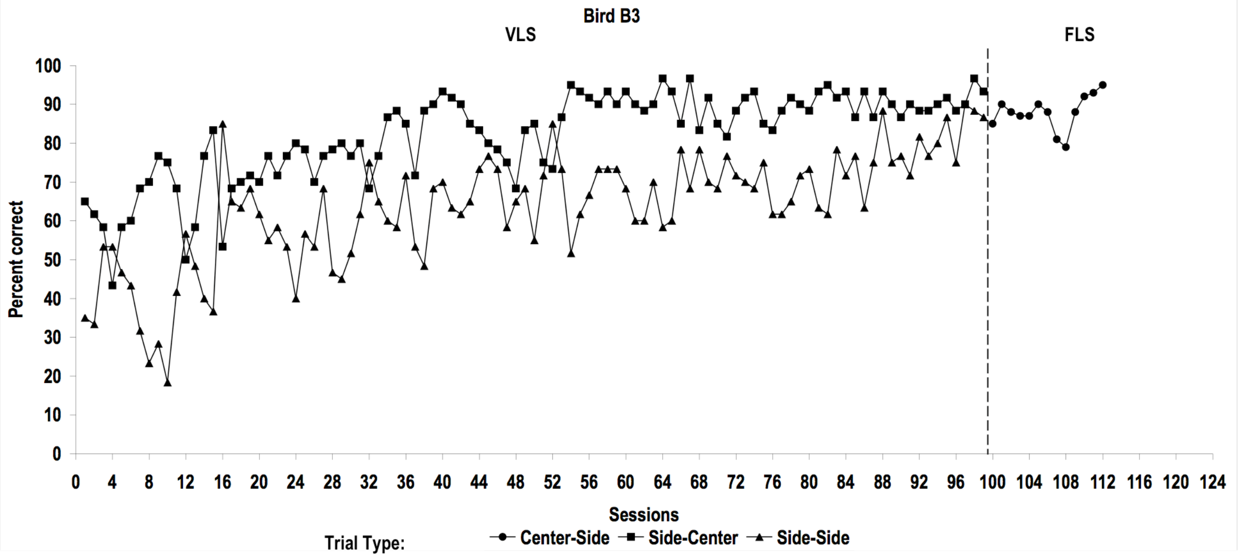
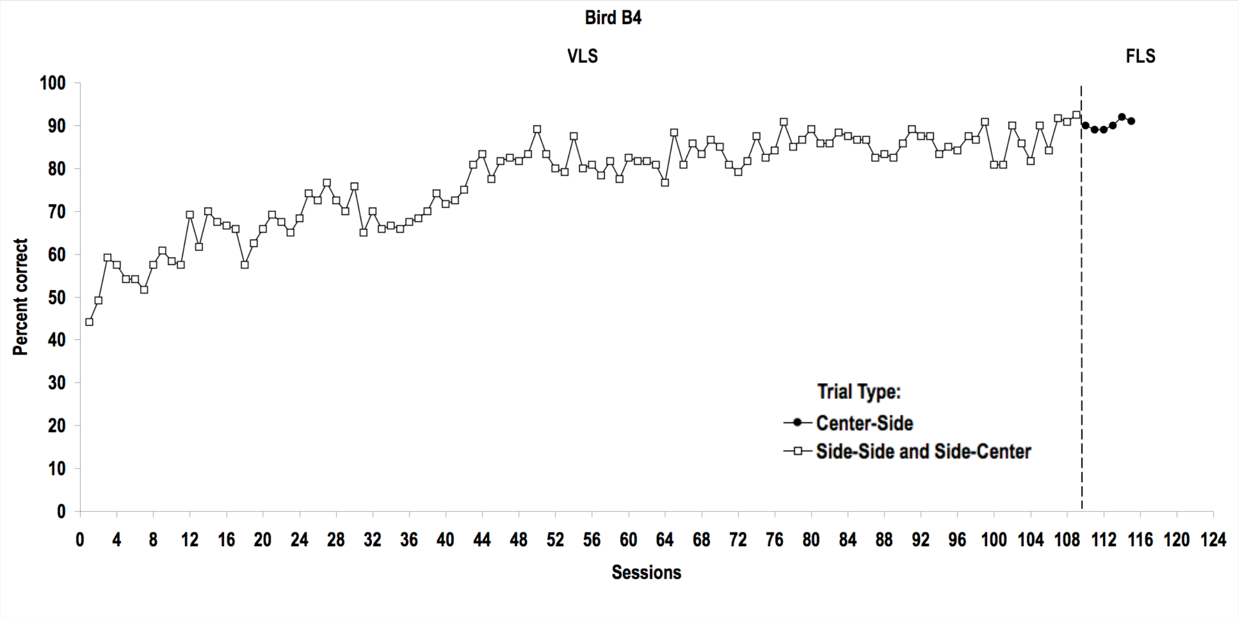
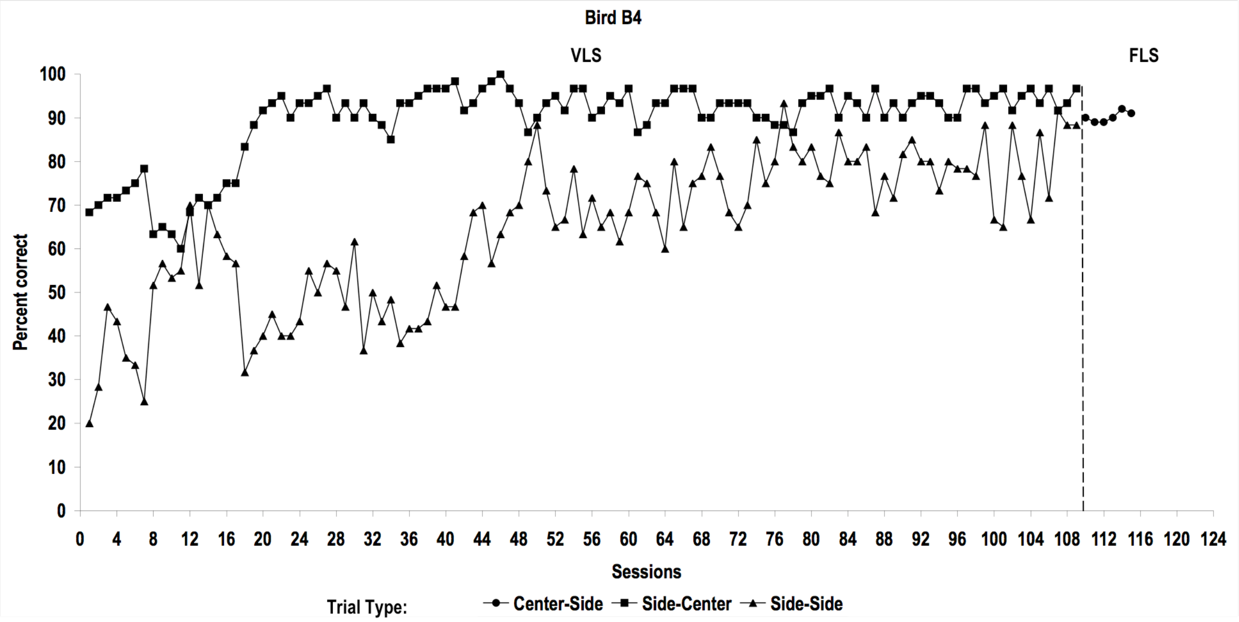


Figure 8. Bird B4. Top panel: Overall percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases. Bottom panel: Percentage of correct trials over the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) experimental phases expressed in terms of three trial-types in the line discrimination condition. Accuracy of performance on the VLS functions is shown in terms of total percent correct possible for each trial type.





The bottom panels of Figures 1 through 4 illustrate Group A's performance by trial-type on the FLS (Phase 1) and VLS (Phase 2) conditions, respectively. The FLS condition consisted of a single C→S trial-type. Accordingly, the Phase 1 data represented in the top panels of Figures 1 through 4 are identical to the data represented in the first phases of the bottom panels of those figures. The data represented in the second phases of the bottom panels of Figures 1 through 4 are analyzed by individual trial-type and are discussed in detail in the section on the post-transfer performance. The performance of Group A birds in Phase 1 is included in the bottom panels of Figures 1 through 4 to assist with direct comparison of performance between phases.

The bottom panels of Figures 5 through 8 illustrate Group B's performance in Phase 1 (VLS) by individual trial-types (namely, S→C and S→S). In a given VLS session, accuracy of performance on each trial-type is represented in terms of total percent correct. While Bird B1's combined score on the first VLS session was 51%, analysis by trial-type reveals that the bird reached 62% accuracy on the S→C session and only 40% on the S→S trials (Figure 5, bottom panel). Following a brief decline in accuracy, Bird B1's accuracy on S→C trials began to steadily improve, reaching 92% by session 42. The birds' accuracy maintained at relatively high levels for the remainder of the phase. As shown in Figure 5 (bottom panel), Bird B1's accuracy on S→S trials followed a highly variable pattern for most of the phase, only showing somewhat steady improvement beginning with session 100.

The discrepancy between trial-types was even more profoundly featured in Bird B2's initial acquisition of oddity on the VLS condition. As shown in the bottom panel of Figure 6, while overall accuracy on the first Phase 1 session was 51% (Figure 6, top panel), analysis by trial type reveals that Bird B2 reached 70% accuracy on S→C trials and only 32% on the S→S trials (in other words, showing high levels of responding on the center key). Furthermore, the bird continued to perform at substantially below-chance levels on S→S trials until session 16 and at moderately below-chance levels for most of the phase. The accuracy on S→C trials remained relatively variable from session-to-session. However, by session 61, the variability on S→C trials decreased, as accuracy steadily improved. The bird reached 93%, 97%, and 95% accuracy, respectively, on the last three Phase 1 sessions. In comparison, the Bird B2's accuracy on S→S trials for these three sessions were 87%, 85%, and 87%, respectively. Acquisition of these accuracies, combined with the S→C accuracies, enabled the bird to reach Phase 1 criterion in the VLS condition (namely, three consecutive sessions of 90% or above).

The bottom panels of Figures 7 and 8 illustrate acquisition of oddity by trial-type on VLS sessions for birds B3 and B4, respectively. As with Birds B1 and B2, the initial pattern of acquisition of oddity is characterized by greater overall accuracy on the S→C trial than on S→S trials. For Bird B3, this difference became more pronounced by session 54, where the bird's performance on the S→C trial-type reached 95% accuracy while its performance on S→S trials remained at near-chance levels. Bird B3's accuracy on S→C trial type remained at near 90% for the remainder of Phase 1. Following session 65, the bird demonstrated a relative decrease in session-to-session variability on S→S trials (accompanied by an improvement in accuracy), as its performance on that trial type continued to improve, peaking at 90% on session 97.

Bird B4's overall accuracy on the first VLS session was at 44% (Figure 8, top panel). However, an analysis by trial-type reveals a substantial difference in the accuracies between the bird's performance on the S→C trials, where the bird responded at 68% correct and its performance on the S→S trials, where, at 20%, the bird's accuracy was substantially below chance (Figure 8, bottom panel). Similar to the other three birds in Group B, Bird B4's accuracy on S→C trials remained relatively high for the remainder of the session. The bird's performance on S→S continued to improve at a much slower rate. Furthermore, the bird's performance on S→S trials remained highly variable throughout Phase 1 until the overall criterion of 90% across three sessions was met.

Transfer of oddity

Following acquisition of the accuracy criterion in Phase 1, the pigeons in Groups A and B were transferred to the VLS and FLS conditions, respectively. As shown in the top panels of Figures 1 through 4, transfer to the VLS condition, resulted in a substantial drop in accuracy for all birds in Group A. Bird A1's accuracy dropped from 95% of the last FLS session to an overall of 65% on the first VLS session (Figure 1, top panel). As shown in the top panel of Figure 2, Bird A2's accuracy also dropped to 65% from 98% on the previous, pre-transfer session. As the top panels of Figure 3 and Figure 4 illustrate, Bird A3 and A4's accuracies dropped to 64% and 68%, respectively. Following the transfer, Group A slowly re-acquired the oddity criterion. Birds A1, A2, A3, and A4 required 61, 83, 72, and 49 sessions, respectively, to re-acquire the oddity criterion.

The bottom panels of Figures 1 through 4 illustrate Group A's performance in Phase 2 (VLS) by individual trial types. The obtained post-transfer functions closely resemble those of Group B on the VLS condition. Figure 1 (top panel) shows that Bird A1's overall accuracy on the first post-transfer session was at 65%. However, as shown in the bottom panel of Figure 1, Bird A1 began Phase 2 at 70% correct on S→C trials and 60% on S→S trials. Over the course of subsequent sessions, the difference increased. By session 28, Bird A1's accuracy on S→S trials dropped to 30%, while its accuracy on S→C trials was at 88% for the same session. However, following session 28 the bird showed a steady increase toward the criterion, with relatively little day-to-day variability on both S→C and S→S functions.

The bottom panels of Figures 2 and 3 demonstrate post-transfer performance in Phase 2 for Birds A2 and A3, respectively. For both pigeons, the acquisition curves remained highly variable. Nevertheless, both birds were more accurate on S→C trials than on S→S trials. Of particular significance is the birds' performance on the initial post transfer sessions, with both pigeons performing with greater accuracy on S→C trials than on S→S trials. This difference in performance between the two trial types was also prominent in Bird A4's post-transfer functions (Figure 4, bottom panel). While the bird's overall accuracy was at 68% on the first post-transfer session, the trial-type analysis of that session reveals a substantial difference in the accuracy levels between the two types of VLS trials with the bird reaching 88% correct on the S→C trials and only attaining 48% accuracy on the S→S trials.

The top panels of Figures 5 through 8 show Group B's performance following transfer to the FLS (C→S) condition. As shown in the top panel of Figure 5, Bird B1's accuracy dropped from 90% accuracy on the last pre-transfer session to 80% on the first post transfer session. Bird B1 re-acquired oddity to criterion in 7 sessions. Following the transfer, Bird B2's accuracy dropped to 82% (Figure 6, top panel). While the bird's accuracy remained high throughout Phase 2, it required 21 sessions to re-acquire the oddity criterion. Birds B3 and B4 (Top panels of Figures 7 and 8, respectively) did not demonstrate a substantial drop in accuracy following the transfer to the FLS condition. Birds B3 and B4 required 13 and 4 sessions, respectively, to re-acquire the oddity criterion.

Analysis of bias: Group A

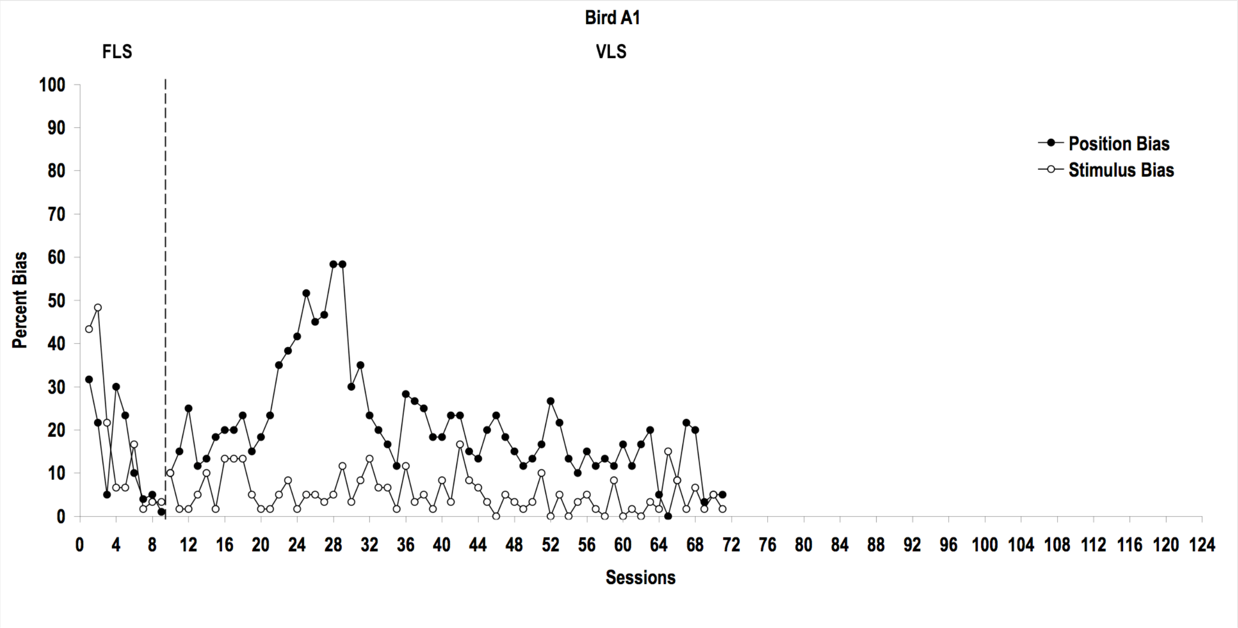
The birds' performance was further analyzed for position and stimulus (line-tilt) bias. Given equal reinforcement distribution between the contingencies, position and stimulus preferences may be categorized as inherent biases. As a number of researchers pointed out, an inherent bias refers to a preference in responding that remains invariant across changes in the relative reinforcer distribution (Baum, 1974; Davison & McCarthy, 1987; McCarthy & Davison, 1982).

For FLS sessions, the position bias data were calculated in terms of Left/Right comparison positions. For VLS sessions, the bias data were calculated in terms of Side/Center comparison positions. In a given session, position preference percentage was calculated by adding the absolute values of the deviations from 60 (chance responding) for each of the two comparison positions and dividing the obtained sum by 120, which was the total number of times any position could be chosen in a given session. Stimulus bias data for VLS and FLS sessions were calculated in the same manner, in terms of vertical and horizontal stimuli (Berryman, et al., 1965; Goldman & Shapiro, 1979).

Figures 9 through 12 demonstrate position and stimulus preference for the birds in Group A across the two experimental phases. As shown in Figure 9, during the first phase of the procedure, Birds A1 did not show substantial levels of position preference. By the end of Phase 1, position preference disappeared as the accurate performance on the C→S trials reached criterion level. Bird A1 showed some stimulus preference for the initial two sessions; however, by the third session stimulus preference dropped substantially and remained at negligible levels for the remainder of Phase 1.

As shown in Figure 9, following transfer to Phase 2, Bird A1 developed strong position preference, which culminated at 58% over sessions 28 and 29. High levels of position preference were correlated with low accuracy of performance on S→S trials, representing strong center-key preference. However, a decline in the position preference was not highly correlated with an improvement the bird’s overall performance on the VLS sessions. Furthermore, the failure of Bird A1 to improve its performance did not appear to be correlated with the presence of a stimulus bias (Figure 9).

Figure 9. Bird A1. Percentage of position and stimulus bias on the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) phases.



Bird A2 (Figure 10) developed a strong position bias in the early stages of Phase 1, reaching 100% (complete position preference) on sessions 3, 4, and 8. Accurate performance on C→S trials was highly correlated with the disappearance of the position bias. Although the bird's position preference remained somewhat variable for the duration of the phase, as with Bird A1, a reduction in position preference was not highly correlated with higher overall accuracy in a given session. Figures 11 and 12 show similar findings for Birds A3 and A4. As shown in Figure 10, Bird A2 did not demonstrate notable stimulus preference in either phase of the experiment.

While Bird A3's initial performance in Phase 1 (C→S) remained at 50% for the duration of 13 sessions, the analysis of bias reveals complete position preference on those sessions (Figure 11). While the bird's departure from complete position preference was correlated with an improvement in accuracy on C→S sessions, reduction in position bias did not guarantee an immediate improvement in accuracy. By session 12, Bird A3's position preference declined to an average of 6% for the remainder of the phase. Following the transfer to the VLS condition, Bird A3 showed an increase in both stimulus and position preference. The bird's stimulus bias reached 55% on session 48 (the second session of Phase 2), which was followed by a rapid decline in stimulus preference over the next five sessions. Nevertheless, the bird continued to show moderate levels of stimulus and position preferences for the remainder of Phase 2.

As shown in Figure 12, Bird A4 showed stimulus preference on the initial four sessions of Phase 1. By session 5, Bird A4 showed a substantial decline in stimulus preference, which remained at low levels for the remainder of Phase 1. Bird A4 demonstrated low levels of position preference for the duration of Phase 1, showing no relationship between position bias and accuracy of performance. During Phase 2, Bird A4's stimulus and position preference remained below 50%.

Figure 10. Bird A2. Percentage of position and stimulus bias on the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) phases.

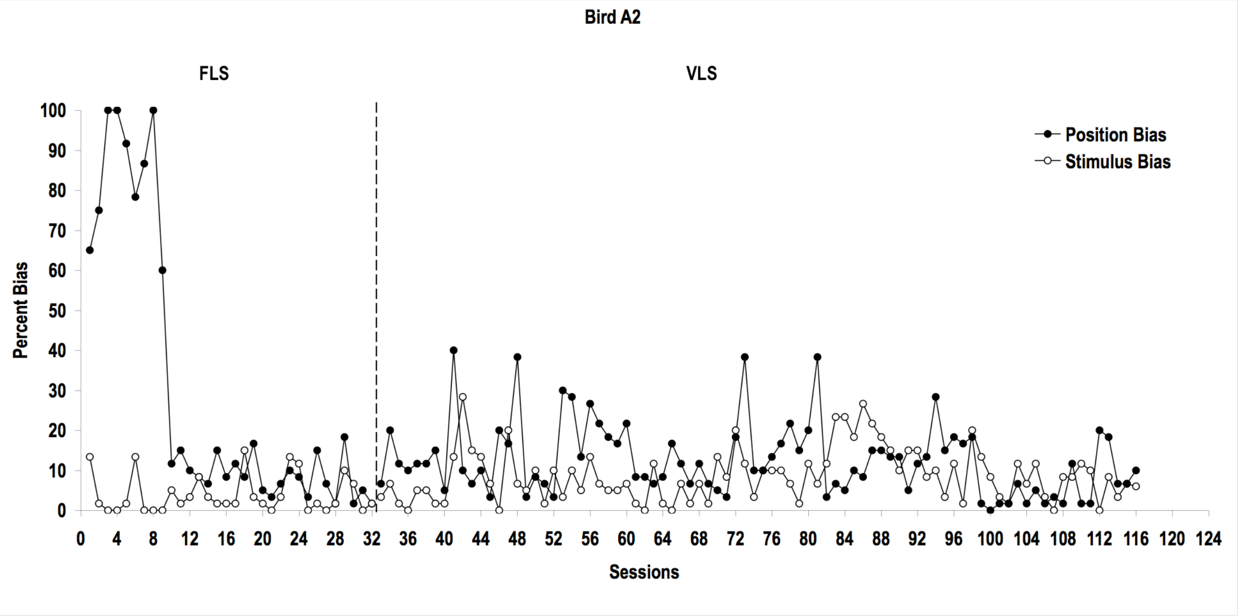


Figure 11. Bird A3. Percentage of position and stimulus bias on the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) phases.

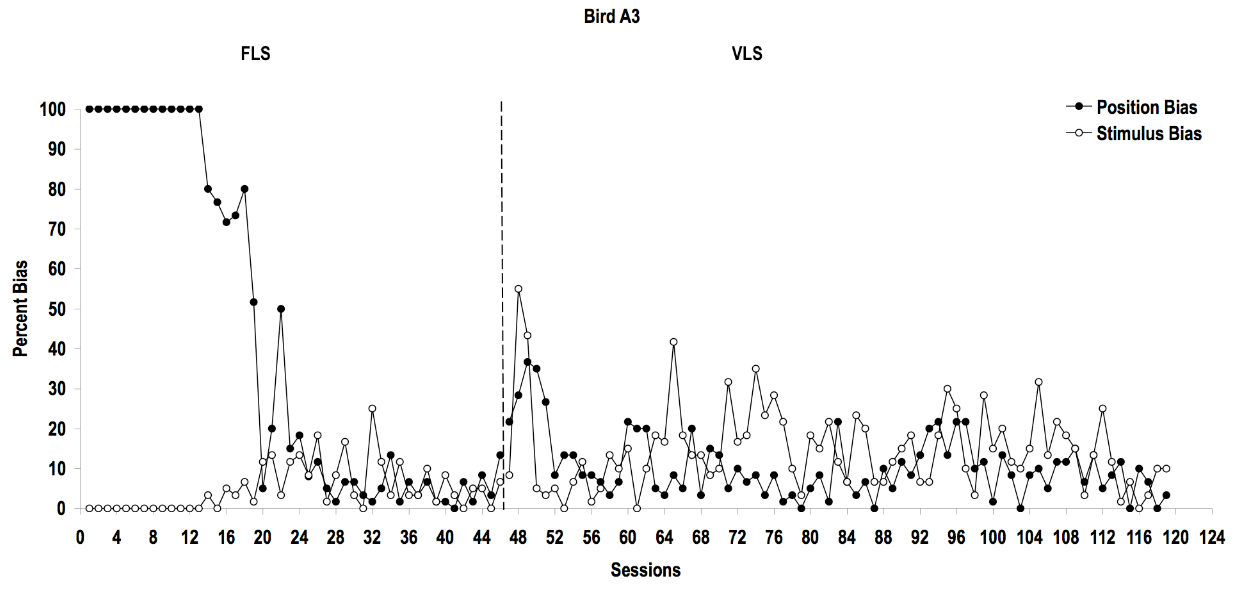
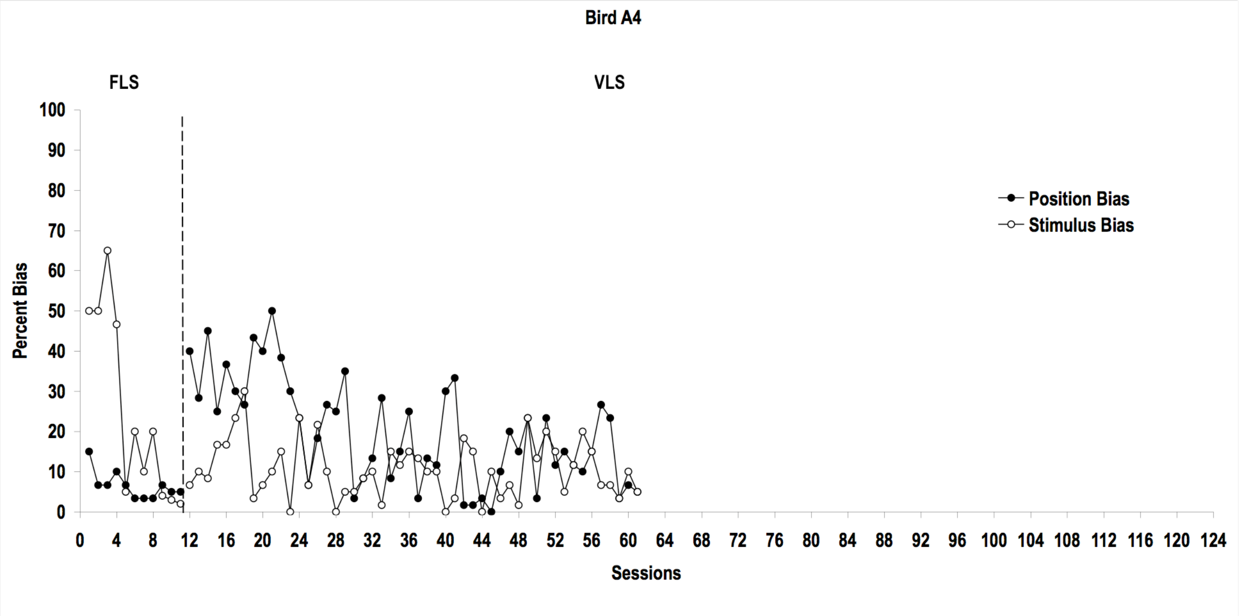


Figure 12. Bird A4. Percentage of position and stimulus bias on the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) phases.



Analysis of bias: Group B

As shown in Figures 13 through 16, Phase 1 (VLS) position preference functions of Group B closely resemble those of Group A during the VLS sessions, in terms of session-to-session variability. Similar to Group A's performance on VLS sessions, high levels of position preference were shown to be correlated with low levels of accuracy of performance on S→S trials, demonstrating strong center-key preference. As with Group A birds, Group B's decline in the position preference did not appear to be highly correlated with an improvement in the bird's overall performance on the VLS sessions.

With the exception of Bird B4, the variability in the position preference of the Group B birds generally subsided toward the end of Phase 1, showing little relation with the relatively high accuracy values as the birds approached oddity criterion levels.

Transfer to Phase 2 (FLS) did not yield notable position bias for Group B birds, with the highest percentage of 15% produced by Bird B2 on the 6th post-transfer session.

By definition, an error on an S→S trials is a center key response. When exposed to the VLS condition, all eight pigeons showed a temporary strong center-key bias, as is evidenced by the substantial below-chance performance on a number of S→S trials in that condition. However, as shown in the bottom panels of Figures 1 through 8, a low scores on S→S trial-types did not systematically correlate with high scores on S→C trial-types, indicating relative independence of the S→C acquisition functions for all eight birds. Furthermore, neither of the eight birds in the VLS condition demonstrated absolute position preference, as they had in the FLS condition.

The birds' performance was further assessed for stimulus preference. As shown in Figures 13 through 16, none of the Group B birds demonstrated notable stimulus bias.

Figure 13. Bird B1. Percentage of position and stimulus preference on the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) phases.

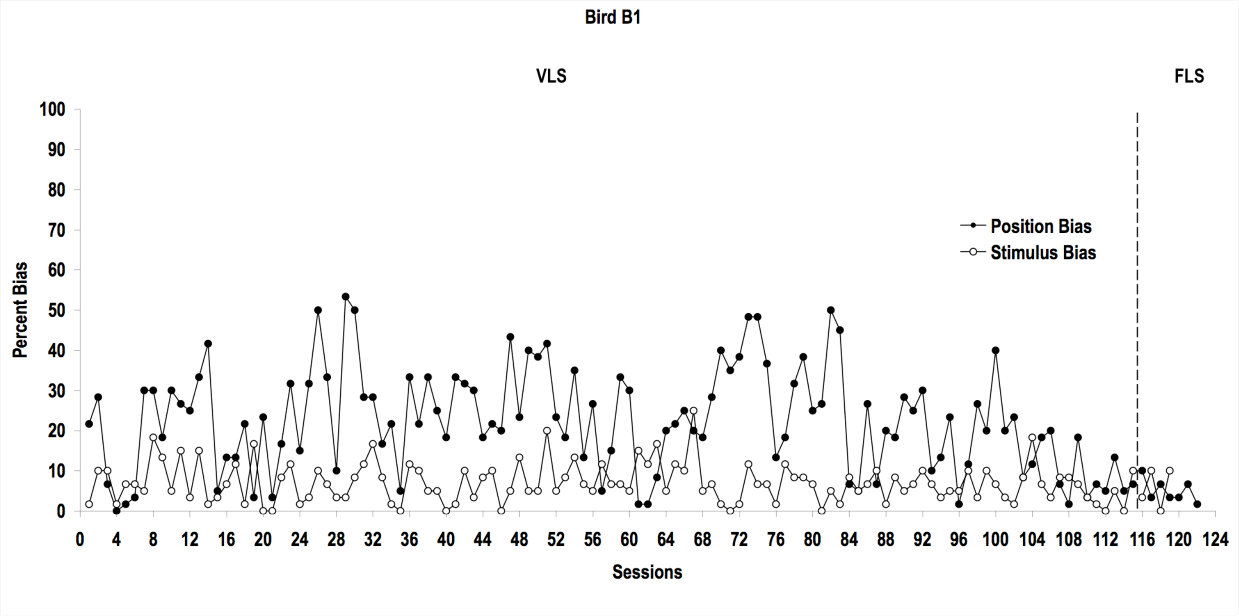


Figure 14. Bird B2. Percentage of position and stimulus bias on the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) phases.

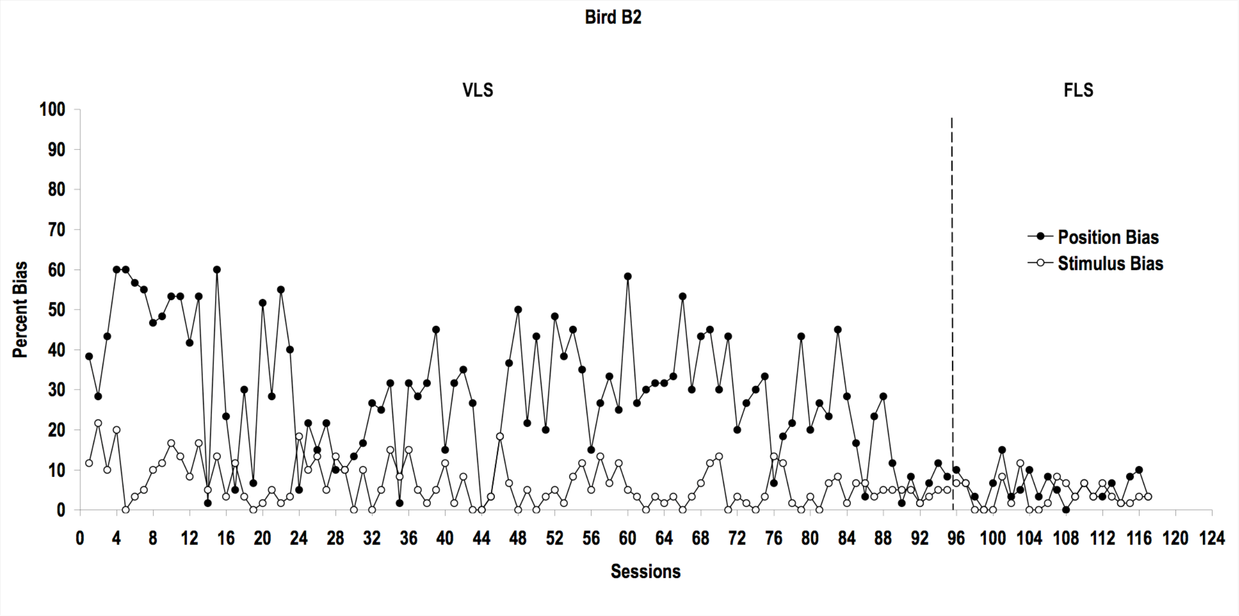


Figure 15. Bird B3. Percentage of position and stimulus bias on the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) phases.

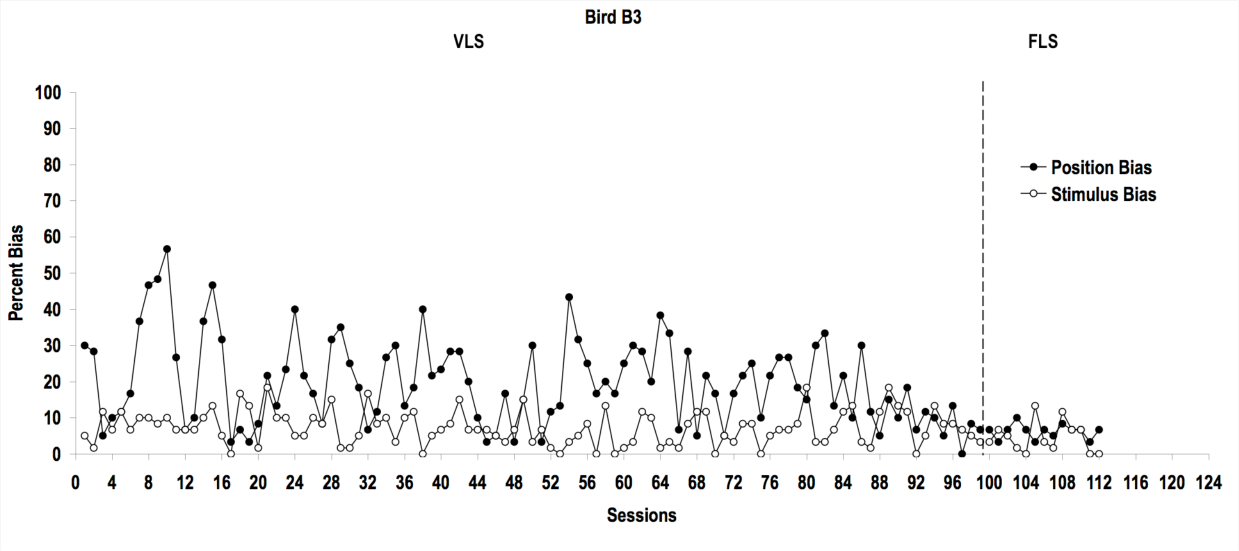
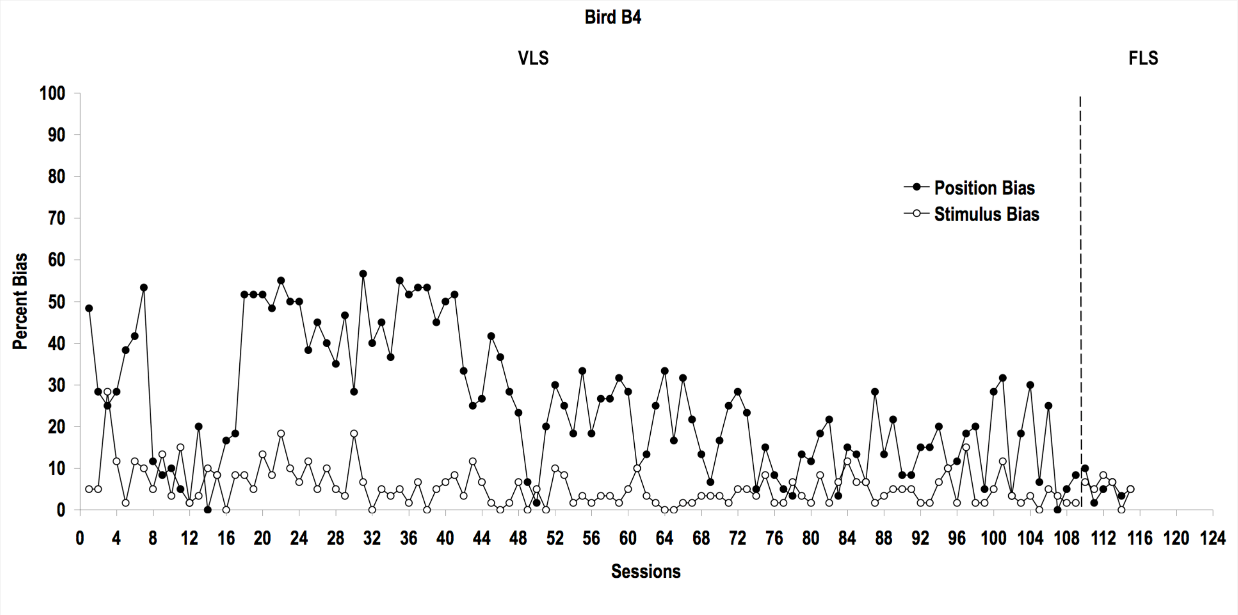


Figure 16. Bird B4. Percentage of position and stimulus bias on the Varied-Location Sample (VLS) and Fixed-Location Sample (FLS) phases.



Discussion

In the present study, pigeons in Group A were trained on oddity-from-sample with vertical and horizontal lines, with the sample always appearing on the center key and the comparison stimuli appearing on the side keys (Fixed Location Sample condition). Following acquisition of oddity, the pigeons were transferred to the Varied Location Sample condition, where the sample stimulus appeared on either the left or the right keys and the comparisons were presented on the center key and the remaining side key. The transfer resulted in a breakdown in accuracy of performance to levels resembling those observed during the initial acquisition of oddity for that group.

These findings were consistent with those of the Iversen et al. (1986) study with monkeys on the transfer of matching-to-sample performance to novel locations, where a substantial breakdown in accuracy was also observed. Iversen and his colleagues further analyzed the post-transfer performance in terms of three trial-types. “Baseline” trials were those where the sample stimulus appeared on the center key and the comparison stimuli were presented on the side keys. Accordingly, “baseline” trials corresponded to the C-S trial type of the present study. “Old” trials were those where the sample appeared on either side key and the correct comparisons were presented on the center key. These trials corresponded with S-C trial-type of the present study. Finally, on “new” trials the sample was presented on either side key and the correct comparison was presented on the remaining side key. The new trials corresponded with the S-S trial-type of the present study.

In addition to the breakdown of matching performance, Iversen et al. (1986) observed that during the post-transfer sessions, the monkeys’ performance on “new” trials dropped to levels substantially below chance, reaching as low as 20% in one of the monkeys. The authors further observed that the monkeys' performance on "old" trials quickly improved and was subsequently maintained at levels approaching performance those observed on "baseline" trials.

An analysis by trial-type conducted in the present study showed a similar pattern of post-transfer performance in oddity-from-sample in the pigeon. As shown in the bottom panels of Figures 1 through 4, the accuracy of performance of Group A birds on what Iversen referred to as "new" trials (here referred to as S→S trials) was substantially lower than the accuracy obtained on "old" trial types (termed S→C in the present study). To further investigate the obtained gradation in the accuracy of performance between trial-types, an analysis of position preference was performed. The data shown in Figures 9 through 12 show relatively high levels of position biases for the birds in Group A on the post-transfer condition that were maintained for most of the phase. Substantial levels of position preference were correlated with low accuracy of performance on S→S trials, representing strong center-key preference. Nevertheless, a decline in position preference was not highly correlated with an improvement in the birds' overall performance on the VLS sessions.

The birds had more difficulty with acquiring oddity on S→S trials than on S→C trials. Additionally, Iversen et al. (1986)'s analysis of post-transfer matching performance showed a brief stimulus preference for the vertical stimulus in one of the monkeys. As Sidman (1980) pointed out, stimulus preference indicates discriminability between the stimuli used in an experiment. In the present study, Group B birds showed no substantial preferences for vertical line or horizontal line comparison stimuli, indicating the possibility that the line stimuli in an oddity procedure are not as readily discriminated by the pigeon, particularly when the sample and comparison stimuli are initially presented in varied locations. Birds A1 and A4 showed stimulus preference during the initial sessions of Phase 1. Birds A1 and A4 demonstrated a rapid decline in stimulus preference by sessions 3 and 5, respectively. While Bird A2's stimulus preference remained at low levels during both phases of the procedure, Bird A3 showed an increase in stimulus and position preference following the transfer to Phase 2. As Bird A3's stimulus preference began to decline from the peak of 55% on session 48, the bird's accuracy did not immediately improve due to the presence of position preference. The data obtained in the present study suggest that, in addition to the acquisition of specific stimulus-comparison associations, acquisition of oddity-from-sample in the pigeon is closely associated with a reduction in position preference. Furthermore, with Bird A3, acquisition of oddity was also associated with a reduction in stimulus bias.

In accordance with Sidman's (1980) analysis, dependence on accuracy alone in the assessment of conditional discrimination may lead one to erroneous assumptions regarding the extent to which the controlling relations are those specified by the researcher. Sidman's assertion is illustrated in the initial acquisition of oddity by Bird A3 in Phase 1 (Figure 3, top panel). The bird reached 50% accuracy on the first 13 sessions, which would typically be regarded as "chance" performance. However, further analysis reveals that the bird demonstrated complete position preference (Figure 11). While responding exclusively on a particular key, the bird did not meet experimental contingencies. As Sidman pointed out, with a key preference exerting complete control, the line stimuli may be irrelevant to the subject. Bird A3's performance offers some support to Sidman's claim. When compared to the Phase 1 performance of the other birds in Group A (as shown in the top panels of Figures 1 through 4), Bird A3 required more sessions to reach the criterion than did the other birds in the group, particularly Birds A1 and A4, which showed substantially lower rates of position preference (as shown in Figures 9 and 12, respectively).

Sidman's (1980) argument concerning the limitations of overall accuracy as a measure of conditional discrimination may be further extended to the pigeons' performance on the VLS condition of present study. An observation of each bird's overall accuracy on the VLS session, as shown in Figures 1 through 8, may lead to a misleading conclusion concerning uniformity of performance on the two trial types. However, an analysis of performance by trial-type reveals that nearly all birds performed with higher accuracy on S→C trials than on S→S trials.

To further investigate the findings of Lionello-DeNolf and Urcuioli (2000), and to compare their findings to those obtained by Iversen and his colleagues using a single species in a single study, the birds in Group B of the present study were exposed to a reversal of the procedure used with Group A. Accordingly, in Phase 1, the sample stimulus appeared on either side key and the comparison stimuli appeared on the remaining two keys. The birds' performance was assessed by trial type. The obtained functions were similar to those obtained by Iversen and his colleagues, with the birds showing greater accuracy on S→C than on S→S trial types. Following acquisition of oddity, the birds were transferred to the FLS condition. As expected, Group B birds did not demonstrate substantial breakdown in oddity performance (Figures 5 through 8).

Lionello-DeNolf and Urcuioli (2000) argued that the type of procedure used was responsible for the birds actually acquiring matching-to-sample, irrespective of the location. In other words, the authors explained their findings in terms of the pigeons operating under a single rule. However, it should be noted that a multiple-rule explanation of the present findings with Group B is possible. By being exposed to the VLS condition during the first phase of the procedure, the pigeons were required to learn twice the number of rules than did the birds in Group A (hence the difference in the number of sessions required to reach the criterion).

Following transfer to the FLS condition, the pigeons were required to learn oddity on a single trial-type. Furthermore, because the number of trials in each session was equal (120), the pigeons in the FLS condition were exposed 120 trials per session, compared with 60 S-C and 60 S-S trials in the VLS condition. Therefore, twice the amount of training in the FLS relative to the VLS condition may have contributed to the faster acquisition of oddity in the FLS condition.

The high levels of position preference demonstrated by the birds in the present study are consistent with similar findings on matching-to-sample performance in rats (Iversen, 1997), and monkeys (Iversen et al., 1986). Thus, the present research allows for the extension of the conclusion that stimulus location is an important variable in conditional discrimination to oddity-from-sample in the pigeon.

The design of the present study allowed for the comparison of pre- and post-transfer data between groups A and B within the context of the multiple-rule model: As predicted by the multiple-rule model (Cumming & Berryman, 1965), in Phase 1, the birds in Group A acquired oddity substantially faster than did the birds in Group B, simply as a function of the number of rules each group had to acquire to demonstrate oddity. In a similar manner, the multiple-rule model accounted for faster acquisition of oddity in Phase 2 by Group B birds compared with Group A.

A breakdown in oddity in Group A demonstrated that the pigeons' performance is best described as governed by a series of S^D associations, or rules (which include stimulus location), and not a universal S^Δ rule (Cumming & Berryman, 1965). The present study also extended the findings of Lionello-DeNolf and Urcuioli (2000) by allowing for a more precise, multiple-rule explanation for the way transfer of conditional discrimination performance in the pigeon to novel stimulus locations is understood.

The Group A birds in the present study required a greater number of sessions to reach the oddity criterion than did the birds in previous studies, such as the one carried out by Cumming & Berryman (1965). Although the researchers did not use a percent-based performance criterion, all birds reached 90% accuracy by 2700th trial. The birds in Group A of the present study required an average of 2940 trials to reach the accuracy criterion in Phase 1. A possible explanation for this difference could lie in the types of stimuli used in the respective studies. In their experiments, Cumming and Berryman used hues, while lines were used in the present research. Nevertheless, it should be noted that Cumming and Berryman used three hues, whereas two line stimuli were used in the present study. There is evidence to suggest that lines are more difficult for the pigeons to acquire than are hues (Urcuioli, 2008). Additionally, Iversen's (1997) rats received a daily 16-trial warm-up session prior to each daily session, which may have eliminated some of the erroneous responses. No warm-up sessions were used in the present study.

It should be noted that in the present study the birds did not demonstrate the initial above-chance performance in oddity acquisition reported by Berryman, et al. (1965). Goldman, Lanson, Ramirez, and Korber (1980) offered an interesting insight into this discrepancy. Unlike the earlier investigators, the authors reported initial accuracy at an average of 52%. Goldman, et al. (1980) reasoned that the initial performance on oddity tasks may be attributed to the birds' history, specifically, to the shaping procedure used.

As Goldman, et al. (1980) pointed out, the birds in Cumming and Berryman's procedure were shaped to peck each of the three keys when they were illuminated with each of the three hues used. Each of the three keys were individually illuminated with red, green, or blue. Responding to each of the three keys was reinforced. Each of the three hues was presented an equal number of times on the left, right, and center keys. Accordingly, the birds had a history of reinforcement with each of the three keys, as well as in the presence of each of the three hues. However, as in the present study, the birds in the Goldman, et al. study were shaped to perform using white light illuminated on the keys, and not the actual stimuli used during the experimental procedure.

Interestingly, Bird A4 required substantially fewer sessions to reach oddity criterion following the transfer to the VLS condition, compared to the other birds in Group A. Given that Bird A4 was female poses the question whether the difference in performance was gender-related. However, to address this question would require further research.

Limitations

One of the goals of the present study was to compare pre- and post-transfer conditional discrimination performance between the two groups of birds. It was hypothesized that, as a function of the number of rules each group must acquire to demonstrate oddity, the birds in Group A would reach the initial oddity criterion (before being transferred to Phase 2) substantially faster than would the birds in group B. Similarly, it was also expected that following the transfer to Phase 2, the birds in group B would reach the mastery criterion substantially faster than would the birds in Group A.

It should be noted that this difference in the rate of acquisition would mean that the birds in Group A would receive less training than would the birds in Group B during the initial training phase. Accordingly, an important, though rarely acknowledged limitation of the interpretation (inherent in transfer designs of this type) should be recognized: The disparity in the amount of training received by both groups during Phase 1 may have an effect on the birds' performance during Phase 2.

While overtraining the Group A birds to equalize the number of Phase 1 trials across both groups could control for this limitation, it is also likely that such overtraining would have generated two new problems. First, the birds in Group A would have had more rehearsal, post-acquisition trials, and therefore, while the trials between the groups would be equal in number, they would have been qualitatively different. Second, the rehearsal of performance on the contingency beyond acquisition could have resulted in an inequality of the amount of extinction between the two groups in Phase 2, thus presenting a whole new transfer problem. In light of these potential problems, and considering the necessity to procedurally replicate the studies on which the present research was based, the procedure remained unmodified.

An additional limitation of the interpretation is presented by the disparity in the number of sample locations between the two experimental conditions. In the FLS condition, the sample stimulus was always presented in the same location (the center key), whereas in the VLS condition, the pigeons were trained with the sample stimulus presented on either the left key or the right key. In the VLS condition, the comparison stimuli appeared on any of the three stimulus locations. In the FLS condition, the comparison stimuli were presented only on the side keys. Accordingly, it may be argued that the post-transfer deterioration of Group A’s accuracy may be, at least partially, attributed to the addition of the center key as a comparison stimulus location (inherent in the VLS condition). Further research may address transfer of oddity performance to novel locations where the number of stimulus locations is equal between conditions.

Conclusion

The bias to peck on the center-key was demonstrated by Group B birds in Phase 1. Thus, the modification to the training procedure proposed by Lionello-DeNolf and Urcuioli (2000, Experiment 1) does not entirely eliminate the bias from oddity procedure. Furthermore, Lionello-

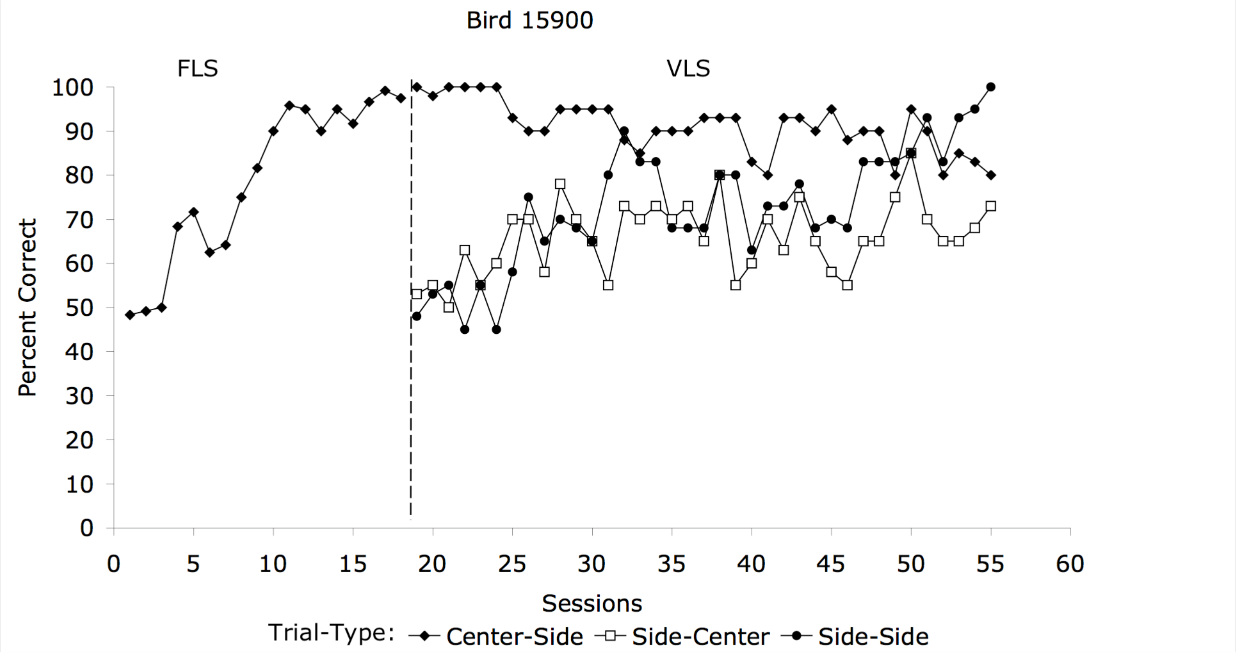
DeNolf and Urcuioli's argument that the bias to peck on the comparison closest to the sample (i.e., the center key) may alone be responsible for the failure of the birds to transfer to novel sample locations is inadequate in explaining the current findings with oddity. Namely, the transfer to VLS would have only affected Group A's performance on S-S trials. Nevertheless, trial-type analysis revealed that the transfer to novel locations resulted in a breakdown of oddity on S-C trials as well, while the distance between the sample and the correct comparison remained the same as it had been during training.

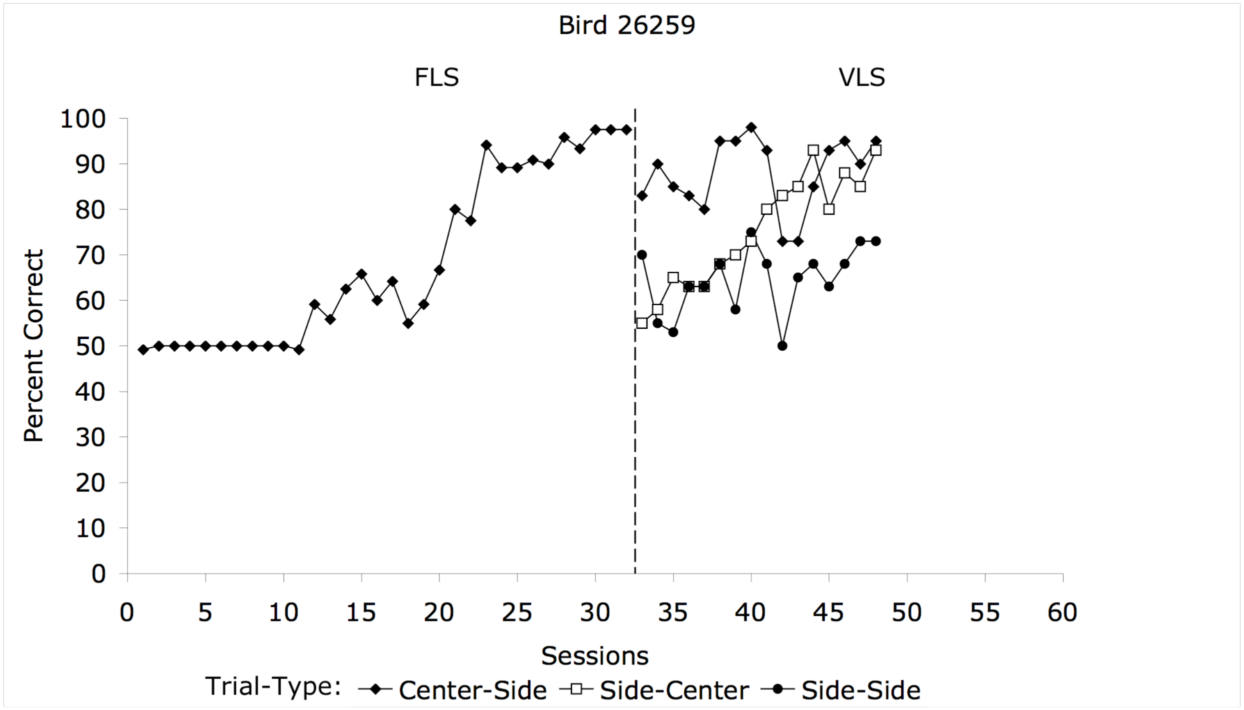
The results of the present study support earlier research (Cumming & Berryman, 1965) in demonstrating that oddity-from-sample performance in the pigeon is best described within the context of the multiple-rule model. The present study extended the matching-to-sample findings of Iversen (1997) and Iversen et al (1986) in showing that stimulus location is a part of what pigeons learn about stimuli in oddity-from-sample conditional discrimination. Accordingly, an accurate description of an oddity problem necessitates the specification of stimulus locations as possible sources of stimulus control. The present study also examined the transfer of oddity performance to novel stimulus locations following multiple-location training (Lionello-DeNolf and Urcuioli, 2000, Experiment 1). The above modification resulted in a more rapid post-transfer acquisition of the oddity problem than that shown by the birds initially trained on a single, sample-on-the-center key problem. Nevertheless, the within-group differences are predicted by the multiple-rule model as a function of the number of rules the birds had to acquire in each phase to reach accuracy criterion on the oddity tasks.

Furthermore, the multiple rule model predicted the observed between-group differences in Phase 1 and Phase 2, respectively. Unlike the single-rule model, which fails to consider stimulus locations as a possible source of control, the multiple-rule model explains the between-group difference as a function of the acquisition of location-specific sample-comparison associations. Accordingly, multiple-rule model requires the specification of not only the type of training to be used in a conditional discrimination procedure but also the type of test.

Appendix

Percent correct trials over the Fixed-Location Sample (FLS) and Varied-Location Sample (VLS) experimental phases expressed in terms of thee trial-types in the line discrimination condition of the pilot study. The top and bottom panels show Bird 15900 and 26259 data, respectively.





Bibliography

Baum, W.M. (1974). On two types of deviation from the matching law: Bias and undermatching. *Journal of the Experimental Analysis of Behavior, 33,* 187 – 211.

Berryman, R., Cumming, W. W., Cohen, L R., & Johnson, D. F. (1965). Acquisition and transfer of simultaneous oddity. *Psychological Reports, 17,* 767 – 776.

Brown, P. L., & Jenkins, H.M. (1968). Autoshaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior, 11,* 1 – 8.

Carter, D. E., & Werner, T. J. (1978). Complex learning and information processing by pigeons: A critical analysis. *Journal of the Experimental Analysis of Behavior, 29,* 565 – 601.

Cumming, W. W., & Berryman, R. (1965). The complex discriminated operant: Studies of matching-to-sample and related problems. In D. I. Mostofsky (Ed.), *Stimulus generalization* (pp. 284 – 330). Stanford, CA: Stanford University Press.

Davison, M. & McCarthy, D. (1987). The interaction of stimulus and reinforcer control in complex temporal discrimination. *Journal of the Experimental Analysis of Behavior, 48,* 97 – 116.

Goldman, M., Lanson, R. N., Ramirez, E., & Korber, E. J. (1980, September). *The effects of intermittent reinforcement on oddity-from-sample acquisition.* Paper presented at the American Psychological Association meetings, Montreal, Canada.

Goldman, M., & Shapiro, S. (1979). Matching-to-sample and oddity-from-sample in goldfish. *Journal of the Experimental Analysis of Behavior, 31,* 259 – 266.

Iversen, H. I. (1997). Matching-to-sample performance in rats: a case of mistaken identity? *Journal of the Experimental Analysis of Behavior, 68,* 27 – 45.

Iversen, H. I., Sidman, M., & Carrigan, P. (1986). Stimulus definition in conditional discriminations. *Journal of the Experimental Analysis of Behavior, 45,* 297 – 304.

Lionello-DeNolf, K. M., & Urcuioli, P. J. (2000). Transfer of pigeons' matching to sample to novel sample locations. *Journal of the Experimental Analysis of Behavior, 73,* 141 – 161.

McCarthy, D. & Davison, M. (1982). Independence of stimulus discriminability from absolute rate of reinforcement in a signal-detection procedure. *Journal of the Experimental Analysis of Behavior, 37,* 371 – 382.

Pisacreta, R., Lefave, P., Lesneski, T., & Potter, C. (1985). Transfer of oddity learning in the pigeon. *Animal Learning and Behavior, 13,* 403 – 414.

Sidman, M. (1980). A note on the measurement of conditional discrimination. *Journal of the Experimental Analysis of Behavior, 33,* 285 – 289.

Urcuioli, P. J. (1977). Transfer of oddity from sample performance in pigeons. *Journal of the Experimental Analysis of Behavior, 25,* 195 – 202.

Urcuioli, P. J. (2008). Associative symmetry, antisymmetry, and a theory of pigeons' equivalence class formation. *Journal of the Experimental Analysis of Behavior, 90,* 257 – 282.

Zentall, T. R., & Hogan, D. E. (1974). Abstract concept learning in the pigeon. *Journal of Experimental Psychology, 102,* 393 – 398.